CURRENT STATE OF MOLLUSCAN RESOURCES OF THE GULF OF MEXICO

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IMPORTANCE

Mollusk production in Mexico in 2001 totaled 135,204 metric tons, with a total value of 724 million Mexican pesos (~72 million US dollars), corresponding to 10.2% of the volume and 5.62% of the value of national fishing production; 50.8% of the volume and 59.44% of this value was produced on the Atlantic coasts, coming mostly from coastal artisan fishing, with a total of 43,392 boats, of independent fishermen or those working in organizations or cooperatives (Table 10.1). Mollusk fishery production is classified into six groups: abalone (not found on the on the coasts of the Gulf of Mexico and the Caribbean), clam, squid, conch, oyster and octopus.

In the Bay of Campeche and most of the rest of the Gulf of Mexico and Caribbean, the molluscan fishery is comprised of 24 species (Table 10.2) that are exploited by both independent fishermen and those working in organizations or cooperatives. With the exception of oyster cooperatives in which exploitation of that species is the main activity, the extraction of mollusks by all the other groups of fishermen is a secondary activity, which complements fishing for finfish or agricultural activities. The exploitation of all species is carried out by artisanal methods, employing collection by hand, as in the case of oysters in the Laguna de Términos, and various reef bivalves in Veracruz or using tongs, dredges and scoops operated from boats to extract clams from the lagoon in Alvarado, Veracruz and Términos, Campeche and in open water, free-diving or scuba diving to extract clams and scallops in Yucatan and Quintana Roo. Octopus is caught by fleet of over 10,000 artisanal boats in the states of Campeche and Yucatan and a fleet of about 600 medium-sized boats in the state of Yucatan. Squid is caught incidentally in shrimp trawls.

For the coasts of the Gulf of Mexico and the Caribbean the various bivalve groups constitute 63% of volume and 7% of value; oyster accounts for 61% of the volume 75% of the value (Figure 10.1; CONAPESCA 2001). Of the six states on the Mexican Atlantic coast, the state of Veracruz is first in volume (30.8%), followed by Yucatan (24.3%), whereas in value, Yucatan is first (31%), followed by Veracruz (30%; Figure 10.2). Gastropod catch has increased in the last ten years from a little over 3,182 metric tons in 1989 to 7,362 metric tons in 1999. In addition, there has been a significant change in the contribution per state with Campeche increasing from 2% in 1980 (Baqueiro 1988) to over 66% in 2001.

BIOLOGY

BIVALVES

Rangia cuneata (almeja gallito; common rangia) is an estuarine species that inhabits waters ranging in salinity from 0 to 25‰, and tolerating salinity of up to 32‰, with an optimum range of 5-15‰. The optimum range is required for hatching and larval survival, which reach metamorphosis at 6 or 7 days. Adults can live up to 20 years in salinity ranges that are too high or too low for reproduction (Hopkins *et al.* 1973). It is distributed from Chesapeake Bay, on the east coast of the USA, to Texas (Abbott 1974), and extends to Laguna de Términos, covering the whole of the Gulf of Mexico. It inhabits muddy bottoms with high organic matter content. It is the most important ecological component of the benthos in this salinity range, as a consumer of

Table 10.1. Registered fishing organizations and number of members by state and coast, 2000 (CONAPESCA 2001). OFOS = Otras Formas de Organización Social (other forms of social organizations that are not typically formally instituted, e.g., groups of coastal residents that supplement their incomes by seasonally exploiting shrimp or other fisheries resources, or by cultivating fish like tilapia).

Coast or State	Number of Organizations			Number of Members		
	Total	Co-ops	OFOS	Total	Co-ops	OFOS
Gulf & Caribbean coasts	1,641	737	904	48,060	27,454	20,606
Tamaulipas	133	104	29	5,986	5,176	810
Veracruz	600	166	434	16,294	6,053	10,241
Tabasco	326	179	147	12,216	8,053	4,163
Campeche	299	184	115	6,924	4,824	2,105
Yucatan	231	59	172	5,275	2,058	3,217
Quintana Roo	52	45	7	1,360	1,290	70

detritus and phytoplankton and its integration into the food chain (Hopkins *et al.* 1974). In Mexican lagoons it is associated with *R. flexuosa* and *Polimesoda caroliniana*, usually in proportions of 72% of *R. cuneata* 23% *R. flexuosa* and about 4% of *P. caroliniana*. Fishing pressure can alter this proportion to as little as 31% *R. cuneata* with 45% *R. flexuosa* and about 23% *P. caroliniana* (Baqueiro and Medina 1988).

Rangia cuneata is dioecious, with 0.1% hermaphrodites, and spawns throughout the year with maximums February-June and August-September in Pom and Atasta lagoons (Rogers and Garcia-Cubas 1981b). However, in U.S. waters spawning has only been recorded during six months of the year and hatching is limited to intervals determined by changes in salinity and temperature (Hopkins *et al.* 1974).

The population of *R. cuneata* rarely consists of cohorts of different ages, with populations of one or two age classes more common. In Pom and Atasta lagoons, Rogers and Garcia-Cubas (1981b) reported two age classes. However, Baqueiro and Medina (1988) found a population of three cohorts in Laguna Pom, dominated by a cohort of individuals over 3 years of age and two cohorts of recruits between 1 and 2 years of age; in Laguna Atasta the population consisted of three cohorts 3-5 years of age. The maximum age attained by populations in Mexican lagoons is due to high fishing pressure, and is well below the 25-year maximum age recorded in some locations in the USA.

