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The use of urban wastewater for the Colorado River delta restoration

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Abstract

The environmental changes due to the Colorado River damming, have affected the ecological functioning of the nursery river delta and consequently the population of fishermen that live of the natural marine resources of the upper Gulf of California. We propose the use of urban wastewaters as a source of nutrients to fertilize the estuary, increase the primary productivity and therefore increase the population size of the estuarine dependent species, which are important for the fisheries in the region. In this way, we could partially restore the delta's ecological functioning and thus solve environmental, social, and economic problems. With a wastewater flow of 800 $l \cdot s^{-1}$ from "Las Arenitas" treatment plant, we could increase the primary organic productivity and ~1000 metric tons (mT) of shrimp landings of the region. These calculations are just for one fishery, but in a magnitude that could also increase in others.

Keywords: Colorado River; environmental impact; restoration program; inorganic nutrients; productivity

1. Introduction

The Upper Gulf of California (UGC) and Colorado River delta were declared by the Mexican government a Biosphere Reserve in order to protect their biological value [1] (Fig. 1), it is located at the northernmost extent of the Gulf of California, which is known to be a large and important nursery ground for estuarine dependent species, a site for migratory birds, and priority for biodiversity conservation [2-4]. Additionally, the region has been recognized as an internationally important wetland by the RAMSAR Convention [5]. The area represents a reproduction and breeding habitat, where there are vulnerable and endanger species, such as the "Vaquita Marina" (*Phocoena sinus*) and the Totoaba (*Totoaba macdonadi*).

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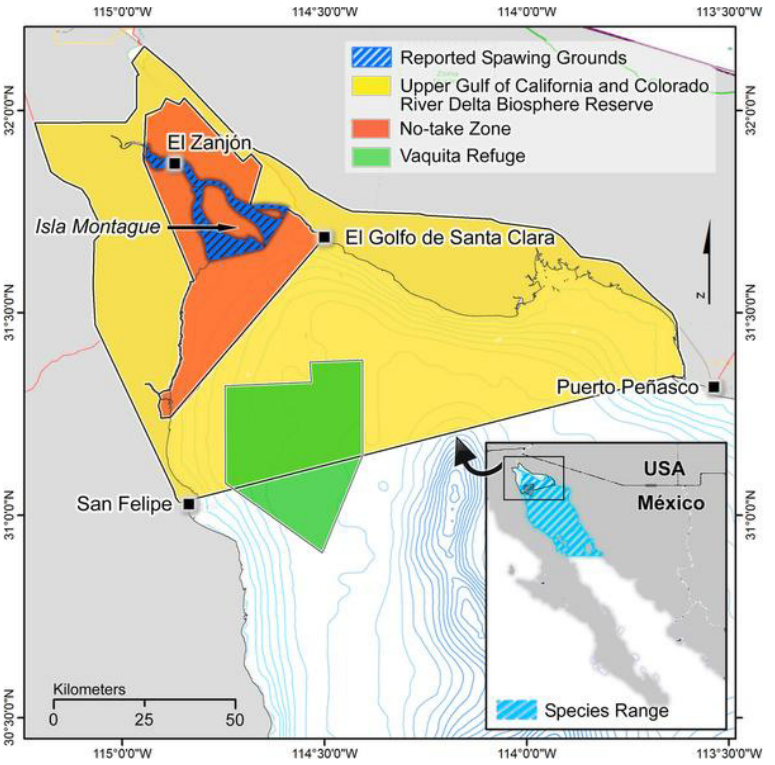

Fig. 1. Upper Gulf of California and Colorado River Delta Biosphere Reserve. (Taken from Erisman et al. [6]).

The Colorado River is the main source of fresh water for the southwestern United States and northwestern Mexico, which flows from the Rocky Mountains in the USA to the Gulf of California in Mexico and is a vital source of water for agricultural and urban areas in both countries. The river has been heavily developed since 1935 through a system of dams in the USA and Mexico, which has limited fresh surface water entering the estuary. The volume of the flow was reduced from ~21,000×10^6 $m^3 \cdot y^{-1}$ to occasional flows. These occasional flows depend on the size of the surplus of the 1.85 × 10^9 $m^3 \cdot y^{-1}$ annual allowance as established in the Boundary Water Treaty signed between Mexico and the USA in 1944 (Fig. 2). It is for this reason in general that the delta has lost its estuarine conditions and has been drastically impacted [7,8]. The environmental and ecological changes associated with the river damming are numerous and varied, physical changes due to the decrease of wetlands and shallow water habitats from ~63,000 Ha with the river to 5,800 Ha without the river [9]; the loss of estuarine conditions has become a hypersaline estuary [8].

