Journal of Environmental Management xxx (2014) 1–12

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Rural aquaculture as a sustainable alternative for forest conservation in the Monarch Butterfly Biosphere Reserve, Mexico

José López-García*, Lilia L. Manzo-Delgado, Irasema Alcántara-Ayala

Instituto de Geografía, Universidad Nacional Autónoma de México Circuito Exterior, Ciudad Universitaria, 04310 Coyoacán, México, D.F., México

ARTICLE INFO

Article history:
Received 20 February 2013
Received in revised form
10 December 2013
Accepted 22 January 2014
Available online xxx

Keywords:
Payment for Environmental Services
Monarch Butterfly Biosphere Reserve
Forest recovery
Aquaculture
Environmental sustainability

ABSTRACT

Forest conservation plays a significant role in environmental sustainability. In Mexico only 8.48 million ha of forest are used for conservation of biodiversity. Payment for Environmental Services in the Monarch Butterfly Biosphere Reserve, one of the most important national protected areas, contributes to the conservation of these forests. In the Reserve, production of rainbow trout has been important for the rural communities who need to conserve the forest cover in order to maintain the hibernation cycle of the butterfly. Aquaculture is a highly productive activity for these protected areas, since it harnesses the existing water resources. In this study, changes from 1999 to 2012 in vegetation and land-use cover in the El Lindero basin within the Reserve were evaluated in order to determine the conservation status and to consider the feasibility of aquaculture as a means of sustainable development at community level.

Evaluation involved stereoscopic interpretation of digital aerial photographs from 1999 to 2012 at 1:10,000 scale, comparative analysis by orthocorrected mosaics and restitution on the mosaics.

Between 1999 and 2012, forested land recovered by 28.57 ha (2.70%) at the expense of non-forested areas, although forest degradation was 3.59%. Forest density increased by 16.87%. In the 46 ha outside the Reserve, deforestation spread by 0.26%, and land use change was 0.11%.

The trend towards change in forest cover is closely related to conservation programmes, particularly payment for not extracting timber, reforestation campaigns and surveillance, whose effects have been exploited for the development of rural aquaculture; this is a new way to improve the socio-economic status of the population, to avoid logging and to achieve environmental sustainability in the Reserve.

1. Introduction

> What we are doing to the forests of the world is but a mirror reflection of what we are doing to ourselves and to one another
>
> Gandhi

1.1. Sustainable development

Twenty years after the first Earth summit in Rio de Janeiro, international commitment is still directed towards achieving sustainable development. Forest conservation will play a very significant role. In Mexico, only 8.48 million ha of forest are used for conservation of biodiversity (FAO, 2010). The total forested surface in Mexico in 2010 was 64.8 million ha; 5% of it had been designated for production, 82% for multiple use and only 13% for conservation of biodiversity. Primary forest occupied 34.31 million ha (53% of the total forested surface), the area of other naturally regenerated forest was 27.28 million ha (42%), and planted forest occupied 3.2 million ha (5%). Overall, there was a decrease in the national forest area of 0.52%, 0.35%, and 0.24%, during the periods 1990–2000, 2000–2005 and 2005–2010, respectively, while at world level the decreases were of 0.20%, 0.12% and 0.14% (FAO, 2010).

1.2. Rural aquaculture as a sustainable alternative for forest conservation

In Mexico in the early 1930s aquaculture was concentrated on rural aquaculture and replenishment of water reservoirs; in the following years exotic species were introduced. Decades later, aquaculture production increased at an average rate of 8.6% annually from 1983 to 1989, but decreased by 7.03% in 1994 (Aldana-Aranda, 2002). During 2000–2010, trout was 17th nationally among fish species in terms of production, but 7th in terms of monetary value. Annually, average growth rate of trout production in the past ten years was 3.98% (SAGARPA, 2005; 2011).

* Corresponding author. Tel.: +52 5556230222; fax: +52 5556162145.
E-mail address: jlopez@unam.mx (J. López-García).

http://dx.doi.org/10.1016/j.jenvman.2014.01.035
0301-4797/

Rainbow trout (*Oncorhynchus mykiss*), a salmonid species native to North America, has in Mexico been cultivated mainly in the north and central-west sectors. Essential factors include water quality (>5 mg/l dissolved oxygen (Klontz, 1991), temperatures of 7–18 °C, and a stable pH within the range of 6.5–8.0) and an abundance of natural food (Woynarovich et al., 2011). Water quality is particularly crucial; any contaminant may cause considerable mortality. Hence, the producers have a vested interest in conservation, with particular emphasis on the development and conservation of the forests that are such an important element in water catchment (CONAPESCA, 2006).

National trout production increased from 2659 tons in 1995 to 8500 tons in 2011. México and Puebla states are the most productive, accounting for 54.20% and 22.60% of the total production during 1995–2011, followed by Durango and Michoacán with 6.01% and 5.90% respectively (Fig. 1). The increase is due to a campaign by the federal authorities throughout the country to set up new trout farms and encourage the consumption of this species because of its high nutritive value (SAGARPA, 2011; CONAPESCA, 2011).