Geukensia demissa (mejillón amarillo; Atlantic ribbed mussel) is a species from the Caribbean province, distributed from Florida and the Yucatan Peninsula to Venezuela. It lives in close association with *Rhizophora mangle* (red mangrove), in fine mud with high content of organic material, among the roots in the intertidal zone.

Asaphis deflorata (almeja blaca de arrecife; gaudy sanguin) live in association with coral reefs, in the muddy areas of the reef lagoon with high carbonate content and coral and shell fragments. *Codakia orbicularis* (almeja rayada or blanca; tiger lucine) is found in beds of *Thalassia testudinum* (turtle grass) where the bottom is muddy and organic matter content is high. *Mercenaria. campechiensis* (concha; southern quahog) and *Chione cancellata* (almeja

Table 10.2. Commercial and aquacultural status of mollusk fishery species in the Campeche Bay. Commercial status: E = fishery species in danger of extinction; C = currently fished; p) species with fishery potential. Aquaculture status: + = possible candidate for cultivation; ++ = species with aquaculture potential; +++ = successfully cultured.

Scientific name	Spanish Common name	English Common Name	Commercial Status	Aquaculture Status
Gastropods				
Busycon carica	Sacabocados, lix or caracol trompillo	Knobbed whelk	C	+
Turbinella angulata	Caracol tomburro or negro	West Indian chank	C	+
Pleuroploca gigantea	Caracol rojo or chac pel	Florida horse conch	E	+
Strombus costatus	Caracol blanco or lanceta	Milk conch	E	+
Strombus pugilis	Caracol canelo or lancetita	West Indian fighting conch	P	++
Fasciolaria lilium	Caracol campechana	Lined tulip	C	+
Fasciolaria tulipa	Caracol campechana	True tulip	C	+
Melongena melongena	Caracol chivita or chirita, or molón	Crown conch	P	++
Melongena corona bispinosa	Caracol negro or moloncito	Crown conch	P	++
Bivalves				
Codakia orbicularis	Almeja rayada or blanca	Tiger lucine	P	+
Anadara transversa	Arca transversa	Transverse ark	P	+
Atrina rigida	Callo de hacha	Rigid pen shell	C	
Argopecten irradians concentricus	Almeja abanico	Atlantic bay scallop	P	+++
Geukensia demissa	Mejillón amarillo	Atlantic ribbed mussel	P	++
Modiolus americanus	Mejillón	Tulip mussel	P	+
Mercenaria campechiensis	Concha	Southern quahog	P	+++
Chione cancellata	Almeja china or roñosa	Cross-barred venus	P	+++
Rangia cuneata	Almeja gallito	Common rangia	C	+++
Rangia flexuosa	Almeja chira	Brown rangia	P	+
Polymesoda caroliniana	Almeja negra	Carolina marsh clam	P	+
Crassostrea virginica	Ostión	Eastern oyster	C	+++
Cephalopods				
Octopus vulgaris	Pulpo	Common octopus	C	++
Octopus maya	Pulpo rojo	Yucatan octopus	C	+++
Loligo spp.	Calamar	Squids	C	

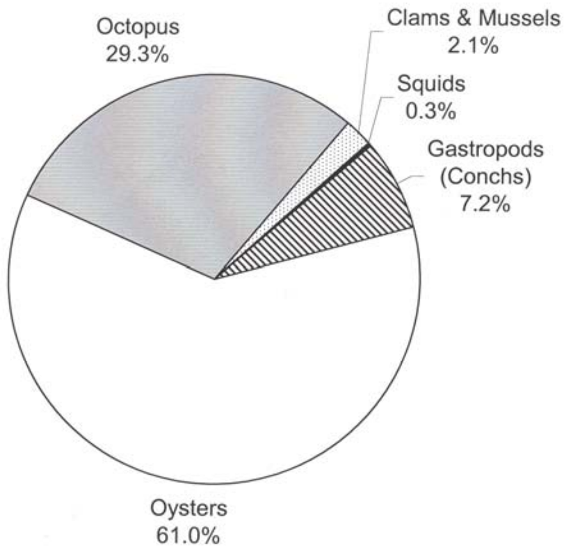


Figure 10.1. Contribution (%) of various molluscan groups to the mollusk fishery in the Gulf of Mexico and Caribbean.

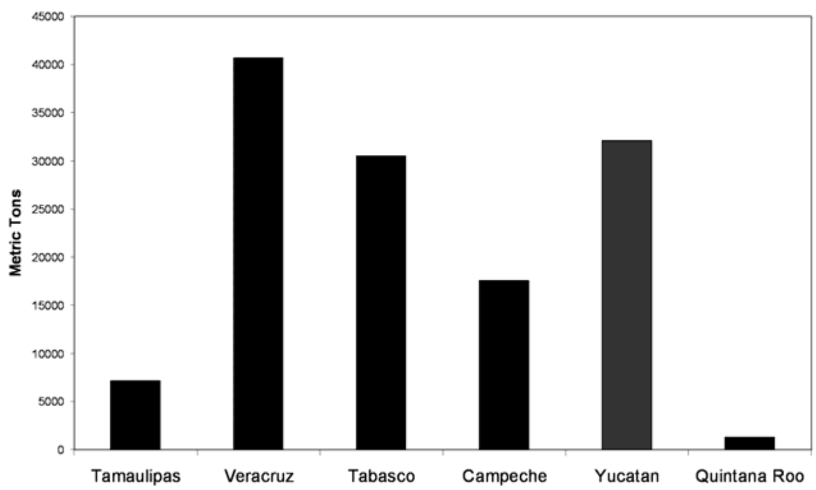


Figure 10.2. Mean production (metric tons) of mollusks from the six states bordering the Mexican Atlantic.

