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SHORT COMMUNICATION

RIVER REGULATION IN SPAIN

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ABSTRACT

The expansion of river regulation and of related scientific research in Spain since 1982 is reviewed. The number of dams completed each year has decreased and, moreover, the average size of reservoir has continued to decline. It is the creation of many new, relatively small, irrigation reservoirs that is having the greatest impact on the fluvial systems. Recent legislation may promote greater involvement of scientists in the management of these systems not least in the setting of minimum ecological flows.

KEY WORDS Dams Water transfers Environmental studies

INTRODUCTION

During 1982, there were two important international symposia dealing with river regulation. First, at the 14th International Congress on Large Dams, celebrated in Rio de Janeiro, the Spanish National Committee of the Dam Surveillance Service presented the status of dams constructed and under construction up to 1981: 803 large dams existed in Spain with a storage capacity of 42,750 millions of cubic metres and 56 were under construction, with 3,850 10^6 m^3 of capacity. This Spanish National Committee (1982) concluded that in the period 1978–81 the greatest increase in the number of dams was caused by the increase of those dedicated to water supply (15 per cent). There was also an increase in those for irrigation (12 per cent) especially concentrated in the southern regions and in the Mediterranean sector. A smaller increase was due to hydroelectric power dams (8 per cent).

In 1982 at the 2nd International Symposium on Regulated Streams held in Oslo, a review was presented (García de Jalón, 1984) dealing with the effects of flow-regulation structures on fluvial systems in Spain. Despite the large number of water regulation systems built in this country, only three case-studies of their effects were reported. Two of these dealt with water supply reservoirs: the effects of the Susqueda reservoir on the aquatic insects of River Ter (Prat, 1981) and the impacts caused by the Pinilla reservoir on the benthic communities of the Lozoya River (García de Jalón, 1980). A third case, dealing with the effects of high altitude irrigation reservoirs of the Duero Basin on the fisheries and macroinvertebrates living in these fluvial systems, was also reported.

This paper discusses the expansion of river regulation and of scientific research associated with river regulation in Spain since 1982.

RESERVOIRS

At the beginning of 1986 there was a total of 925 large reservoirs constructed in Spain, and these have a storage capacity of 43,555 million cubic metres (data taken from Dirección General de Obras Hidraúlicas (in press) modified by the addition of the reservoirs finished during 1985). Fifty-seven per cent of this capacity is used for hydropower production, followed by irrigation purposes (29 per cent). The water dedicated to urban supply represents only 12 per cent and the remaining 2 per cent is destinated to other uses.

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In Figure 1 the number and capacity of large reservoirs constructed in Spain during this century are presented. The effects of the Civil War in 1936 and the intensive development during the fifties and sixties are clearly shown. Since 1975, the rate of dam completion has declined and this is reflected particularly in the water-storage capacity curve which is reaching an asintotic end. The recent reduction of the growth in storage area can be explained by the fact that all the best dam sites have already been used.

Hydroelectric reservoirs

In Spain, the installed electricity capacity is 39 10^6 KW of which 36 per cent is represented by Hydro-power. However, this 36 per cent only produces 28 per cent of the total Spanish production (Dirección General de Obras Hidraúlicas, 1986) as hydroelectric energy is used, most extensively, for absorbing the peaks of energy demands.

