AQUACULTURE IN TROPICAL MEXICAN LAKES AND DAMS: ACHIEVEMENTS AND PERSPECTIVES

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Introduction

Mexico, with highly diverse physiography, geology, soils and climate, is a country with a broad mosaic of aquatic ecosystems within 320 watersheds. Nevertheless, the country has problems of surface water shortage, with rainfall that is unequally distributed, both in time and geographically. 65% of the land is arid or semi-arid (Fig. la) and 10% of soils under irrigation have become saline; 60 to 70% of agriculture is seasonal and harvests are frequently lost in periods of excessive rain or drought (Escolero 1993; Lopez 1997). In general, 85% of precipitation occurs during four months of the year, causing frequent overflowing and flooding, soil erosion by intense rain, significant blockage of water systems, and a lack of vegetation cover more or less permanently throughout the year. The north of Mexico and part of the Central Plateau have scarce precipitation, less than 500 mm per year, while part of the Peninsula of Baja California and the State of Sonora receive less than 100 mm annually (Fig. lb). On the other hand, towards the south-east of the country, annual precipitation reaches levels of more than 2000 mm, producing exuberant vegetation and widespread permanent flood-zones (Acosta 1993).

The uneven distribution of rainfall severely affects agricultural activities and the most prosperous agricultural zones are those with irrigation water from reservoirs, which permits a much longer period of sowing and harvesting. In Mexico, 60 to 70% is subsistence-seasonal agriculture and typically of the traditional migratory type ("slash-timber-burn"), and the poorer section of the rural population is frequently forced to subsist using marginal land, characterized by poor soils and steep slopes; similar conditions are found in Central America (Vargas & Vaux 1988). In the zone bordering directly on the Mexican lakes and reservoirs, agriculture and cattle grazing occupy a higher proportion of total land than they do in the basin as a whole. Farming and physical man-made changes and natural processes within watersheds, including uncontrolled development, discharge of pollutants, erosion and channelization, has led to an increased rate of eutrophication in all lakes and reservoirs. These show some of the common symptoms of

