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Article

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From Aquaculture Goals to Real Social and Ecological Impacts: Carp Introduction in Rural Central Mexico

Aquaculture has been seen as a solution to food/protein availability in rural populations of poor countries. It is mainly based on exotic species, that produce changes in host system dynamics once introduced. Aquaculture not only changes the ecology of freshwater systems, but can also lead to modification of social relations. Until now, aquaculture programs have not been adequately analyzed no questioned enough. We evaluate both ecological effects and local social benefits of common carp aquaculture programs in shallow ponds of rural areas, using a municipality in Central Mexico as a case study. Using an "environmental entitlements" approach, our findings suggest that: *i*) carp aquaculture increases water turbidity and depletes native species reducing the poor people's access to them; *ii*) aquaculture mainly benefits pond owners rather than poor peasants. This mainly results from changes in fishing rights. We conclude that aquaculture policy goals and assumptions of benefits should be reviewed, if the negative ecological effects are to be decreased and conditions for people in rural areas are to be improved.

INTRODUCTION

In the last few decades, aquaculture activity has been widely promoted in developing countries. This activity has been seen as a solution to the nutritional problems of rural poor communities. On these grounds, international research and technology on a limited number of species have been encouraged, resulting in a standardized fish production. Consequently, aquaculture helped to disperse these species in many lakes and rivers where originally they would never have colonized. Within this context, nearly 25 years ago the Mexican government launched the aquaculture program to produce Asian carp, a fish which can now be found in 95% of the country's freshwater systems (1).

Studies of ecological invasions in lakes and rivers have shown that exotic species can produce negative impacts on host systems. But the ecological awareness about fish introductions in lakes was developed relatively recently compared with decades of aquaculture promotion. Additionally, it could be argued that a trade-off existed between conservation and social aims. Biodiversity conservation might not compensate the social benefits that exotic fish production were able to provide to poor people. However, we think that aquaculture programs until now have not been analyzed deeply, nor challenged enough. The terms in which they have been evaluated have been conceptually poor and we believe that common frameworks have not captured the full picture of environmental losses and social benefits where exotic fish have been introduced. Among other things, the success of aquaculture programs has been measured simply by production (around 30 000 tonnes (t) per year) (2–4) and these numbers have been considered adequate to support promotion (5).

Focusing on this problem, our study evaluates both the ecological effects and the local benefits of a common carp aquaculture program in shallow ponds of rural areas in Central Mexico. We considered the "environmental entitlements" and common natural resources approach (6–8), in order to understand the relation between the differentiated benefits received by social groups with biodiversity and ecological processes. Based on this focus, social benefits for poorer members, and conservation of native species do not necessarily constitute a trade-off, but these two may complement each other.

This paper explains the evolution of aquaculture policy together with the assumptions and goals of policymakers about native and introduced species, and describes the research methodology and the studied area used for the evaluation of the aquaculture program. The ecological and social findings of this study are also addressed. Finally, the results are discussed in the light of recent conceptual approaches.

CARP INTRODUCTION POLICY

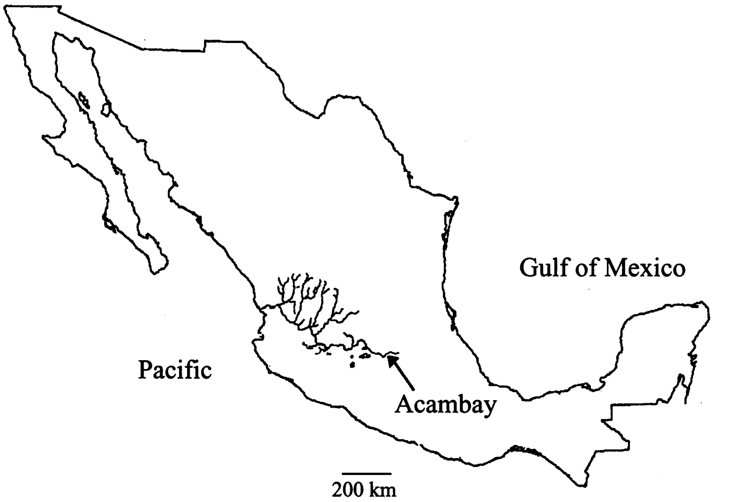
The policy of carp introduction in Mexico resulted from a series of international cooperation agreements signed in the late 1960s by the Mexican Government with the Food and Agricultural Organization (FAO) and the Chinese Government (9). These agreements promoted the technology transfer needed to reproduce and cultivate carp, based on standardized production. Carp was chosen as an ideal organism for freshwater aquaculture because it was easy and cheap to produce. The simplicity of carp cultivation lies in its biological flexibility, which allows it to live and grow in almost any environment. Carp can survive under low food conditions, relatively anoxic waters (below 0.8 g L^{-1}) and in very turbid systems (10). Carp grows better in eutrophic systems, in contrast to most of its competitors (11).