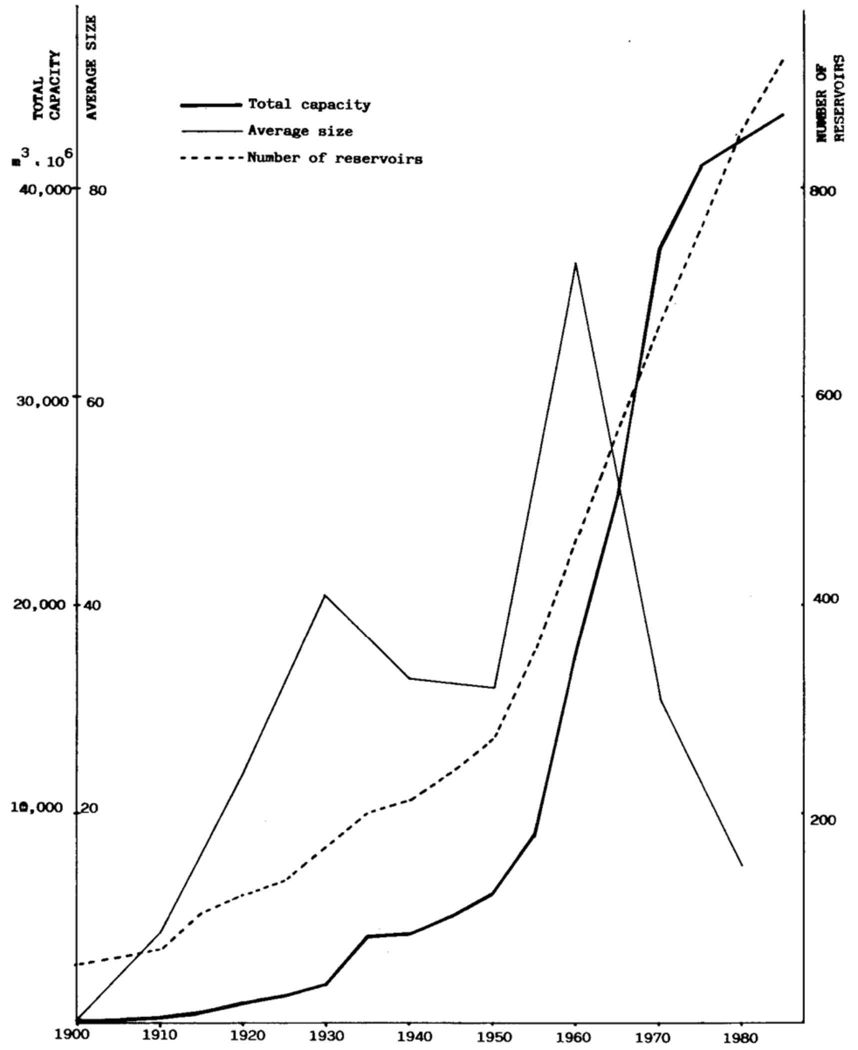

Figure 1. The increase in total number of large reservoirs, their capacity and average size constructed in Spain during the 20th century

The recent evolution of the installed energy-power shows that actually there has been an enormous increase of energy demands, and these have been mainly absorbed by conventional thermal or nuclear plants. In contrast, hydroelectric power increases smoothly. This later increase has been achieved, to a large extent, by the expansion of existing hydroelectric plants, with dam heightening, the introduction of reversible turbines, or by connecting systems of associated reservoirs, and as a consequence, the water-mass used for hydroelectric purposes has not increased accordingly.

Irrigation reservoirs

In anticipation of joining the European Common Market Spanish agriculture has diversified and the area of irrigated land has increased considerably in the last year. The creation of many new irrigation reservoirs in Spain is having the greater impact on our fluvial systems. Moreover it seems that irrigation dams will be even more important in the near future, as they store greater volumes of water and impound considerable lengths of river. This type of reservoir is being concentrated especially in the meridional regions and in the Mediterranean littoral basins, so an intensive process of eutrophication, with long summer stratification, should be expected in the impounded reaches (Ortiz *et al.*, 1983). A clear example of these irrigation reservoirs will be the Embalse de la Serena in river Zújar (Badajoz) which is under construction; this will be the largest Spanish reservoir with a storage capacity of 3,232 10^6 m^3 and an area of almost 14,000 ha will be impounded.

In some areas, the new water demands are met from groundwater resources. This is the case, for example, at La Mancha where after the big drought in Spain from 1980 to 1983 a paradoxical change in land use from dry-farming to groundwater irrigation farming has taken place.

Water-supply reservoirs

Although there has been a notable increase in the number of water supply reservoirs during the last few years, their size is generally small and their storage capacity is relatively insignificant. The exception is those reservoirs that supply water to large cities and industrial concentrations. However, a major problem has arisen from the delay in the building or operating of corresponding sewage treatment plants especially in small rural towns. As a consequence, the water quality of our rivers has deteriorated sharply. These effects have been remarkable in those streams and rivers far away from big cities and industrial centres, which were previously unpolluted.

WATER TRANSFERS

Apart from those interbasin water transfers caused by the great demand of water-supply by big cities (Madrid, Barcelona, Bilbao, Sevilla, etc.), the water transfer system that connects the upper reaches of Tajo River with the Segura Basin should be mentioned because it is the largest one in Spain (Garcia de Jalón, 1984). This system has been working since 1979 and has a potential capacity for transferring 1000 10^6 m^3 annually. However, the reality is that it was over dimensioned. Only 100 to 350 10^6 m^3 are transfered each year, depending on the annual precipitation, because this quantity is limited by water availability in the Tajo headwater reservoirs and the capacity of the Segura impoundments. A clear example of the biological effects of the Tajo–Segura transfer is the colonization of the Segura basin by the gudgeon (*Gobio gobio* L.). This species was introduced to the Iberian Penninsula in the last century and distributed in the Tajo Basin. The effects of its recent introduction in the Segura Basin on the autocthonous fish populations are at the present unknown.