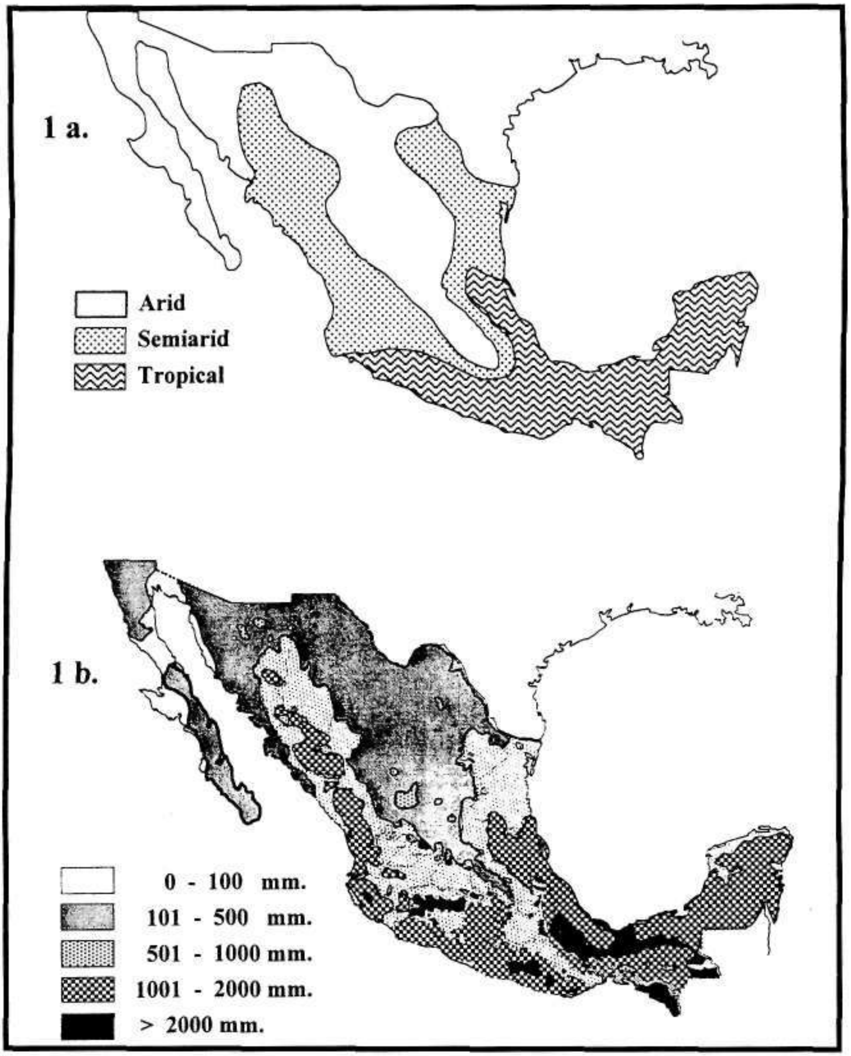

FIG. 1. General distribution of climate and annual precipitation in Mexico.

eutrophication: blooms of algae, rapid loss of volume, noxious odours and fish kills, thus affecting the sustainability of commercial (eyelids and carps) and sport (black bass) fisheries.

Mexican fresh waters have a broad potential for fish aquaculture, ranging from management of some fish species for subsistence of rural people and opportunities to build up commercial cooperatives, to production of fish for the most exclusive international markets. Aquaculture in inland waters is growing around the world and, in general, demand for the products of aquaculture can be expected to grow, with ups and downs related to the conditions of supply and demand (Nash 1991; Stickeney 1994). Thus the production by aquaculture in Mexico during the period 1988 to 1997, based on carps (6000-8000 tonnes per year) and eyelids (4000-8500 tonnes per year), showed peaks in 1992 and 1997 but was low in 1995 (FAO 1999).

The need for management

Proper management of water, biotic and aquacultural resources can coexist only when based on a sound foundation of scientific data, constructing a single historic ecology for each system; otherwise any problems that arise will be solved only incompletely, even in developed nations (Brenner & Whitmore 1995; Welch & Cooke 1995). To solve environmental problems in the tropics (including most of the developed countries), critically requires management in a setting that is often devoid of a reliable database, and must avoid directly transferring scientific data, theories, management methods and models that have been produced in temperate regions (Limon & Lind 1990). Unfortunately, the general status of tropical freshwater ecology is in a relatively parlous position; better knowledge is desirable and needed for the conservation and management of aquatic systems. It is important to examine more closely their structure and function, and identify both the similarities and differences in pattern and processes operating in tropical and temperate latitudes (Dudgeon & Lam 1994; Williams 1994). However, in recent years there have been several positive developments in the management of aquatic systems in the tropics, mainly in reservoirs (Vargas & Vaux 1988).

The full range of potential benefits available from aquaculture and fishery projects (commercial and sport fisheries) will often become reality only if the particular aquatic system and its catchment are wisely managed (Chacon 1993; Jones & Knowlton 1993; Hendricks et al. 1995). Lakes and reservoir management in the tropics must often operate under a somewhat different set of demands and constraints than it does, for example, in the USA. For example, the economic situation in many developing countries is such that funding for lake restoration and/or management projects is often extremely scarce. This and other constraints mean that not only must there be an emphasis on limnological research that is directly applied to the most pressing