By promoting carp, policy makers made 3 wrong assumptions: *i*) that waterbodies in rural areas used for irrigation purposes were nonproductive systems; *ii)* they assumed a low consumption of native species by local people and that larger size fish meant larger benefits—most of native species in Mexico are comparatively small. A final assumption *iii)* was that with few native benthivorous species in the system, carp would not compete with other species, and would thus occupy an "empty niche" (an incorrect assumption) (12).

Between 1976 and 1982, carp introduction in Mexico was supported with high levels of financial and human resources, within the framework of a food security program to provide cheap proteins to the rural areas. Breeding and nursery centers were built and a network of aquaculture extensionist agents was created to convince and train rural populations in carp aquaculture. The dominating vision was that aquaculture, through the introduction of freshwater fish, would bring "progress" to marginalized populations.

Possible ecological damage produced by the introduced species was not considered, until in recent years. In 1994, when the Environment, Natural Resources and Fisheries Secretariat (SEMARNAP) was created, the link between aquaculture exploitation and concern for the environment became obvious. However, even now, concern about the potential negative effects of introduction of aggressive species is small.

Figure 1. Study site. Acambay is located in the Lerma River Basin, which crosses the central part of Mexico from the center to the west.



Ecological damage may be justified by potential social goals. Among the aquaculture policies promoted (most of them marine), carp introduction is regarded as a policy with a high social component aimed to provide rural poor with means of self-consumption, and not for profit. Following this principle, seedlings and fingerlings bred in governmental centers are distributed free to rural producers who follow specified procedures. Carp introduction policies have been justified as of social benefit and are sustained with high levels of public resources. We maintain that the distribution of benefits should be evaluated with regard to the success of these policies in promoting increased welfare among the poor.

STUDY SITE AND METHODOLOGY

Acambay, our study site, is located in a valley close to the highest part of the Lerma-Santiago Basin, in Estado de Mexico. This Basin crosses Mexico from the center of the country to the Western Pacific coast (Fig. 1). The Basin hosts the largest lakes in the country and many endemic freshwater organisms. In Acambay, there are 3 endemic freshwater species: the crayfish (acocil) *Cambarellus montezumae*, the axolotl *Ambystoma* sp., and a small fish of the family Goodeidae, the charal *Girardinichthys multiradiatus*.

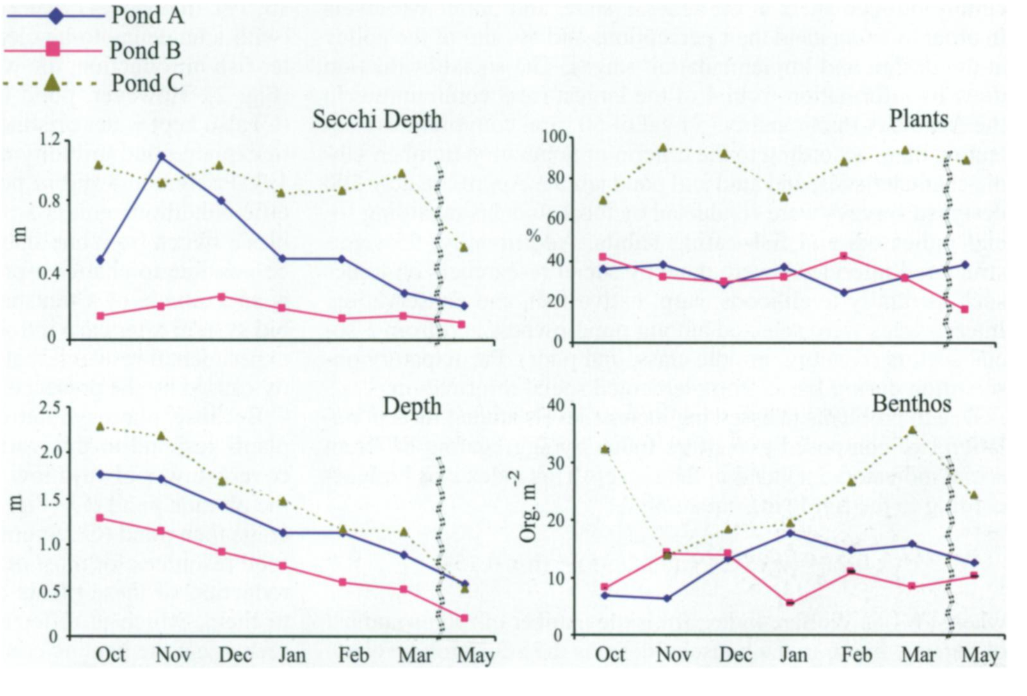
Acambay is located in a high mountain system (altitude close to 2200 m). The average temperature during the year changes only from 10.6°C in coldest days to 16.8°C in the hottest (mean 14.2°C) (13), but the daytime temperatures within the day can vary from 8°C in the morning to 24°C at midday (14).