high. *Mercenaria. campechiensis* (concha; southern quahog) and *Chione cancellata* (almeja china or roñosa; cross-barred venus) can be found from in sandy and shelly substrates from the intertidal zone to a depth of 36 m, sometimes in association with *Thalassia* in shallower areas. All of these species are tropical marine species with limited tolerance ranges for salinity and low temperatures (Sunderlin *et al.* 1975; Menzel 1987), although all of them can tolerate desiccation for a relatively long time.

Asaphis deflorata, *Mercenaria campechiensis, Chione cancellata* and *Geukensia demissa* are dioecious with external fertilization and a larval life span of 4-6 days. They prefer to establish themselves in locations with the characteristics required for adult survival, but if these are not found, they will establish in any other kind of substrate. Baqueiro (1988, 1991) determined patterns of reproduction for mollusk populations inhabiting similar environmental conditions along the coasts of Mexico. Similar species living in differing environmental conditions exhibited different patterns of reproduction. Some populations spawned continually with an annual peak, some spawned continually with two or more annual peaks and some spawned only during a well-defined period. For example, from the analysis of reproductive cycles for *Mercenaria campechiensis, Chione cancellata* and *Geukensia demissa* populations inhabiting the same location (Baqueiro and Castillo 1987; Baqueiro *et al.* 1993), exhibited continual spawning with two peak periods: January-March and August-September.

Growth of *M. campechiensis* is 25.5 mm in 13 months in a natural environment and the same in 6.5 months when under cultivation (Sunderlin *et al.* 1975). Baqueiro *et al.* (1987) determined the growth curves for *M. campechiensis* and *Chione cancellata* in natural beds not subject to exploitation on the coasts of Campeche: *Mercenaria campechiensis*: lt = 127.7(1-e-0.1165(t+0.168)); *Chione cancellata*: lt = 36.38 (1-e-0.1392 (t+0.0049)).

Average natural densities of *M. campechiensis* are 2.2/m^2 (range 0.24/m^2-8.5/m^2); average natural densities of *C. cancellata* are 66.72/m^2 (6.2/m^2-148/m^2). When under cultivation, densities of up to 50/m^2 organisms can be obtained for *Mercenaria* (Menzel *et al.* 1975). In Laguna del Ostión, Veracruz Bosada (1987) reported *M. campechiensis* reached commercial size (47 mm) in 3.8 years (a calculation based on the von Bertalanfy equation, very similar to that reported by Baqueiro *et al.* 1987). Survival of *M. campechiensis* in cultivation experiments in a natural environment ranged from 72.5 % to 0.7 % for individuals from 12 mm to commercial size (Sunderlin 1975), whereas for natural beds, average annual mortality rates of 0.44 for *M. campechiensis* and 0.46 for *Chione* were recorded (Baqueiro *et al.* 1987).

Geukensia demissa is a species that is little studied, and the only information available is that of Baqueiro *et al.* (1993), who determine the growth equation for the population in the area of Isla Arenas, Campeche: lt = 146.31(1-e-0.0198 (t+25.36)). This results in the minimum exploitation size of 47 mm to be reached in 6 months, with average density of 330/m^2 and a median annual mortality rate of 0.068.

Atrina rigida (callo de hacha; rigid pen shell) is distributed from North Carolina to the Caribbean and the Gulf of Mexico and can be found associated with beds of *Mercenaria* and *Chione*. It is a marine species that lives from just below lowest low tide to 25 m deep, in substrates ranging from sandy-mud to sandy seagrasses, primarily *Thalassia* (Abbott 1974). It forms beds with average densities ranging from0.3/10 m^2 to 5.5/10 m^2 (Baqueiro *et al.* 1987). Some beds of young individuals (47-56 mm long) reach densities of up to 20/ with beds of adults reaching a maximum of up to 4/m^2 (Baqueiro 1990).

Atrina rigida is dioecious and it first reproduces when reaching a length of 110 mm. Intensity of gamatogenesis is greatest from April to July, with two hatching periods in May and

September (Baqueiro 1990). Populations on the Campeche coast consist of more than 5 age groups, with the dominant cohorts between 1 and 3 years of age. I have recommended a minimum fishing size of 83 mm wide, which is equivalent to 155 mm long and corresponds to 3-year old organisms.

GASTROPODS

The conchs, *Strombus costatus* (caracol lanceta or blanco; milk conch), *S. pugilis* (caracol chivita; West Indian fighting conch), *S. alatus* (Florida fighting conch), *S. raninus* (hawkwing conch), and *S. gallus* (roostertail conch), are distributed from Florida to Venezuela, in the Caribbean province. In Mexico they are located from Veracruz to Quintana Roo and live in sandy and sandy-mud bottoms, in seagrasses (e.g., *Thalassia*) and algae. During reproduction they gather on sandy bottoms with little vegetation and/or filamentous algae from the intertidal zone to a depth of 10 m (Bandel 1976).