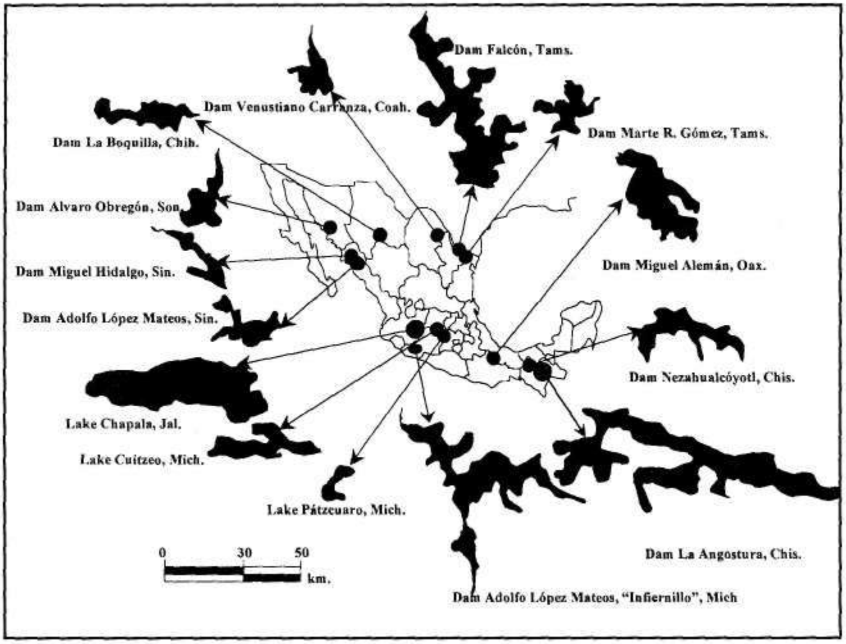

FIG. 2. Locations and comparative sizes of some principal lakes and large dams (reservoirs) in Mexico.

issues, but also that limnology must be integrated as much as possible into the general field of environmental management (Vaux et al. 1988).

Table 1. The principal natural lakes of Mexico. (From Arredondo & Aguilar 1987).

Name	Location	Surface area (ha)
Chapala	Jalisco-Michoacán	110,000
Cuitzeo	Michoacán	42,000
Catazajá	Chiapas	20,000
El Corte	Campeche	20,000
Ravicora	Chihuahua	20,000
Bustillos	Chihuahua	10,800
Pátzcuaro	Michoacán	10,775
Encinillos	Chihuahua	10,000

Table 2. The principal large dams (reservoirs) of Mexico. (From Vidal et al. 1985; CNA 1991; Carranza & Lopez 1995; Contreras 1995; Juarez 1995; Palacios 1995; Rodriguez et al. 1995; Tomassini 1995).

Name	Location	Surface area (hectares)
Doctor Belisario Domínguez "La Angostura"	Chiapas	60,000
Vicente Guerrero	Tamaulipas	46,785
Falcón	Tamaulipas	46,000
Miguel Alemán "Temazcal"	Oaxaca	43,300
Adolfo López Mateos "Infiernillo"	Michoacán	36,000
Nezahualcóyotl	Chiapas	30,000
Miguel de la Madrid Hurtado "Cerro de Oro"	Oaxaca-Veracruz	22,000
Venustiano Carranza	Coahuila	19,800
El Cuchillo	Nuevo León	17,750
Marte R. Gómez	Nuevo León-Tamaulipas	15,866
Miguel Hidalgo	Sinaloa	15,000
Adolfo López Mateos	Sinaloa	11,320
La Boquilla	Chihuahua	10,904
Alvaro Obregón	Sonora	10,155
José López Portillo	Sinaloa	8,972
Adolfo Ruíz Cortínez	Sonora	7,692
Plutarco Elías Calles	Sonora	6,396
Carlos Ramírez Ulloa "El Caracol"	Guerrero	5,000

Lakes and reservoirs in Mexico

The total area of interior waterbodies in Mexico is estimated at *c.* 1,100,000 hectares, of which 371,000 ha comprise 70 natural lakes with surface areas ranging from 1000 to 10,000 ha (de la Lanza & Garcia 1995). The principal natural lakes (>10,000 ha) are: Chapala, Cuitzeo, Catazaja, El Corte, Ravicora, Bustillos, Patzcuaro and Encinillas (Table 1). These, with the smaller Lake Zirahuen (Bernal-Brooks 1998), together total 244,551 ha (Arredondo & Aguilar 1987).

In order to solve the problem of floods, and to use water for several purposes, such as storage for irrigation, generation of electricity, and production of fish, a programme for constructing dams and reservoirs has had a high priority for the Mexican government since 1926, when the construction of large-scale storage reservoirs began. By 1995, several sources report the existence of 2396 reservoirs throughout the national territory of Mexico, providing more than 600,000 ha of surface water. Some of the biggest

FIG. 3. *(Right above):* The lagoon "Huizache-Caimanero", State of Sinaloa, Mexico, and a fisherman throwing the atarraya. The net is used to catch fish and macrocrustaceans such as the shrimp *Pennaeus.* Small boats are equipped with oil lamps or torches for use in the evening. The shrimp fishery is the most important and valuable activity in both intensive and extensive aquaculture. *(Right below):* Fish caught at the hydropower dam "El Caracol", State of Guerrero, Mexico. The fish are tilapia and carps; the largest in the picture is *Cyprinus carpio,* about 50 cm in length. These fish form the basis of fisheries in Mexican dams and support numerous co-operatives of fishermen.

reservoirs, their locations, and surface areas, are shown in Fig. 2 and Table 2. Environmental and social impacts generated by building reservoirs is another issue; planning and design of large reservoirs in Mexico aims to minimize or completely avoid any harmful effect on the environment, and also includes compensatory action for local inhabitants (CNA 1991).