Carp culture in Acambay occurs mainly in a series of ponds (56 ponds ranging from 0.5 to 10 ha), typical of the central region of Mexico. These shallow ponds do not exceed 10 ha in size and 3 m in depth. Most of them were created to store water for irrigation and they are dependent on precipitation during the rainy season—starting in June and ending in November (average precipitation is 903.8 mm yr^{-1}) (13). Ponds are filled between June and August from temporal streams created by heavy rains, depth decreases slowly until March, through evaporation (Fig. 2). Just before Easter (dry season), ponds become partially or totally dried out as a result of irrigation to the surrounding agricultural land. Although the pond water regime is highly influenced by human activities, it is similar to that of the natural lakes and rivers in the region. The similarities in regime may have helped native organisms from natural systems to colonize and establish themselves in these small man-made ponds.

Ecological Methods

The results presented here consist of the third part of a study that started with a preliminary assessment of carp influence in 12 shallow ponds of the region. In the first part of the study, we found a significant positive correlation between carp abundance with turbidity (r^2 = 0.69), a negative correlation with macro-

Figure 2. Pond dynamics during the rainy season. Pond A is the pond where carp was introduced in November. Pond B, without carp, but turbid since the beginning of the season, and Pond C also without carp. Values in each line are based on averages for 1996 and 1997. Values in the plants section are based on macrophyte coverage in the ponds.



phytes coverage (r^2 = 0.76) and with benthic organisms (r^2 = 0.58) (14). These correlations proved to have a cause-effect relation as seen in the second part, where experimental ponds where used. High carp densities increased water turbidity within 5 weeks and produced significant benthic abundance depletion as well as some plant species (15). In the third part of the study, we investigated pond dynamics during the rainy season, with carp and without carp. Because pond measurements were continuous, we chose only 3 ponds to study a variety of physical, chemical, and biological variables. This limited data interpretation in the statistical analysis. However, we based our analysis of the results on the parts 1 and 2 of the research (14, 15). We chose the 3 ponds because they belonged to the same owner (and therefore had the same yearly water regime), were constructed at the same time, had similar sizes (2 were as big as 1 ha, and the third was 1.5 ha) and the distance between them was not more than 200 m. In pond (A) we added 5000 carp fingerlings in November 1996. Ponds (B) and (C) were carp free. Pond (B) was originally turbid, while ponds (A) and (C) had more pristine water. We collected data each month during 2 rainy seasons from October to May between 1996 to 1998. However, since 1998 was drier, pond (A) was not fully filled and it was impossible to obtain data from this pond during the second season. Thus, results present an average data for the 2 seasons from ponds (B) and (C), but not pond (A).

We collected physical variables such as pond morphometry (area in ha and mean depth in m), Secchi depth and temperature. As an index of macrophyte abundance, cover of rooted (submerged and emergent) and floating macrophytes was estimated within a 40 cm diameter circular frame (16) at 5 sample points along each of 12 transects (each 10 m in length)—60 samples per pond in total. Sampling encompassed the zone close to the littoral margin, where the majority of macrophytes occurred. Since ponds were generally square, 3 transects were taken at equal distances along each side, originating from and perpendicular to the littoral margin. The abundance of epibenthic invertebrates and small native fishes was estimated using a small beam net (17) along 3 transects of 12 m length in each pond. The abundance of benthic organisms was estimated from a 5 L pooled sample of mud taken by means of an Ekman grab in a variety of locations. Organisms were separated from the mud in the field by sieves.

Sociological Methods

Between 1997 and 1998, we carried out interviews with aquaculture policymakers at the federal, state, and municipal levels in order to understand their perceptions and the aim of the policy at the design and implementation stages. The social evaluation drew its information from 4 of the largest rural communities in the Acambay municipality (a total of 60 rural communities), selecting them according to the criteria of population number, ethnic characteristics, and land and pond tenure. Approximately 500 designed surveys were conducted by local students regarding social indicators and fish-eating habits. Additionally, 95 semi-structured interviews were done by social researchers on topics such as family livelihoods, carp, native fish, and conservation. Interviewees were selected among pond-owners and from 3 social sectors (wealthy, middle class, and poor). Participatory observation during Easter complemented social information.