The conchs are dioecious with internal fertilization. Sexual dimorphism is only detectable by the presence of a penis in males. The ovigerous mass is typical of the *Strombus* genus, consisting of a string of eggs that forms an oval mass of mucous and cemented sand 5 cm in diameter by 10 cm long. Each embryo develops individually in the ovigerous mass over 12-16 days, depending on temperature. Embryos develop into planktonic veliger larvae, which lasts 15-20 days depending on temperature and food availability (D'Asaro *et al.* 1970; Cruz 1984). Upon reaching a size of 600 μ (pediveliger), metamorphosis begins; they prefer to settle red algae, although they are not particularly selective. As juveniles they are generally found located on protected beaches with sandy bottoms and mixed seagrasses (*Thalassia*) and algae. As the cohort grows, it migrates into deeper waters and gradually disperses.

The crown conchs, *Melongena melongena* (chivita) and *M. corona bispinosa* (caracol negro) are distributed from Florida to the Yucatan Peninsula and the Caribbean. They inhabit sandy-mud and muddy bottoms, mangroves and seagrass (e.g., *Thalassia*) and macroalgal beds in the intertidal zone. These gastropods are dioecious prosobranchs with internal fertilization; the only evidence of sexual dimorphism is the penis in males. They lay in string of opaque, ovigerous capsules shaped like coins (Abbott 1974). Embryos develop individually over 12-16 days, depending on temperature. They hatch as veliger larvae, and enter the plankton for 15-20 days, depending on temperature and food availability.

At 600 μ (pediveliger), metamorphosis begins, and they select bottoms with abundant worms or bivalves, such as oyster beds, for settlement. They remain at the location while the food lasts and moving only to seek food of the appropriate size, which increases as they grow. Full maturity can be reached without dispersing from their initial settlement location. Commercial size is 8-10 cm; however, in Celestun, Yucatan, juveniles (4-6 cm) are exploited in the mangroves because fishers believe they are of another species.

The whelks (sacabocados, lix or caracols trompillos), *Busycon carica*, *B. cadelabrum*, *B. coarctatum*, *B. contrarium*, and *B. perversum*, tulip shells (caracols campechanas), *Fasciolaria tulipa* and *F. lilium*, horse conch (caracol rojo or chac pel), *Pleuroploca gigantea*, Atlantic Triton's trumpet (caracol fotuto), *Charonia variegata*, and West Indian chank (caracol tomburro or caracol negro), *Turbinella angulata* (= *Xancus angulatus*), are components of the Caribbean and Louisiana provinces and they are distributed throughout the Gulf of Mexico and the Caribbean. They live on mud to boulder bottoms, where any other type of mollusk, bivalve or gastropod, is available as prey. *Pleuroploca*, *Charonia* and *Turbinella*, due to their larger size, tend to prey upon the smaller species/individuals of *Busycon, Fasciolaria, Strombus* and *Melongena*.

These gastropods are dioecious, with internal fertilization, and all have a specific type of spermatophore. *Busycon* and *Pleuroploca* lay strings of coin-shaped ovigerous capsules with each species displaying different ornamentation on the edges of the capsules; the diameter of each capsule is 2-3 cm for *Busycon* and up to 7 cm for *Pleuroploca* and *Turbinella*. *Fasciolaria* capsules are individual, placed in groups that give the appearance of crimped surfaces, with characteristics that enable the species to be identified. The larval cycle is fully carried out inside the ovigerous capsule and the young emerge with a shell but without adult characteristics, which are acquired as the first spiral whorl is formed after emergence. As with other carnivorous gastropods, they will remain in the same place as long as there is sufficient food, however, once food is depleted, or food of the correct size is not available, they will move to new areas.

There are few reports on the timing of reproduction for populations of these species inhabiting Mexican waters. For species of *Busycon* inhabiting the waters of the U.S. Atlantic, ovigerous capsules have been reported from March to June (Castagna and Kraeuter 1994). Production of ovigerous capsules on the coasts of Campeche to Yucatan has been detected throughout the year, with greater frequency from March to September, whereas in the Caribbean ovigerous capsules of various species have been found from December to February (Bandel 1976).

THE FISHERIES

GASTROPOD FISHERY

In fishing production statistics, the gastropods are considered as a single species along the Mexican coast. There are, in fact, numerous species of gastropods that are collected in four ecological provinces. On the Atlantic there are the Carolina and Caribbean provinces. The former covers the Gulf of Mexico and the latter the northern part of the Yucatan Peninsula, with a transition zone that goes from Veracruz to the north of Yucatan. In general, the fishery is focused on the conchs (e.g., *Strombus*) and larger species such as the whelks (*Busycon*).

History of the Fishery

The queen conch (caracol rosado, caracol de abanico or caracol reina; *Strombus gigas*) fishery is well differentiated from that of other mollusks, although it only represented 26% of the catch in the region (De la Torre 1984). It is the target species on the northern coasts of Yucatán and Quintana Roo. Up until the 1950s when Cozumel and Isla Mujeres were opened to tourism, it was only exploited for local consumption, and catch records were not kept. In the 1960s, export began to the USA, which rapidly became the main market and little was kept for local consumption. Conch fishing increased after the development of Cancun, which caused declines in production to a minimum in 1978, two years after having reached a maximum in 1976, with 350 metric tons of meat.