Without mainstream river flows, the only fresh water to reach the delta came from the Hardy River, which was created by agricultural returns from irrigated fields [9]. After construction of Las Arenitas treatment plant in the 2008, the wastewater has been discharged to the Hardy River, which together with the water from the agricultural returns caused eutrophication in the river. The high nutrient concentrations in the waste waters could have helped increase the organic productivity in the Upper Gulf of California and Colorado River delta. However, in the year 2001, a small dam was constructed in the Hardy River in order to redirect the water away from the delta and increase riparian wetlands [10].

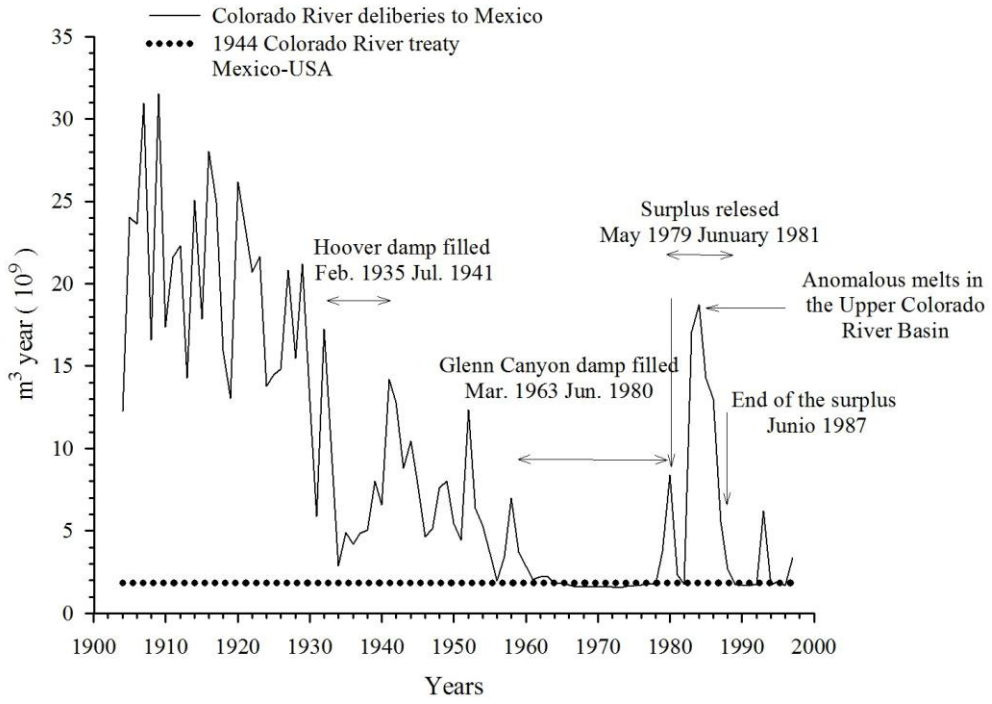

Fig. 2. Colorado River flow over the Mexico-USA border. Data from Rodriguez-Bernal [11].

One could hardly expect to restore all of the ecological functions lost by the Colorado River damming, however, considering that the nutrients delivered to the upper Gulf of California have decreased, we propose a restoration plan to fertilize the delta and Upper Gulf of California by bringing back at least a partial flow of dissolved nutrients from the wastewater treatment plant "Las Arenitas". The return of nutrients to the delta could increase the primary productivity and would partially restore the population sizes of estuarine-dependent species. Since the Colorado and Hardy rivers are no longer the primary sources of fresh water to the upper Gulf of California, we propose the use of treated urban wastewaters, as a restoration alternative to fertilize the delta region.