Table 3. Yields (tonnes) of the main species of fish and shellfish produced in the inland fresh waters of Mexico (Secretaría de Pesca 1989).

Species	Yield
Mojarra (mainly *Tilapia*)	73,766
Carp (*Cyprinus* spp., *Carassius*)	22,504
Charal (*Chirostoma*)	7,898
Prawn (*Macrobrachium* spp.)	3,151
Catfish (*Ictalurus* spp.)	2,941
Shrimp (marine yield excluded)	2,846
Black bass (*Micropterus* sp.)	1,414
Rainbow trout (*Salmo gairdneri*), cultivated	840
Others	9,732
Total	125,098

Fish production in the inland waters of Mexico

The production of fish in the lakes and reservoirs of Mexico is relatively low and figures vary greatly from one waterbody to another; equally, each waterbody can have very considerable variations over time.

In 1989, the total production of inland waterbodies (i.e. excluding estuaries and lakes along the coastline) was 125,100 tonnes or 125 kg per ha (Table 3). 77% of this production came from "mojarra", principally *Tilapia* spp. (59%); 18% was carp *(Cyprinus* spp. and *Carassius auratus).* Other important species were "charal" *(Chirostoma),* prawn *(Macrobrachium),* catfish *(Ictalurus)* and shrimp *(Pennaeus).*

There is no reliable detailed information on the levels of productivity in most of the major waterbodies, but some particular cases are presented below.

Lake Patzcuaro, Michoacan

Patzcuaro has a surface area varying from 9000 to 10,777 ha and an average depth of 4.9 metres. Its production of fish has shown a constant increase from 1980 to 1987, rising from 396 tonnes in the first year to 1484 tonnes in the last year, with a maximum of 1714 in 1985 (Lizarraga & Tamayo 1988). Annual production of fish, based on an average lake surface area of 10,000 ha, has oscillated between 39.6 and 171.4 kg per ha, with an average of 102.7 kg per ha during 1980-1987.

Lake Cuitzeo

Cuitzeo is an expanse of shallow water which, according to Orbe (1991), produced very considerable annual variations in fish production during the 1980s, averaging 27.9 kg per ha and ranging from 3.2 kg per ha to 55.6 kg per ha (Table 4).

Table 4. The yields (tonnes) and production (kg per ha) of fish in Lake Cuitzeo in the period 1980 to 1990. (From Orbe & Acevedo 1991).

Year	Yield	Production
1980	190	28.3
1984	136	3.2
1987	1036	24.6
1990	2337	55.6

Table 5. The yields (tonnes) and production (kg per ha) of fish in Dam Adolfo Lopez Mateos ("El Infiernillo") during the period 1981 to 1987.

Year	Yield	Production
1981	8,784	253
1982	11,557	334
1983	9,457	273
1984	13,377	386
1985	13,038	376
1986	13,813	399
1987	22,272	643

Dam Adolfo Lopez Mateos ("El Inflernillo")

One of the biggest reservoirs in Mexico, with a maximum surface area of 40,000 ha, this reservoir has the highest fish production. Its yield has varied between 8784 tonnes in 1981 to 22,272 tonnes in 1987 (Romero & Orbe 1988). Assuming an average superficial area of 34,600 ha, average annual productivity between 1981 and 1987 has been 380 kg per ha, with a minimum of 253 in 1981 and a maximum of 643 kg per ha in 1987 (Table 5).

Dam Miguel Alemán (Temascal)

Another of the largest reservoirs in Mexico, Miguel Aleman has a surface area of 43,330 ha. In the 1960s, intensive re-stocking with young tilapia was undertaken and within a few years an important fishing industry based on this resource was established. In 1975, production reached 6300 tonnes, a figure that was maintained with some annual fluctuations until it settled at slightly lower levels. For this reservoir an annual production of 130 kg per ha is estimated.