Methods of Extraction

Species such as *Melongena* spp. *Strombus pugilis* and *Fasciolaria* spp. are caught during low tide on beaches and coastal lagoons. *Purpura pansa* is collected on rocky beaches. Most muricids (e.g., *Hexaplex*) on the Pacific coasts are caught using pots with bait. All other species are caught by diving, either free diving, scuba diving or surface-supply diving.

The Gulf of Mexico is the main source of income for young fishermen, who in groups of 5 or 6 per boat, practice open diving. On the coasts of Quintana Roo it is the lobster fishermen who catch conchs. In Quintana Roo, the number of registered fishermen up until 1980 was 325, increasing to 850 in 1983, which resulted in a decline in catch per unit effort (CPUE) from1 metric ton per fisherman per year in 1976, to 200 kg in 1988 and the trend continues downward (Polanco *et al.* 1988; Quijano 1988). This trend was also seen nationally up until 1991, but in 1992 overall production increased due to increased effort in some states, such as Campeche with a total catch of over 9,000 metric tons, but subsequently production declined. For the state of Campeche, Baqueiro *et al.* (1997) determined that optimum effort was 18,063 trips per year, with an average catch per trip of 36 kg and an average of 3 divers per boat, which guarantees fishermen an income of 2 to 3 minimum wages per trip.

Species Composition & Volume

Gastropods represent an alternative resource for artisan fishermen, and of subsistence for the poorest coastal groups, becoming a species of interest when other species become scarce. National catch has reached over 6,400 metric tons per year, and prices have increased, resulting in an increase in production value despite diminished catch (Figure 10.3).

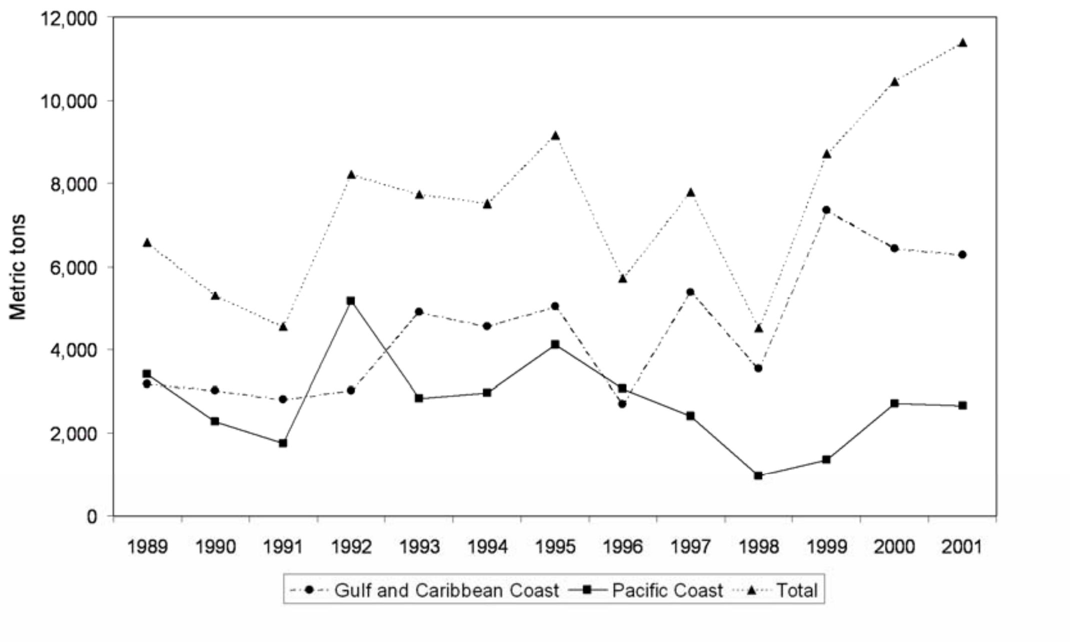


Figure 10.3. Annual variations in the production of gastropods on the coasts of Mexico.

As mentioned, only 26% of production in the state of Quintana Roo consists of *S. gigas*, 70% of *S. costatus* and the remaining 4% of the species vary, dominated by *Turbinella angulata* and *Busycon carica* (De La Torre 1984). For the rest of the Gulf of Mexico, catches are multi-specific, with various species of *Busycon* predominating in the states of Tabasco, Veracruz and Tamaulipas, and *Strombus costatus* in Yucatan and Campeche. Production in Yucatan has fallen so much that a permanent closure of the fishery has been necessary since 1989. For Campeche, Baqueiro *et al.* (1997) determined a sustainable catch of 750 metric tons per year, a volume that was reached in 1984 and continued to rise throughout the 1990s until 1999 when it peaked at 6,850 metric tons; since then catch has decreased but still remains well above the sustainable level (Figure 10.4).

Mechanisms of Management & Administration

The gastropod fishery is open to all fishermen, although in Quintana Roo permits are only granted to cooperatives. The total number of permits granted for extracting gastropods is small in comparison to the number of fishermen and boats that carry out this activity. Regulating the management of different fisheries is determined locally and based on stock assessment and biological population studies. Minimum sizes, seasons and fees are the management measures most frequently employed.