2. Methodology

We used data of the Colorado River flow in the US-Mexico border [11], which was compared with the commercial shrimp landed in the three fishing ports in the UGC (San Felipe, Santa Clara and Puerto Peñasco) [12]. We calculated the rate of carbon fixation according to the ratio 106C:16N:1P of Redfield et al. [13], for which we used the surplus to the 1.85×10^9 $m^3 \cdot y^{-1}$ established in the México-USA International Boundary Treaty and urban wastewater data.

3. Results and discussion

In the UGC there are two endemic marine endangered species, the totoaba (*Totoaba macdonaldi*) which is part of the family Sciaenidar and the "vaquita marina" (*Phocoena sinus*) which is part of the

porpoises family Phocoenidae. Although it has been established that the decrease in population abundance of both species has been caused by fishing pressure, these species may also be under pressure by the environmental changes due to the damming of the Colorado River.

The population sizes of estuarine-dependent species, as fishes and crustaceans for fisheries in the UGC, have been tied to changes in the primary productivity in the upper Gulf of California. For example, during a period of relatively low primary productivity (1990-1991) [14], the shrimp landings were less than 1,000 mT, which had an ecological, social, and economic impact, while during a period of relatively high productivity during the 1980's [15], the shrimp landings were above 5,000 mT, (Fig. 3). The damming of the Colorado River would not only cause a decrease in the population size of important crustacean and fishing species, but also in species as vaquita and totoaba that potentially become endangered.

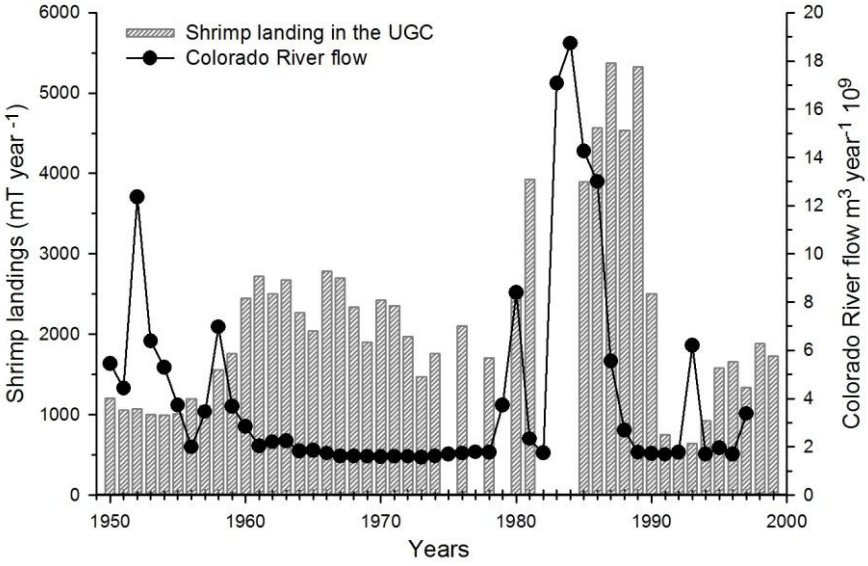

Fig. 3. Blue shrimp landings in the Upper Gulf of California associated with the Colorado River flow. Data from Bernal-Rodriguez [11] and Instituto Nacional de la Pesca [12].

The river flow before damming was the most important source of dissolved inorganic nutrients into the upper Gulf of California. As a consequence, the primary productivity has decreased, and therefore impacting the food web and the population size of the estuarine-dependent species. With the dissolved nitrates measured in the Colorado River at the Mexico-USA international border (30 μM), it was possible to calculate the metric mT of nitrogen that could have entered the delta during the 1979-1988 period (considering only the surplus to the 1.85×10^{9} $m^{3}\cdot y^{-1}$ established in the México-USA International Boundary Treaty, (Table 1). With this estimation we can calculate the rate of carbon fixation according to the ratio 106C:16N:1P of Redfield et al. [13], which could be transformed into phytoplankton available in the food web. If 10% of the calculated carbon concentration goes to the shrimp trophic level, we can estimate how this could increase the shrimp population for fishing (Fig. 4).