Trout farming is an ideal option for sustainable use of water resources in mountainous regions because here both surface and underground waters are suitable for this purpose. In regions where income-generating and employment opportunities are scarce, trout farming could help to ensure employment and steady incomes. In addition to the product itself, trout farming could also ensure increased income and employment through angling tourism, restaurants and related services (Woynarovich et al., 2011). It is an excellent production activity for protected areas because it conserves forest resources.

In Mexico, the General Directorate for Aquaculture was set up in 1972. From then onwards, aquaculture has been regarded as complementary to social assistance for rural communities, by which it was hoped to increase the consumption of animal protein and thereby to improve the nutritional status of the population (Juárez and Palomo, 1985).

Trout farming in Michoacán and Estado de México began in the 1990s, when federal programs promoted by the Secretaría de Desarrollo Social (SEDESOL) and Secretaría del Medio Ambiente Recursos Naturales y Pesca (SEMARNAP) were accepted by various communities in the municipalities of Zitácuaro, Angangueo, Ocampo and Donato Guerra. Between 1992 and 1997, four trout farms were set up in the El Lindero basin, in the El Capulín and Nicolás Romero ejidos, to complement existing agricultural and forestry activities. With the official decree that recognized the Monarch Butterfly Biosphere Reserve (MBBR) in 2000 the El Lindero basin became part of the buffer zone, and aquaculture was actively promoted; this resulted in the establishment of 12 more trout farms during 2000–2006, bringing the total to 16, at 2260–2400 m asl. In "San Luis Manzana" ejido El Rosario, 26 trout farms were constructed between 1992 and 2000 (Contreras, 2012).

With support from the Secretaría of Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA), producers of rainbow trout in the MBBR created the Pro-Monarch Aquaculture Union in the state of Michoacán; this brought together 31 farms for the promotion of trout products and now supports their marketing at major distribution points in the country.

1.3. Forest resources and Payment for Environmental Services (PES) in Mexico

The present state of the environment and the urgent need to achieve sustainability at global level demands attention to sustainable development not only at the regional level, but also at the national, subnational and, more specifically, local levels (United Nations, 2012). On this basis, instruments for biodiversity conservation that have been used in both developing and developed countries include natural protected areas, payment for ecosystem services (PES), and decentralization of natural resource management. PES (Kerr et al., 2004; Engel et al., 2008; Jack et al. 2008) seeks, through forest conservation, to sustain ecosystems and contribute to the UN collaborative programme Reducing Emissions from Deforestation and Degradation (REDD) (Bond et al., 2009).

The distribution of water resources is also important in these areas; the water courses of the river basins concentrate 21.7% of the water captured at national scale (Boege, 2008). The national forest policy is directed towards strengthening sustainable development of natural resources in the forest ecosystems, and programmes such PES have been operating since 2003, with the Comisión Nacional Forestal (CONAFOR) being in charge of their implementation. In the period 2007–2012, the PES programme involved more than 2.9 million ha and benefited 5402 stakeholders to the value of 6134 million pesos, the equivalent of ~500 hundred million USD.

Within the MBBR, one of the most important protected areas of Mexico, PES has operated since 2000 in the three core zones, where 3 small properties, 9 indigenous communities and 20 ejidos are situated. Rates of deforestation in the MBBR have been estimated

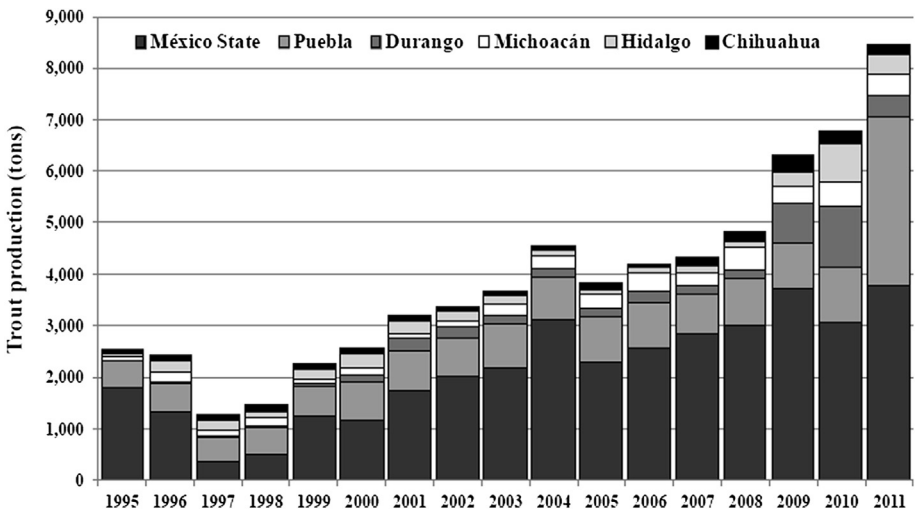

Fig. 1. Trout production in Mexico from 1995 to 2011.
Source: SAGARPA, 2005; 2011.

Please cite this article in press as: López-García, J., et al., Rural aquaculture as a sustainable alternative for forest conservation in the Monarch Butterfly Biosphere Reserve, Mexico, Journal of Environmental Management (2014), http://dx.doi.org/10.1016/j.jenvman.2014.01.035