Dam Yosocuta

Situated in the State of Oaxaca, in the Mixtec region, Yosucata is one of the best studied reservoirs from a limnological point of view (Carranza & Rojas 1972, 1973, 1974). It is a small reservoir (1000 ha), constructed in 1969 for irrigation purposes. After a detailed study of its limnological characteristics, in 1973 it was re-populated with a combination of tilapia, black bass and carp. One year later a fishery had been established, based on tilapia and black bass, with an annual yield calculated at 242 kg per ha; this figure was later reduced to 150 kg per ha as an established fishable population. At the present time, due to an imbalance between the populations of tilapia and black bass, the annual catch has decreased to *c.* 80 kg per ha, but this figure could increase with adequate management of the reservoir.

Alternative procedures to increase fish production in lakes and reservoirs

Lakes and reservoirs are circumscribed bodies of water, with relatively small limits, and these ecosystems can be managed in a more efficient way than ocean environments. Their exploitation for the production of food can be increased by using the following methods, briefly summarized under the following three headings.

Fishing regulation

When a lake or reservoir already has a developed fishing industry, yields can be optimized with the application of fishing science. For this the maximum sustainable yield that can be obtained from the exploited species must be calculated, and measures for fishing regulation applied so that production can be maintained at the sustainable level, but not increased above the biological level of productivity for the capacity of the particular waterbody.

Extensive aquaculture in artificial waterbodies

In the majority of artificial lakes and reservoirs, fishing is not developed for high yields in a natural way, owing to the fact that many of the native fish species present in the original ecosystem are not appropriate. Consequently, after making a limnological study of a reservoir, the species considered to be most suitable is introduced into the new environment and its cultivation is then developed. Later, continual follow up must be undertaken in order to increase the population of fish, and recommended aquacultural techniques for each particular case must be applied. When a population of fish has been fully established and a fishing industry has developed, the administration and optimization of the fishery ceases to be a problem of aquaculture and now falls into the category of fishing regulation. The fish-yields in artificial waterbodies may be considerably greater than those of inland fisheries based on natural populations, as is the case in the reservoirs of Adolfo Lopez Mateos and Miguel Alemán, mentioned in previous sections.

Intensive aquaculture

The productivity of a reservoir can be increased considerably by the production of fish in floating boxes, taking advantage of surface waters that are of the best quality and have the highest dissolved oxygen content. In spite of the fact that this technology has been experimentally investigated in Mexico, the economic results have not been totally satisfactory. Reasons for this include the use of small boxes, which affect the growth of the organisms (boxes with a surface area of 30 to 60 m^2 and a depth of 1.5 to 2.5 m should be used to avoid excessive confinement of fish), inadequate control of balanced feed, and experimentation with species of low commercial value in the market.

Intensive aquaculture for high yields requires the following basic conditions: (1) water with a sufficient quantity of dissolved oxygen, constantly available; (2) elimination of metabolic waste, by means of periodic or constant renovation of the water; (3) good quality water, free from contaminants; (4) artificial food that is strictly balanced.

The three first requirements are amply covered in a reservoir. Thus, with reference to dissolved oxygen, even where deep waters are anoxic, surface layers normally have a high oxygen content throughout the year, providing sufficient depth of water for cultivating fish in boxes. In some cases this surface zone remains saturated with oxygen for very long periods, and its concentration does not decrease to critical limits even during the night, for which reason it is ideal for aquacultural uses.

The metabolic waste products of the fish do not constitute a problem for cultivation in boxes, as they are eliminated through the bottom by currents and turbulence provoked by the wind. In the case of fish cultivation in small ponds, this is the limiting factor for obtaining a high yield and has been resolved by the use of flow channels.

Finally, the good quality of the water and absence of contaminants are the predominant characteristics of the greater part of the larger lakes and reservoirs in Mexico, so they do not constitute a limiting factor for aquaculture in boxes.