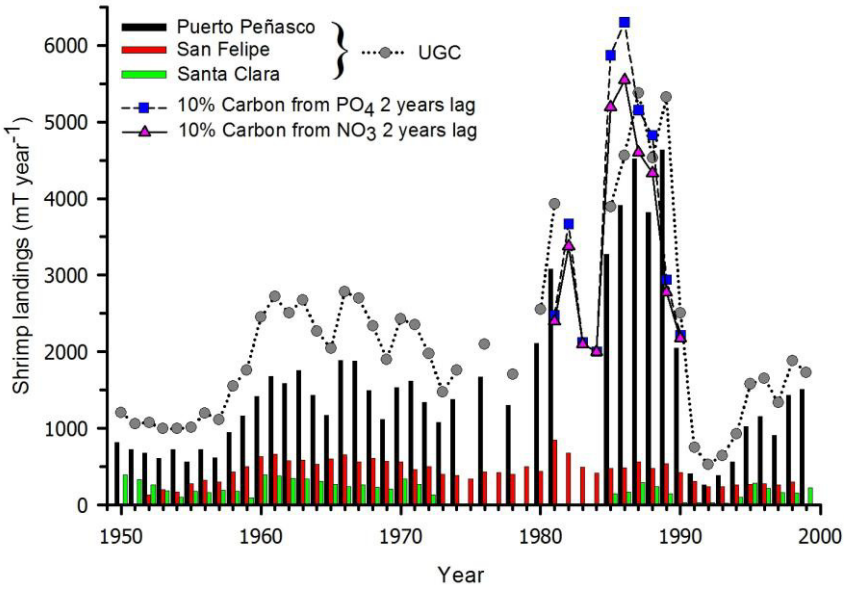

Fig. 4. Blue shrimp landings in the UGC, compared to the calculated according to the treaty's water surplus.

The Hardy River is the other source of nutrients to the delta region, which after the construction of a small dam showed an 88% reduction in the concentration of dissolved silicates and 40% in the concentration of dissolved inorganic nitrogen in the internal region of the Colorado River delta, Santa-Rios [16]. The decrease in dissolved nutrients has generated a decrease in the abundance of diatoms and copepods, and subsequently a change in the species composition of the phytoplankton. Changes in the phytoplankton community have repercussions for the entire pelagic food web and an economic impact due to the change in fishable species [17].

We propose to send urban wastewater from "Las arenita" treatment plant to the Colorado River delta (Fig. 5). The urban wastewater has a nitrate concentration of ~ 40 $mg \cdot l^{-1}$ and the Colorado River water has 30 μM, if we make an estimate of nutrient equivalency in relation to volume, we can calculate the carbon fixation in relation to the ratio of Redfield et al. [13] and the possible increase in shrimp landing (Fig. 6). The increase in the production of organic carbon may lead to an increase in biomass of the economically important fisheries. An example is seen in the shrimp fishery.

The available wastewaters from the "Las Arenitas" treatment plant are actually being discharged into the Hardy River channel. A group of ecologists built a small dam in order to create wetlands and open spaces for vegetation and migratory birds, but its construction does not allow the water to reach the remnants of the Colorado River and subsequently the delta region and the upper Gulf of California. Furthermore, the high nutrient concentrations discharged into the Hardy River have been causing eutrophication problems, with the consequent social and environmental problems.

In case this proposal is carried out: 1.- The wastewater treatment plant has to ensure high water quality in order avoid contamination problems; 2.- The wastewaters must be carried through pipes in order to prevent the formation of algae and nutrient uptake along the way; 3.- Basic information for an engineering project will be needed: topography of soil mechanics, hydraulics, electrification, budget work, among other data required.