Due to problems in assessing income levels among rural population, we composed a Welfare Index by aggregating different social indicators included in the survey. This index was built according to the following equation:

$$WI = (h \times 0.2) + (e \times 0.3) + (s \times 0.35) + (n \times 0.15)$$

where (WI) is Welfare Index, (h) is the number of rooms/number of persons living in the household, (e) is the education level adjusted from 0 to 5 (0 no schooling and 5 university education). (s) is the access to basic services: sewage, drinking water and electricity (0 no access and 1 access to the service). These services were given different values; drinking water and sewage weighted more than electricity, the latter being present in almost all households in the municipality. (n) is nutrition, based on the consumption of different products (0 if products were consumed and 1 if they were not). Each value was standardized between 0 and 1.

We tested the index and the relative weight given to the values to avoid any misinterpretation by correlating index results from weighted values with unweighted values (r^2 = 0.93, $p <$ 0.001). The correlations suggest that nutrition was the least reliable variable, as it was the most subjective (e.g. answer and recollections). The other values and their relative weights are closely related, suggesting that they are good indicators of the index.

ECOLOGICAL EFFECTS OF CARP INTRODUCTION IN PONDS

Once a year, carp producers receive fingerlings from governmental production centers (at a cost of approx. USD 15, plus transport) and grow them in their ponds. Carp fingerlings are stocked normally in sizes from 3 to 5 cm between September to November, when the water level is high (Fig. 2), fish then have at least 5 months to grow. Extensionist agents recommend 2 ind. m^{-2}, but the producers stock as much as they can get from fish providers. The result is a wide range of carp densities in ponds, with unpredictable yearly production. Fish densities at the end of the season are higher because the water level is lower, reducing pond area volume (Fig. 2).

In natural conditions, these ponds do not contain benthivorous fish such as carp since native fish are zooplanktivorous. Although there is no competition, carp can modify the environment indirectly, mainly through feeding habits (18, 19). Carp suck the sediment, select food with their gills, and eject the sediment (20), increasing the turbidity. The result being an increment in water turbidity which modifies the trophic web (21). Changes in freshwater systems due to carp introductions have been widely described (22–24) and, apparently, Acambay is no exception (14).

Based on the dynamic results and the previous studies it is possible to argue that high carp abundances increased water turbidity and decreased macrophytes and benthic organisms (14, 15, 19). In pond (A) where carp were introduced, water was clear (with a tendency to be clearer) before the fish were added. After fish introduction, the water became more turbid each month (Fig. 2). However, pond (B) kept its turbid status while pond (C) also kept water pristine throughout the season. It is possible to explain pond turbidity dynamics as a two-stable system (18, 19). Pristine and turbid ponds will tend to maintain their specific conditions unless a modification in trophic structure enables a switch from one stable condition to another (21). It should be possible to change a pristine lake to a turbid one. Pond (A) is an example of a transparent pond system changing to a turbid system after carp introduction. This change is supported by experimental research that has shown a change in water turbidity caused by the presence of carp (15, 18).

Because photosynthetic light depends on water turbidity, plants respond to this variable (23). In Acambay, macrophyte coverage was always low in the turbid pond (B) and higher in the pristine pond (C) (Fig. 2). Pond (A) had also less plant coverage than pond (C). Submerged plants provide both spatial and food resources for most of the small species in the pond (18). A reduction of these plants also diminished the species attached to them, which is reflected in benthic abundance (Fig. 2). It seems that the benthic community is affected directly by predation, but also indirectly through plant reduction, particularly in the carp relation with crayfish. This has been observed in a series of experiments in a parallel study. Although there is no evidence that carp affect axolotl, we only found them in the pond that was free of carp (Pond C). However, *charales* do not seem to be affected by the presence of carp and their abundance appears to depend on other factors (14).

SOCIAL EFFECTS OF CARP INTRODUCTION

The main beneficiaries of the carp introduction policy are those who own a pond. Most of the ponds are owned as private property by individuals, except for four *ejido* (common property tenure) ponds and a large seasonal reservoir shared with other municipalities. Most of these ponds have been the property of wealthy families in the region for almost a century; a few others were built by a state government program (now suspended) or with the owners' own resources.

Our research showed that the majority of pond owners have large cultivated land areas (20 to 200 ha) compared to the local average (1 to 2 ha). They also own large stocks of cattle and are involved in trade and diverse business activities in the main town. They have higher education levels and most of their siblings have become professionals with a university degree. A relevant characteristic of this pond-owner "elite" is that they have political connections inside and outside of the municipality, which have helped them to become the main beneficiaries of the public support and subsidies in the area. Certainly, they do not require the complementary proteins that carp programs were designed to provide to rural populations. They are then not the needy peasants that policy-makers had in mind when the aquaculture program was conceived.