The annual production of fish in boxes may be *c.* 2 to 3 kg per m^2 or 20,000 to 30,000 kg per ha, if the quality of balanced feed is controlled and species capable of achieving high yields are used, such as canal catfish or red tilapia. These are very high yield-values in comparison with conventional fish production in the most productive reservoirs (380-634 kg per ha in Adolfo López Mateos reservoir), and amply justify adequate financing for developing technology to utilize Mexican reservoirs for producing fish in floating boxes.

Importance of developing aquaculture in fresh water

In the last few years, the productivity of inland waters has been noticeably increasing throughout the world, due to the development of aquaculture. In the 1950s a production of 3 tonnes of fish per ha was considered ample. Twenty years later, 30 tonnes per ha are produced annually by aerating water in reservoirs, preventing contamination by excrement from domestic animals, and by supplementary feeding of fish. Currently, up to 1000 tonnes per ha can be produced annually in drainage canals or "raceways", an extraordinarily high figure for any kind of agriculture or fishing worldwide.

One of the greatest problems facing humanity is the supply of food for a population that is growing at an accelerated rate. Gladwell & Bonell (1990) estimated that the world population will increase from 4400 million in 1980 to 6200 million in the year 2000. The greatest levels of growth will be in Africa (75%), Latin America (65%), South Asia (55%) and East Asia (24%); the developed countries will have a much lower growth level and we surmise that the population of the USA will increase by 17% in the same period, Russia by 18% and Europe by only 7%. Fishing and aquaculture are very important sources of protein for the human populations and, in fact, provide at least 24% of the proteins that are consumed in the world (FAO 1983). This proportion will increase more now that the demand for fish products is growing very fast as a consequence of, among other factors, a greater consciousness, especially in developed countries, of the dietary advantages of fish compared with red meat. For example, fish are more digestible and the cholesterol content is much less damaging to humans than that derived from other food sources.

However, the production of fish from natural populations is not growing at the desired rate because of overexploitation, increased costs of production, and readjustments in maritime fishing operations with the objective of enforcing the new Law of the Sea. Hence aquaculture will have to provide the necessary increase in demand. In fact, production from aquaculture worldwide has increased at 19% annually between 1975 and 1985, whereas agricultural-fisheries production was 3.5%. In 1985 the total estimated production was 10,587,300 tonnes, increasing to 14,466,306 tonnes in 1988, and 17 million tonnes is estimated for the year 2000 (Garcia & Cabrera 1990; Stickney 1994).

The rise in popularity of aquaculture is due to the fact that it has many advantages over conventional forms of fishing. One is that fish are kept alive until moments before they are processed for the market, in contrast to marine fish where the product is conserved by refrigeration for many days or weeks before consumption. Fish cultivated in very pure water, free from contaminants and with appropriate supplementary feeding, are perfectly balanced in terms of the content of fat, protein, mineral and hydrates of carbon. This permits the final production of a very high quality product in terms of hygiene and nutrition. An additional advantage for aquaculture is that meteorological factors do not affect the harvesting of fish to the same extent as fishing with nets, particularly at sea.

The majority of freshwater fishes that are cultivated worldwide can be produced in floating boxes or corrals in the reservoirs and lakes of Mexico, but to do so requires the application of an integrated and adequately supported programme of research and development, comprising biological, technological and economic aspects.

An example may be found in the development of the cultivation of catfish in reservoirs of the USA. This fish was originally consumed largely by the low income population in the south of the USA, but was identified as a species with very great potential for aquaculture by scientists at the University of Auburn, Alabama. With support from the public and private sectors, a strongly financed project was undertaken to develop biotechnology for cultivating catfish, and in a few years a biotechnological and economic package was made available for industry. A coordinated programme of aquaculture and business has increased production from 140 tonnes annually at the beginning of the 1960s to 40,000 tonnes in 1973 and 85,000 tonnes in 1985. In the four years between 1979 and 1985, the extent of water dedicated to catfish culture in the state of Mississippi (one of the principal producers) increased from 11,000 to 30,000 ha.

The aforementioned considerations lead us to regard aquaculture as a biotechnology with far-reaching possibilities, equally at a world level as well as nationally. Its development in Mexico has been achieved in some rural reservoirs, but very little has been done so far to take advantage of the wide and rich potential of numerous other lakes and reservoirs. Generous funding of research and development is now required to develop a biotechnological and economic programme for cultivating selected species of fish in floating boxes.