ENVIRONMENTAL STUDIES

With the new 'Ley de Aguas' (Water Act) approved by the Parliament in August, 1985 and a Decree-Law of 28 June, 1986, environmental impact studies become obligatory for any type of hydraulic work to be done in Spanish fluvial systems. This fact opens new expectations, but at the moment there is a period of two years until these environmental aspects of the law will come into force. However, it is not the accuracy of the predictions of these future impact studies what will be the most useful, as there are few data, little experience and not enough scientific teams prepared in these topics, especially in fluvial limnology. More importantly the legislation will stimulate the collection of field data before works are undertaken. The data will permit comparisons with the situation of the fluvial ecosystem after the impacts so that it will be possible to detect changes in the fluvial system caused by flow regulation, to determine their intensity, and to define recovery rates.

Minimum ecological flows

The Spanish Water Authorities have defined the 'ecological flow' as 10 per cent of the mean annual flow (Centro de Estudios Hidrográficos, 1981). However, this is only a theoretical consideration because in most cases, irrigation, urban and industrial supply or hydroelectric needs have priorities over environmental requirements. So, often our rivers below reservoirs suffer periods in which they are completely dry or support ridiculously low flows in relation to their bed size.

In recent years 'ecological flows' have been evaluated for only a few reservoirs currently under construction and affecting trout fisheries, and then after pressure from anglers and Fish Services. However, it is debatable whether Water Authorities will accept them or not. This is the case with the irrigation and hydroelectric project at the confluence of the Pyreneean rivers Cinca and Ara. There are four reservoirs: Jánovas (at 730 m altitude) and Boltaña (at 615 m altitude) in the river Ara: Escalona (592 m altitude) in the Rivers Cinca, and Ainsa (592 m altitude) located outside both rivers. Water is diverted away from the river channels through a pressure pipe from one reservoir to the next and finally returned to the rivers at their confluence (Figure 2). Minimum flow in the reaches below the reservoirs was estimated in order to maintain trout fisheries stocks: 6 $m^3 s^{-1}$ in the River Cinca (35 $m^3 s^{-1}$ is its mean annual flow) and 3 $m^3 s^{-1}$ in River Ara (18 $m^3 s^{-1}$ is its average flow).