However, carp culture does not bring economic benefits to pond owners. They are interested in maintaining the program for other reasons. The ponds are usually opened around March and April, when many relatives and friends from outside the municipality come for holidays, and carp fishing has become the center of local Easter rituals, following the religious traditions of abstinence from eating meat. Those who do not have a direct link with the pond owners are not invited to these gatherings and do not receive free carp. Therefore, the majority of the Acambay population have access to carp only through market transactions. Of the surveyed who eat carp, the majority buy them in the Sunday market (45%) and an important proportion purchase from women who sell them from house to house (24%), while less than 5% have free access to carp fishing.

In the local market, carp prices vary according to size from USD 2 to USD 3.75 reaching the highest price of USD 5 in Easter week. Although this may appear to be a cheap product, the fact that according to official statistics a third of the municipality's population has no income and 45% live on one or two minimum wages (USD 8 day^{-1}) needs to be taken into account (25). Carp prices are thus beyond the means of the majority of the people in the area.

Our findings in Acambay indicate that although the carp introduction was a governmental program designed for the poor in rural areas, in fact, its benefits are being reaped by local elites. Even more interesting were the interactions between differentiated social groups and biodiversity, interactions that cannot be described solely through property relations.

ENVIRONMENTAL ENTITLEMENTS AND BENEFITS

Since property relations cannot fully explain the complex picture of how socially differentiated groups interact with biodiversity, the concept of environmental entitlements is more relevant to describe these processes. The entitlement approach was first developed by Sen to explain famines (26, 27), but the term has rapidly become widely adopted in the development literature to refer to the elaborated processes by which groups of people gain access to and control over different resources.

There are many ways to gain access to and control resources; some can have them as endowment (as given), others can obtain them through market exchanges, but institutional arrangements such as social conventions and norms can also be legitimate ways for people to gain resource access and control (7, 27).

Another approach has since developed that refers to particular ways by which people gain access over environmental resources. Environmental entitlements aimed to explain not only how people gained control of resources, but also to the rights and "the set of utilities derived from environmental services" (6). Ostrom developed the concept of "Common Pool Resources" (CPR) referring to resources systems that are too "costly to exclude potential beneficiaries from obtaining benefits from its use" (7). Thus, groups of people might have access to certain natural resources and their services without fully owning them.

We consider more relevant to our study the concept of environmental entitlements than the rights of use for 3 reasons. It is a wider concept that allows differentiation of alternative "sets of utilities" (commodity, rights of use, and services) and how different groups of people have access to them. In Acambay, we found that although the ponds and their irrigation use were owned as private property by individuals, their fishing rights were structured by other conventions. In Ostrom's definition of CPR, the ponds and their water were privately owned systems, but fish production was a flow of resource units that could be appropriated by individuals (7).

However, the access to fish varied according to the type of resource. Before carp were introduced into these ponds, fishing rights were "open". Pond owners allowed anyone to fish native species (charales, crayfish and axolotls) freely, i.e. true open access CPR. But when carp were introduced, fishing rights became exclusive. The introduction of carp transformed the CPR fishing system from open access to individual property rights (8).

The same environmental entitlements were replicated in the common property ponds, where crayfish were more abundant than elsewhere. Before carp were introduced, the property rights of these ponds were open access and people from nearby communities could fish crayfish from them. More recently, while this study was being conducted, carp were introduced. This led to the restriction of carp fishing and access to these resources was reserved only for *ejidatarios* (commoners), transforming property rights from open access to group property, according to Ostrom et al. (8). This increased existing social tensions within the community and the small amount of carp cropped posed the problem of how to distribute them among a larger number of *ejidatarios*. It seemed very unlikely that reciprocity norms would emerge in the near future, since these communities already suffered from conflicts over various CPR that they shared (irrigation water, electricity flows, and grazing lands).

The second reason for using environmental entitlements is that the concept implies that ecological dynamics greatly influence the distribution and access to natural resources (6). As this study indicates, carp introduction has led to decreasing abundance of some of the native species. Therefore, while the restricted fishing resources (i.e. carp) increase, there is a decrease in the free-access fishing resources (i.e. native species) available for the majority of the population, who do not own a pond or have a direct link with pond-owners.

The third argument in favor of environmental entitlements is the highlighting of how customary law and social norms—not just market channels and formal-legal property rights—determine how actors have access to resources. To a stranger, fishing carp or fishing native species in private ponds by nonowners could appear to be the same activity, but social convention within the municipality dictates that the first is "robbery" (sanctioned by the local law) and the second is a permitted act (7).

Eating Habits

The quantitative data showed that local eating habits are related to social differentiation. Pond owners allowed the fishing of native species, because they did not like to eat them. In contrast, the poorest members of the community appreciated them and this free access to native species supplemented their diet (Table 1).