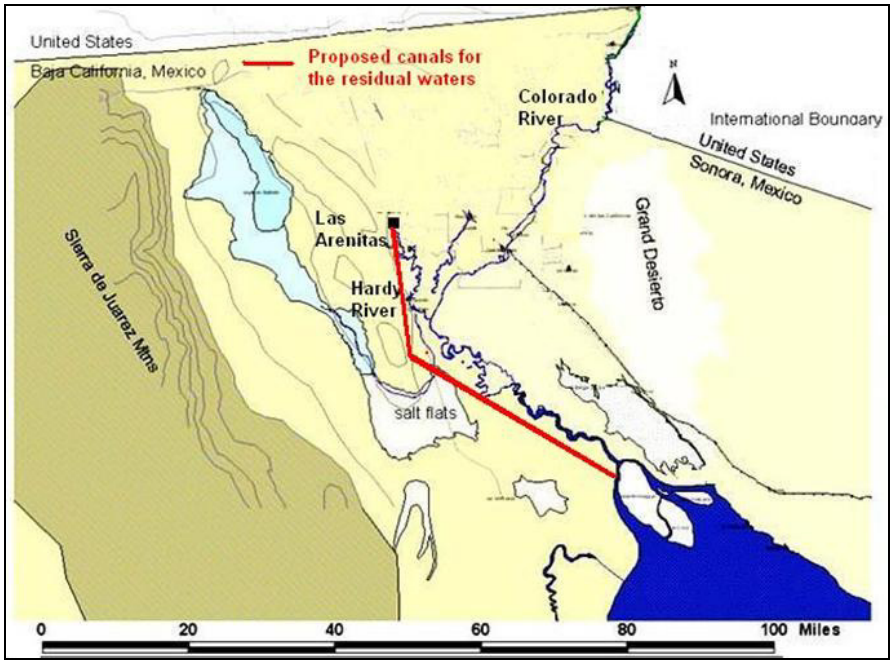

Fig. 5. Potential path to deliver the wastewater from "Las arenitas" treatment plant to the delta.

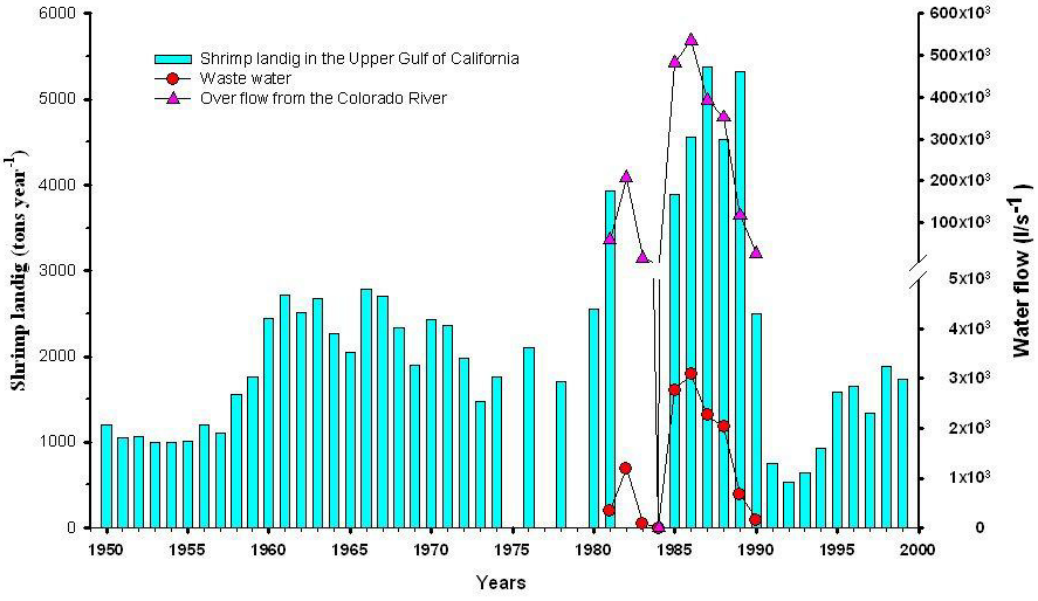

Fig. 6. Shrimp landings in the UGC in relation to the Colorado River surplus and wastewater flow from "Las arenitas" treatment plant.

4. Conclusions

With Las Arenitas wastewater flow of 800 $l \cdot s^{-1}$, the shrimp landing in the UGC could increase to ~1000 mT, and it is likely that there could be a similar increase in magnitude in other fisheries. With this proposal, we would solve environmental, social, and economic problems, increasing the population size of shrimp, fishes and other commercial species.

With a shrimp price of $12 dollars per kilogram, this would represent an economic impact of $12,000,000 dollars in this particular fishery.

We would solve social and ecological problems caused by the dumping of sewage into the Hardy riverbed.

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