History of Regulation

A permanent closure of the fishery for "white conch (*Strombus gigas*), 'lanceta' (*Strombus costatus*), 'tomburro' (*Xancus* sp) and 'chactel' (*Pleuroploca gigantea*) in waters under federal jurisdiction on the coast of the state of Yucatan" was established by decree on July 22, 1988, and was published in the *Diario Oficial de la Federación* on July 25, 1988.

On June 22, 1990 a regulation was published in the *Diario Oficial de la Federación* "that established permanent closed season of the white conch species (*Strombus gigas*), 'lanceta' conch (*Strombus costatus*), 'tomburro' conch (*Xancus* sp.), 'chirita' conch (*Busycon* sp.) and 'chactel' conch (*Pleuroploca gigantea*) in waters under federal jurisdiction on the coast of the state of Quintana Roo to protect these species during the season of greatest biological reproduction that spans May to October every year".

In the Monday October 18, 1993 edition of the *Diario Oficial de la Federación* a permanent closed season was decreed for an unlimited time period for white conch (*Strombus gigas*), "lanceta" (*Strombus costataus*), "tomburro" (*Xancus* sp.) and "chactel" (*Pleuroploca gigantea*) in waters under federal jurisdiction on the coast of the state of Yucatan".

On April 21, 1995 a regulation was published in the Norma Oficial (NOM-013-1994) for the use of gastropod species in waters under federal jurisdiction in the states of Campeche, Quintana Roo and Yucatan, which limited extraction to free and semi-autonomous diving, and minimum sizes were set: 20 cm for queen or pink conch *(Strombus gigas)*; 18 cm for white or 'lanceta' conch *(Strombus costatus)*; 22 cm for 'trompillo' conch *(Busycon contrarium)* and 30 cm for 'chactel' conch *(Pleuroploca gigantea)*. In this same regulation it was specified that the sizes for other species would be set based on studies carried out and that the fees would be set according to studies made by SEMARNAP (Tables 10.3 and 10.4).

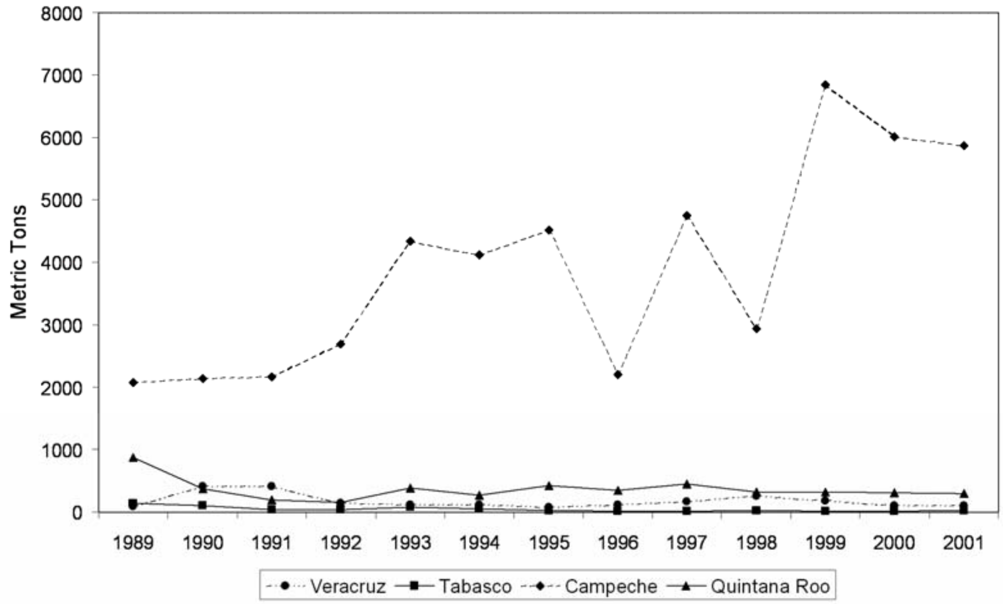


Figure 10.4. Variations in gastropod production from states bordering the Atlantic Gulf. Production in Tamaulipas and Yucatan was only ~1 metric ton/year between 1989-2001, so those states are not shown on the graph.

Table 10.3. Closed seasons for gastropods, oysters and octopus on the Mexican Atlantic coast.

Spanish Common Name	Scientific Name	State	Closed Season	Date Published
Gastropods				
Caracol Blanco.	*Strombus gigas*	Quintana Roo.	May 1 – Oct 31	Mar. 16, 1994
Caracol Chactel.	*Pleuroploca gigantea*			
Caracol Chirita	*Busycon* sp.			
Caracol Lanceta	*Strombus costatus*			
Caracol Tomburro	*Turbinella* sp.			
Oysters	*Crassostrea virginica*	Tabasco	Sep 15 – Oct 30	Sep 14, 2000
Octopus	*Octopus* spp.	Campeche, Yucatán, Quintana Roo	Dec 16 – Jul 31	Mar 16, 1994

Table 10.4. Minimum sizes (height, mm) for commercial species of gastropods on the Mexican Atlantic coast.