The clear picture emerged when the surveyed population was classified according to the explained Welfare Index (Fig. 3). Charales were eaten more widely across social classes, being eaten more by the local middle classes. The lower and low-middle classes ate more native species, such as crayfish and axolots. As the Welfare Index increased, the consumption of these species diminished. These results indicate that the reduction of native species, due to carp introduction, directly affects the poor who are the main consumers of these species. Consequently, the policy of carp introduction directed towards improving the nutrition of rural poor populations had the inverse effect, i.e. their environmental entitlements were reduced.

Carp data are more difficult to interpret. Although carp have been constantly promoted over past decades, consumption takes only third place of the four possibilities; almost the same proportion of people eat axolotl, which are very difficult to fish in these ponds. Even if the quantitative results do not fully support our hypothesis that carp are mainly consumed among the wealthy, and rarely eaten by the poor, qualitative data indicated that members of the lower class had a greater tendency to lie when asked if they ate carps.

Semistructured field interviews revealed 3 qualitative findings. Firstly, charales responded better to smaller incomes of poor people, as they could easily be divided and people could then buy half or 250 g of charales, compared to carp which is usually sold in 1–2 kg units.

Secondly, people in this rural area have introduced fish into their daily diet (a goal of the aquaculture programs), thanks to an informal trade network of older women who cook fish (in *tamal*, a traditional Mexican dish consisting of corn dough and fish wrapped in a corn leaf) and sell them door to door in distant communities. In this way local knowledge allows fish to be kept longer before decomposition sets in. This network of women has also provided credit and affordable prices (USD 0.25 per *tamal*) to the buyers. Thirdly, eating habits (carp *vs.* native species) have been shaped by cultural and social stratification, as well as by the rapid modernization process experienced locally. To eat crayfish and axolotls is perceived as a sign of being poor and "Indian", while eating carp gives higher status and is a "respected" habit. As identities are quickly transformed by urbanization, higher education levels and migration, people have chosen among other things to stop eating native species. As a result, young and old people who would like to be considered "modern" prefer to eat "fish" (carp) and leave "creatures" (native species) for the poor and those "in need".

CONCLUSIONS

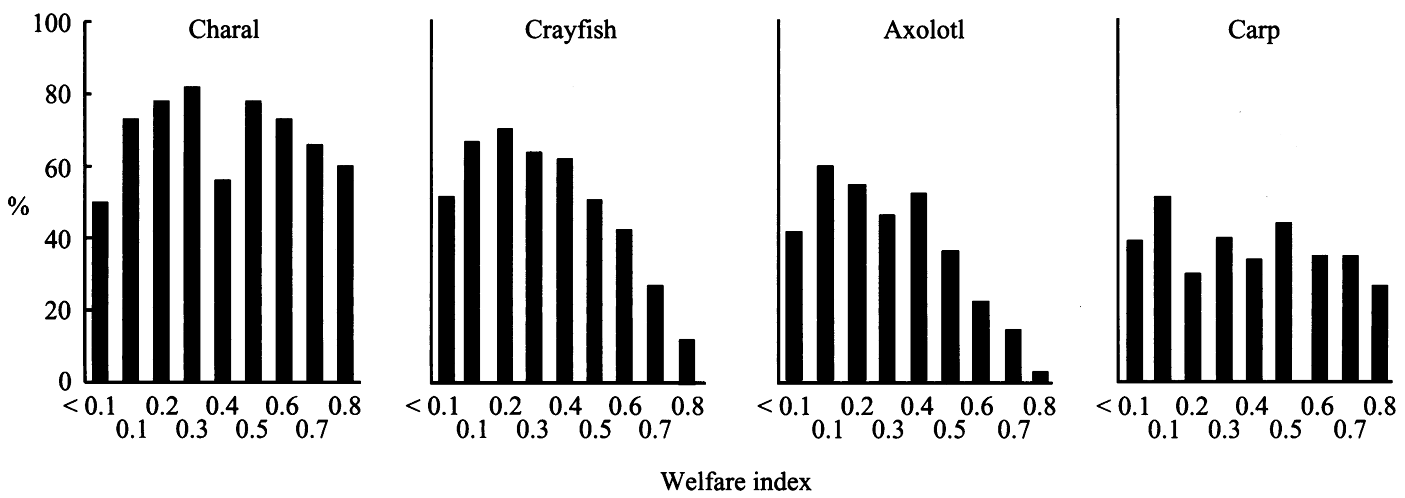
This study builds a conceptual framework for understanding the complex social and ecological interactions surrounding the aquaculture program of carp introduction. Although our findings are derived from one municipality, they are sufficiently representative of the physical and social characteristics of other rural areas across the Lerma-Santiago basin in Central Mexico, where carp has been successfully introduced and grown. Apart from this region, we do not intend to generalize these results, but we

Table 1. Comparative nutrition values of native species and carp.