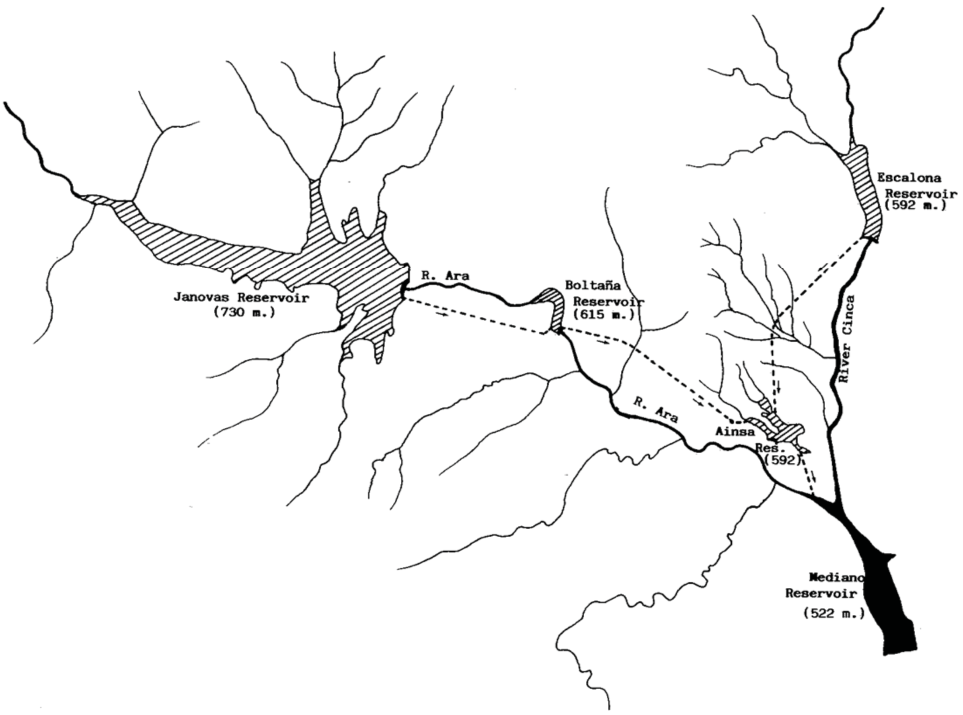

Figure 2. The projected hydro-electric power scheme of the Ara–Cinca rivers

Other evaluations of minimum ecological flows have been calculated using the 'Instream Flow Incremental Methodology' (Bovee 1982). In the River Tera (Zamora) below Cernadilla reservoir, where the mean annual flow is 22 $m^3 s^{-1}$, Navarro (1986) has determined the minimum flow as 5·4 $m^3 s^{-1}$ for summer and autumn, and 14·3 $m^3 s^{-1}$ for winter and spring. This methodology is actually being used also in Catalonia to define minimum flows in the River Santa Magdalena below small hydropower plants (Claudio Racionero personal communication).

Channelization and dredging

During the summer of 1983 important floods occurred in Northern Spain and in the following autumn floods occurred in the eastern Mediterranean littoral. After these events, the respective Water Authorities developed an intensive plan for channelization and dredging the main rivers, in order to prevent flood problems. River beds are lowered and riparian vegetation along the banks is eliminated. No data from these activities are officially available, but from my observations they are quite important in the northern regions at least.

Spanish Water Authorities lack personnel with limnological knowledge, and they actively ignore the effects of dredging on the biota, taking into account hydraulic considerations only. Nevertheless, in Navarra, where stream channelization has been intensive, a research programme studying its effects on the macrobenthos and fisheries has already started.

LOOKING AT THE FUTURE

In 1982, when the Socialist Party (PSOE) took control of the Government, there was an initial intention to increase hydraulic works. However, nowadays we observe that the economic resources have been diverted, primarily to road construction: the only dams that are being built are those that were already projected or under construction at the beginning of this decade.

At this moment, there are in Spain 63 large reservoirs under construction with a total projected capacity of 8,411 $10^6 m^3$. Sixty-nine per cent of this storage capacity will be dedicated to irrigation, so this type of reservoir management should have preferences in the impact studies on their affected river systems. In second place, water-supply for urban consumption will absorb 16 per cent of this increase of capacity. Hydropower, with a growth of 11 per cent, is relatively unimportant as it is being substituted by thermal power plants. Finally, all other uses of this projected capacity represent only 4 per cent.

Some of the schemes have experienced difficulties during and after construction. The most peculiar and well known of these is the Riaño (León) on the river Esla: the 101 m-high dam was completed in 1970 but the inhabitants of the valley to be impounded would not agree to leave it! At this moment there is a great public controversy about it in the newspapers, with the ecology movement confronting governmental agencies. The point is to know what are the objectives of the scheme?, what are the projected benefits? and what are the possibilities to reach them by other means, in relation to the ecological and social impacts caused in the impounded valley?

The increasing environmental awareness of Spanish society is pressing for an improved knowledge of the consequences of stream regulation and for improved approaches for diminishing their negative effects. Actually, this environmental awareness is directed mainly to the new hydraulic works, but it is hoped that soon it will be extended to the management of existing ones. The rational planning of the regulated flows may avoid unnecessary damages to fluvial ecosystems. Unfortunately, this is not common in Spain, because of the uncoordinated use of the water resources by different users and different Water Administration Departments. Also, it must be pointed out that rivers are ecosystems and the management of their flows must take into account the biological point of view. This means that biologists should be integrated within the staff of the Water Authorities.

Finally, it is necessary to emphasise that most rivers in Spain are already regulated; unregulated ones are scarce. Indeed, as Ward and Stanford (1984) suggest, regulated streams can be used as instruments to experiment with theoretical and applied ecology, but all experiments need controls and these are the unregulated rivers. Moreover, in order to detect and analyse the long term effects of stream regulation, base-line data are needed for unregulated rivers. Given the lack of these data, the conservation of a few unregulated rivers with a certain size seems to be a matter of priority but it is a difficult task in Spain because of the economic tendencies of the Authorities. Only a few important rivers are preserved without regulation today; unfortunately, some of these are projected to be regulated soon, as the river Esla in the north and the river Guadiaro in the south.

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