Scientific Name	Height (mm)
Busycon carica	243
Turbinella angulata	205
Fasciolaria tulipa	139
Pleuroploca gigantea	370
Melongena melongena	104
Melongena corona	50
Strombus costatus	186
Strombus pugilis	78

Management Considerations & Recommendations

Based on studies made in Yucatan and Campeche (Baqueiro *et al.* 1997), as well as the analysis of information presented above, a revision of the regulations is suggested so that they are adjusted to the species and conditions of each state and region of each state. For example, based on catch and effort records in the main fishing offices in the state, Baqueiro *et al.* (1997) determined a maximum catch for the state of 349,425-1,012,240 metric tons with effort at 13,895-24,633 trips, resulting in a CPUE of 79.27 to 145.2 kg per trip in the state of Campeche.

In spite of the local and regional importance of these resources, there are no management measures aimed at improving gastropod habitat, with the exception of coral reef marine parks of Veracruz, Cozumel and the biosphere reserve in Quintana Roo. Gastropod fishing has been prohibited in these areas, however, enforcement is inadequate and extraction continues.

Aquaculture

Given the drastic fall in the stock of pink conch, *S. gigas,* in Quintana Roo, in 1984, in collaboration with the state government and the Secretaría de Pesca, a cultivation program was implemented to produce young for the restocking in areas where they had been extirpated (Cruz 1986; Baqueiro 1991). However, the program was suspended in 1986 due to the high cost of conserving young until they grew to a size that guaranteed low mortality and the low impact of the program on the natural population (Berg 1976; Chanley 1982).

NON-OYSTER BIVALVE FISHERY

As in other mollusk fisheries, official statistics do not distinguish between the various species of non-oyster bivalves or even between freshwater species and estuarine/marine species, with 59 component species in the four ecological provinces of the Mexican coasts. Although these bivalves have potential as a resource that could become valuable and in high demand on both national and international markets, the fishery has not developed in the same manner in all the coastal states of the country. Bivalves are mainly extracted in Baja California Sur with little exploitation in other states, and the Gulf of Mexico species are not as valuable as those from the Pacific.

History of the Fishery

In the Gulf of Mexico the only species that has been extracted since the 1950s is has the “gallito” clam *(Rangia cuneata),* and for many years it was the only species that could be bought in Mexico City. Its production in Campeche increased gradually after 1970, when 400 metric tons were produced, whereas after 1987 in Laguna Tamiahua and Laguna Alvarado, production decreased from 1,600 to 800 metric tons.

By the 1970s, reef clam extraction had begun in Veracruz and in 1991 commercial extraction of marine clams began in Quintana Roo. Although some clam species have been extracted sporadically for local consumption and trade in Campeche and Yucatan. In Mérida there is no established fishery and there are numerous virgin banks (Baqueiro 1991). On the other hand, the pen shells are in high demand for both local and national consumption; this resource is not plentiful and is widely distributed, which results in strong pressure on the areas where they are located.

Methods of Extraction

Rangia cuneata is the target species of the lagoon fishery in the Gulf of Mexico, whereas *R. flexuosa* and *Polymesoda caroliniana* are incidental, the former because of its smaller size and the latter because of its low density. They are extracted with spoon nets that consist of a metal rectangle measuring 50 x 20 cm and a light cloth net bag measuring 1.5 cm that is fixed to a pole 3-5 m long. The spoon is buried 10-15 cm into the bottom, and a wooden or fiberglass boat with an outboard motor is used to drag the spoon net for a few minutes. When the net is pulled into the boat, the contents are rinsed and small clams and shells are separated. In Mexico, the capture of these species has been recorded from Laguna Madre de Tamaulipas, to Laguna de Términos in Campeche, although currently the only commercial fisheries are in Laguna Alvarado, Veracruz and Laguna Pom and Laguna Atasta in Campeche.

Reef clams *(Asaphis deflorata* and *Codakia orbicularis)* are extracted during low tide using garden spades and rakes. *Mercenaria campechiensis* and *Chione cancellata* are also extracted during low tide, collected by hand from the sediment surface after being detected by bare feet. In northern Yucatan and Quintana Roo, fishers use free diving to extract clams from depths of 2-3 m.

All other species of venerids that constitute this resource are extracted fishers using SCUBA or surface-supply diving, and are detected by observing the siphon or sand that is thrown out as the clams retract into their shells when the diver probes the bed with a forked instrument. Extraction by free -diving is only for sport.

Geukensia demissa is collected by hand at low tide and is sold without its shell. After collection, its soft parts are extracted by heating the mussel until its shell opens. Its price on the beach is 10-12 pesos/kg (~1 USD/kg), and it is packaged in 20 kg tins that are transported on ice. It is consumed locally and in restaurants in Mérida and Cancún. The same boats and crews used for gastropod fishing are also used for collections of clams, scallops and pen shells.