Food (Content of 100 g)	Real energy (Kcal)	Proteins (g)	Carbohydrate (g)	Fat (g)	Calcium (mg)
Fresh *charal*	88+	25.3*	2.9*	5.9*	2360+
Dry *charal*	354+	74.8+	2.9*	0.0+	3850+
Crayfish	160+	17.1+	2.7*	1.3*	3250+
Carp	91+	19.2+	0.0*	5.6*	15+
Sardine in tomato sauce	193+	15.9+	1.9*	12.2+	223+
Beef meat	268*	17.9*	0.0*	12.2*	10*
Poultry (avg)	215*	18.6*	0.0*	15.1*	11*
Pork (avg)	275*	16.7*	0.0*	22.6*	6*

Sources: +SNCA, INSZ (29) and * Munoz (28)

Figure 3. Percentage of people consuming organisms from ponds, related to the welfare index. It is noticeable that carp is consumed in the same proportions in all social classes, while a higher proportion of poorer members of society eat native organisms. Closer to 1 means higher welfare.



propose diverse concepts that can be used as evaluation tools of both social and ecological impacts of aquaculture programs or other cases where social and ecological trade-offs are at stake. More studies are needed to demonstrate whether or not the negative effects we found are replicated in other regions with different social and ecological characteristics. Additional studies are needed to determine those social and environmental conditions under which carp introduction might be more successful.

From our study, it is clear that beneficiaries of carp culture in rural areas are not the poorest groups, which were the main target recipients. Instead, the benefits have been captured by higher class members. Moreover carp culture also seems to have negative effects, due to the ecological, entitlements and cultural processes that carp introduction has had on the native species and their availability for the poor. Thus, it might be important to review some of the assumptions on which the carp introduction policy was founded, as the design stage did not consider the interactions between species, access to natural resources, and change of cultural values.

The study suggests that carp produce a change in ponds where the species are introduced; water turbidity increases, resulting in major changes in the whole aquatic system. Although carp feeding habits are not compatible with other elements of the food web, it does cause a decrease in the populations of some native species. Native species are mainly consumed by the poorest groups, and analysis of the nutritional properties of these species (Table 1) shows that they can contribute to the enrichment of rural diets. In addition, the smaller size of native species may be an advantage due to their divisibility in market transactions, making them more adequate for the poor income groups.

Due to open access rights, poor members of society have better access to and control over native species. Rich pond owners are more likely to allow people to fish freely on their property when carp are not available, since these owners do not hold native species in high esteem. However, it is uncertain what would happen if as an effort for biodiversity conservation, native species became the center of aquaculture promotion. The open or exclusive nature of fishing rights, as our study shows, is inevitably the main variable to be taken into account, independently of land or water property rights.

Resources invested in carp aquaculture should be redirected from the rich groups who are their current beneficiaries. Different alternatives could be explored, among them a strict selection criteria for distributing free fingerlings to poor people, and introducing charges to cover the production costs of governmental breeding centers. This would allow better targeting of public resources and eliminate subsidies to those who are not in great need. Ecological information, such as biodiversity criteria, should be analyzed before carp are introduced. Governmental aid in production should also shift towards support for fish commercialization, using the already efficient local trade networks.

We are aware that perceptions of natural resources in rural societies are rapidly changing, promoted on the one hand by ideas about technological progress in society, and on the other hand by the desire for conservation. Ecological changes in the pond system and social and cultural factors are closely linked, and it is necessary to consider them in resource-management analyses.

There are important similarities between biodiversity conservation aims and the generation of social benefits for poor people. Native species have not only productive potential, but they should also be regarded as strategically valuable in the long term. Researching the full potential of native species may be a longer process than simply importing and paying for technology, and the controlled success of introduced species. However, we believe that more is to be gained, in economic and cultural terms, if we conserve, study, and adequately exploit native species, and much to lose if they become extinct.