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References

Acosta, A. (1993). Situación general del recurso hidráulico superficial en Mexico. In *El agua recurso vital,* pp. 21-26. Universidad Tecnológica de la Mixteca. Mexico.

Arredondo, J. L. & Aguilar, C. (1987). Bosquejo histórico de las investigaciones limnológicas realizadas en lagos mexicanos, con especial énfasis en su ictiofauna. In *Contribuciones en hidrobiologia* (eds. S. Gómez-Aguirre & V. Arenas Fuentes), pp. 91-133. Proceedings of the meeting "Alejandro Villalobos" held at the National Autonomous University of Mexico, 24-26 October, 1983.

Bernal-Brooks, F. W. (1998). The lakes of Michoacán (Mexico): a brief history and alternative points of view. *Freshwater Forum* 10, 20-34.

Brenner, M. T., Whitmore, J., Curtis, J. H. & Schelske, C. L. (1995). Historical ecology of a hypereutrophic Florida lake. *Lake and Reservoir Management* 11, 255-271.

Carranza, J. & Rojas, J. L. (1972). *Informe de la primera etapa del estudio sobre limnologia y piscicultura en los vasos de almacenamiento Yosocuta y El Encino, Oaxaca.* ler Informe del Contrato de Estudios OC-E-03-71 UNAM-Comisión del Rio Balsas. Mexico. 72 pp.

Carranza, J. & Rojas, J. L. (1973). *Informe de la segunda etapa del estudio sobre limnologia y piscicultura en los vasos de almacenamiento Yosocuta y El Encino, Oaxaca.* 2o. Informe del Contrato de Estudios OC-E-03-71 UNAM-Comision del Rio Balsas. Mexico. 168 pp.

Carranza, J, & Rojas, J. L. (1974). *Informe de la tercera etapa del estudio sobre limnologia y piscicultura en los vasos de almacenamiento Yosocuta y El Encino, Oaxaca.* Informe Final del Contrato de Estudios OC-E-03-71 UNAM-Comisión del Rio Balsas. Mexico. 147 pp.

Carranza, J. & López, M. (1995). Presa El Caracol (Ingeniero Carlos Ramirez Ulloa). In *Lagos y presas de Mexico* (compiladores E. G. de la Lanza & C. J. L. Garcia), pp. 225-241. Centro de Ecologia y
. Mexico.

CNA (1991). *Mexico: large dams 1982-1991*. Comisión Nacional del Agua. Mexico. 102 pp.
Chacon, T. A. (1993). Lake Pátzcuaro, México: watershed and water quality deterioration in a tropical high-altitude Latin American lake. *Lake and Reservoir Management* 8, 34-47.
Contreras, B. S. (1995). Las presas del Noroeste de México. In *Lagos y Presas de México* (compiladores E. G. de la Lanza & C. J. L. Garcia), pp. 277-289. Centra de Ecologia y Desarrollo. México.
Dudgeon, D. & Lam, K. S. (1994). Inland waters of tropical Asia and Australia: conservation and management. *Mitteilungen Internationale Vereinigung für Theoretische und Angewandte Limnologie* 24, 1-3.
Escolero, O. (1993). Panorámica del agua subterránea en Mexico. In *El agua recurso vital,* pp. 37-52. Universidad Tecnológica de la Mixteca. Mexico.
FAO (1983). *El problema mundial de la alimentación.* Food and Agriculture Organization of the United Nations. Informe Especial de la FAO, 1L/2915.
FAO (1999). *Aquaculture production statistics.* Food and Agriculture Organization of the United Nations. Fisheries Circular No. 815, Revision 11. Rome. 203 pp.
Garcia, C. J. L. & Cabrera, J. J. (1990). La acuicultura. Definiciones y Limites. In *La acuicultura en México: de los conceptos a la producción* (compiladores E. G. de la Lanza-Espino & F. J. L. Arredondo), pp. 3-14. Instituto de Biologia, Universidad Nacional Autónoma de México. México.
Gladwell, J, S. & Bonell, M. (1990). An international programme for the development of hydrological and water management strategies in the humid tropics. In: *Water resources management and protection in tropical climates* (eds V. Quezada, J. Gutierrez & L. Landner), pp. 82-90. Swedish Environmental Research Group.
Hendricks, A. S., Maceina, M. J. & Reeves, W. C. (1995). Abiotic and biotic factors related to black bass fishing quality in Alabama. *Lake and Reservoir Management* 11, 47-56.
Jones, J. R. & Knowlton, M. K. (1993). Limnology of Missouri Reservoirs: an analysis of regional patterns. *Lake and Reservoir Management* 8, 17-30.
Juarez, P. R. (1995). Presa Infiernillo (Adolfo López Mateos). In *Lagos y presas de México* (compiladores E. G. de la Lanza & C. J. L. Garcia), pp. 211-223. Centra de Ecologia y Desarrollo. México.
Lanza de la, E. G. & Garcia, C. J. L. (Compiladores) (1995). *Lagos y presas de México.* Centro de Ecologia y Desarrollo. Mexico. 320 pp.
Limon, G. & Lind, O. T. (1990). The management of Lake Chapala (Mexico): considerations after significant changes in the water regime. *Lake and Reservoir Management* 6, 61-70.
Lizarraga, E. Y. & Tamayo, P. (1988). Análisis de la producción pesquera del Lago de Pátzcuaro, Michoacán en el periodo 1980-1987. In *Centro Regional de Investigation Pesquera Pátzcuaro, Michoacán. Informe de labores 1986-1988,* pp. 49-70. Instituto Nacional de Pesca. México.