References and Notes

1. Mujica, C.E. 1987. Los cuerpos de agua continentales adecuados por el cultivo de carpa. *Rev. Mex. Acua. 9*, 7–10. (In Spanish).
2. SEMARNAP (Secretaria de Medio Ambiente, Recursos Naturales y Pesca) 1997. *Anuario Estadístico de Pesca 1996*. México. (In Spanish).
3. SEMARNAP (Secretaria de Medio Ambiente, Recursos Naturales y Pesca) 1998. *Anuario Estadístico de Pesca 1997*. México. (In Spanish).
4. SEMARNAP (Secretaria de Medio Ambiente, Recursos Naturales y Pesca) 1999. *Anuario Estadístico de Pesca 1998*. México. (In Spanish).
5. SEMARNAP (Secretaria de Medio Ambiente, Recursos Naturales y Pesca) 1996. *Programa de Pesca y Acuacultura 1995–2000*. México. (In Spanish).
6. Leach, M., Mearns, R. and Scoones, I. 1997. Environmental entitlements: A framework for understanding the institutional dynamics of environmental change. IDS Discussion paper, n. 359.
7. Ostrom, E. 1990. *Governing the Commons. The Evolution of Institutions for Collective Action*. Cambridge University Press.
8. Ostrom, E., Burger, J., Field, C.B., Norgaard, R.B. and Policansky, D. 1999. Revisiting the Commons: Local lessons, global challenges. *Science 284*, 278–282.
9. SEPESCA (Secretaria de Pesca). Instituto Nacional de Pesca 1988. *Instituto Nacional de Pesca: 25 Años*. Mexico. (In Spanish).
10. Maitland, P.S. and Campbell, R.N. 1992. *Freshwater Fishes*. Harper Collins Publishers. London.
11. Persson, L. 1991. Interespecific interactions. In: *Cyprinid Fishes. Systematics, Biology and Exploitation*. Winfield, I.J. and Nelson, J.S. (eds). Chapman and Hall. London.
12. Schmitt, M. 1987. 'Ecological niche' sensu Guenther and 'ecological licence' sensu Osche—two valuable but poorly appreciated explanatory concepts. *Zool. Beitr. 31*, 49–60.
13. García, E. 1988. *Modificaciones al Sistema de Clasificación Climática de Köppen*. Offset-Lario. México. D.F. (In Spanish).
14. Zambrano, L., Perrow, M., Aguirre-Hidalgo, V. and Macías-García, C. 1999. The impact of introduced carp (*Cyprinus carpio*) in subtropical shallow ponds. *J. Aquat. Stress Ecosyst. Recov. 6*, 281–288.
15. Zambrano, L. and Hinojosa, D. 1999. Direct and indirect effects of carp (*Cyprinus carpio*) on macrophytes and benthic communities in experimental ponds. *Hydrobiologia 409*, 131–138.
16. Necchi, O. Jr., Branco, L.H.Z. and Branco, C.C.Z. 1995. Comparison of three techniques for estimating periphyton abundance in bedrock streams. *Arch. Hydrobiol. 134*, 393–402.
17. Renfro, W. 1962. Small beam net for sampling postlarval shrimp. In: Galveston Biological Lab. June 30. *U S Fish Wild. Serv. Circ. 161*, 86–87.
18. Scheffer, M. 1998. *Ecology of Shallow Lakes*. Chapman and Hall. London.
19. Zambrano, L., Scheffer, M. and Martínez-Rámos, M. 2001. Catastrophic response of lakes to benthivorous fish introduction. *Oikos 94*, 344–350.
20. Lammens, E. 1991. Feeding and behaviour. In: *Cyprinid Fishes: Systematics, Biology and Exploitation*. Winfield I.J. and Nelson, J.S. (eds). Chapman and Hall. London.
21. Scheffer, M., Hosper, S.H., Meijer, M.-L., Moss, B. and Jeppesen, E. 1993. Alternative equilibria in shallow lakes. *TREE. 8*, 275–279.
22. Cahn, A.R. 1929. The effect of carp on small lake, the carp as a dominant. *Ecology 10*, 271–274.
23. Crowder, A. and Painter, D.S. 1991. Submerged macrophytes in Lake Ontario: Current knowledge , importance, threats to stability and needed studies. *Can. J. Fish. Aquat. Sci. 48*, 1539–1545.
24. Roberts, J., Chick, A., Oswald L. and Thompson, P. 1995. Effect of carp (*Cyprinus carpio* L.) an exotic benthivorous fish, on aquatic plants and water quality in experimental ponds. *Mar. Freshwater Res. 46*, 1171–1180.
25. INEGI (Instituto Nacional de Estadística, Geografía e Informática) 1995. *Acambay. Cuaderno Estadístico Municipal*. México: INEGI. (In Spanish).
26. Sen, A. 1981. *Poverty and Famines*. Oxford: Clarendon.
27. Sen, A. and Drèze, J. 1989. *Hunger and Public Action*. Oxford: Clarendon.
28. Muñoz, M. 1996. *Tablas de Valor Nutritivo de los Alimentos de Mayor Consumo en México*. México. (In Spanish).
29. SNCA, INSZ 1996. *Subdirección de Nutrición Experimental y Ciencia de los Alimentos: Tabla de Composición de Alimentos*. México. (In Spanish).

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