Lopez, M. (1997). *Caracterización limnológica del Rio Duero, Michoacán.* Tesis Doctoral. Facultad de Ciencias, Universidad Nacional Autónoma de Mexico. Mexico. 135 pp.

Nash, C. E. (1991). Turn of the millennium aquaculture: navigating troubled waters or riding the crest of the wave? *World Aquaculture* 22, 28-49.

Orbe, A. A. & Acevedo, J. (1991). Informe sobre la Biologia Pesquera del Lago de Cuitzeo. In *Centro Regional de Investigation Pesquera Pátzcuaro, Michoacán. Informe de labores 1986-1988,* pp. 1-90. Instituto Nacional de Pesca. Mexico.

Rodriguez, L. T., Roman, M. M. & Vásquez, S. A. (1995). Presa La Angostura (Dr. Belisaro Domfnguez). In *Lagos y Presas de México* (compiladores E. G. de la Lanza & C. J. L. Garcia), pp. 243-260. Centro de Ecologia y Desarrollo. México.

Romero, A. & Orbe, A. (1988). Análisis de la explotación pesquera en la Presa Lie. Adolfo López Mateos, Michoacán, Mexico, durante el periodo 1981-1986. In *Centro Regional de Investigation Pesquera Pátzcuaro, Michoacán. Informe de labores 1986-1988,* pp. 71-89. Instituto Nacional de Pesca. Mexico.

Secretariá de Pesca (1991). *Anuario estadistico de pesca 1989.* Dirección General de Informática y Estadistica. México. 125 pp.

Stickney, R. R. (1994). *Principles of aquaculture.* John Wiley & Sons, Inc., USA. 501 pp.

Tomassini, O. E. (1995). Presa La Presa La Angostura (Dr. Belisaro Dominguez). In *Lagos y Presas de México* (compiladores E. G. de la Lanza & C. J. L. Garcia), pp. 261-267. Centro de Ecologia y Desarrollo. México.

Vargas, E. & Vaux, P. (1988). Limnological and ecological considerations for hydropower development in Honduras. *Lake and Reservoir Management* 4, 213-220.

Vaux P., Vargas, E., Diaz, A. & Flores, A. (1988). The El Cajon Reservoir: developing management strategies for a tropical impoundment. *Lake and Reservoir Management* 4, 199-211.

Vidal, L., Valera, G. M. & Rangel, M. R. (1985). *Frontera acuicola.* Secretaria de Agricultura y Recursos Hidraulicos. Comisión Plan Nacional Hidráulico. Mexico. 216 pp.

Welch, E. B. & Cooke, G. D. (1995). Internal phosphorus loading in shallow lakes: importance and control. *Lake and Reservoir Management* 11, 273-281.

Williams, D. (1994). Constraints to the conservation and management of tropical inland waters. *Mitteilungen Internationale Vereinigung für Theoretische und Angewandte Limnologie* 24, 335-363.