Species Composition & Volume

Nationally, bivalve production is greatest on the Pacific coast, and in states of Baja California and Baja California Sur (Figure 10.5). In the Gulf of Mexico and the Caribbean,

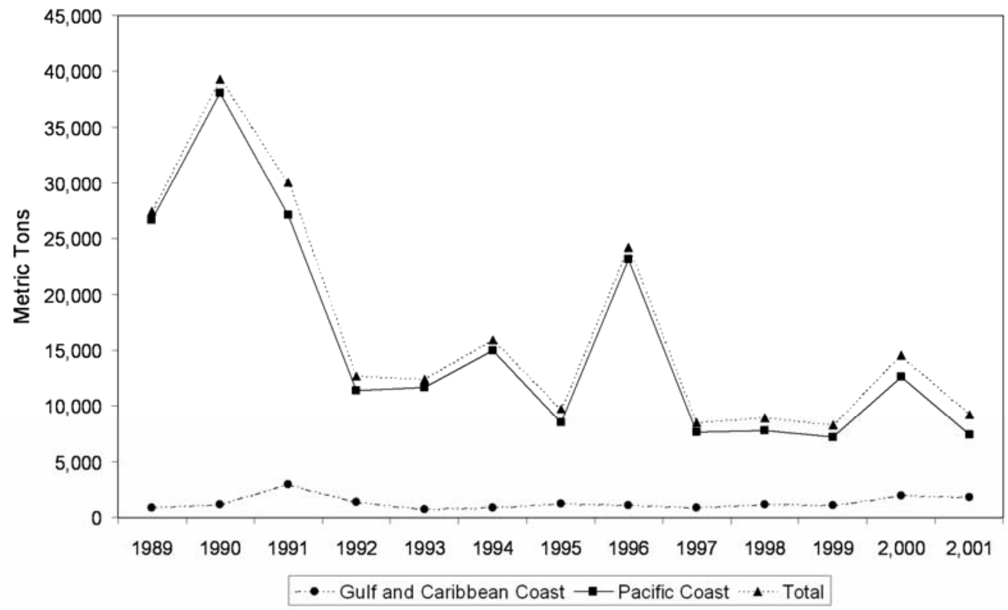


Figure 10.5. Annual variations in the production of bivalves on the coasts of Mexico.

bivalve production is very irregular with the state of Veracruz exhibiting the highest and most stable production level. Bivalve production in Campeche reached a maximum in 1990, and diminished until 1996 when exploitation became insignificant. Production in Tabasco fluctuates greatly from year to year while production in Tamaulipas and Quintana Roo is relatively low. Production in Quintana Roo has been about the same since 1995 (Figure 10.6).

Rangia cuneata production is managed using quotas that have been fixed based on previous evaluations of capture data from Laguna Pom and Laguna Atasta (Campeche) where continuous records of catch have been kept. A quota of 2,000 metric tons that is distributed among four fishing cooperatives with 310 registered fishers has existed in these lagoons since 1981. Baqueiro and Medina (1988) determined that the sustainable level of exploitation for the species was 163 metric tons for both lagoons, but only 5 metric tons for Laguna Pom alone, which is where harvesting activity is greater. These same authors recommended the simultaneous management of the three species, particularly *R. flexuosa*, in the two lagoons, with the objective of reducing interspecific competition to the benefit of both species, resulting in a sustainable mixed capture potential of 193 metric tons.

For the Gulf of Mexico and the Caribbean, the only regulations for the management of bivalve capture is the requirement for an evaluation of the species that will provide information concerning the fishing potential or allowable quota. These types of evaluations have been made for the following species: *Codakia orbicularis* (Castillo 1985), *Mercenaria campechiensis* and *Chione cancellata* (Baquerio *et al.* 1997), *Geukensia demissa* (Baquerio *et al.* 1993), *Atrina rigida* on the coast of Campeche (Baquerio *et al.* 1988) and *Rangia cuneata* in Veracruz (Echevarría *et al.* 1995).

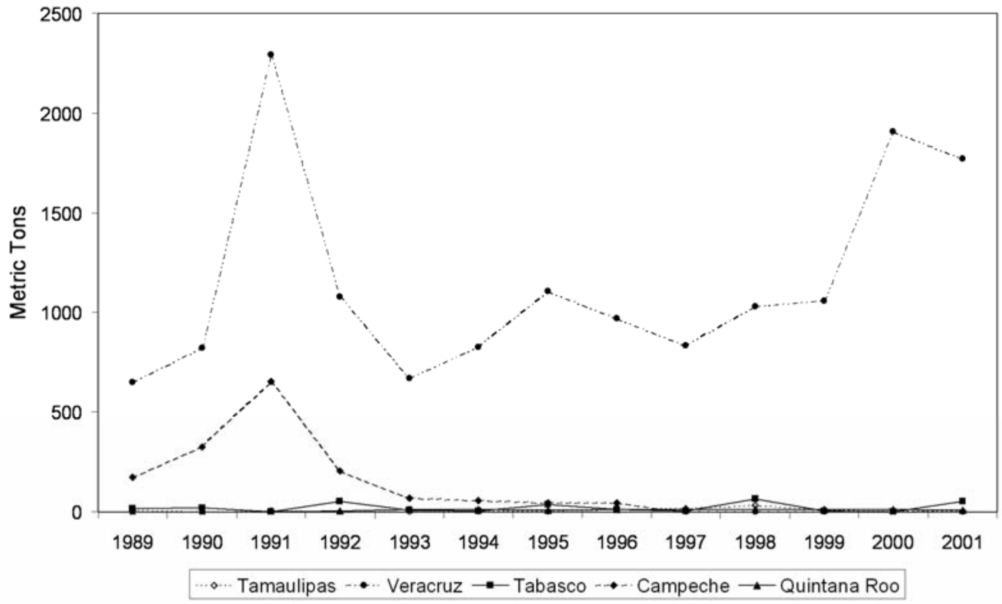


Figure 10.6. Variations in bivalve production from states bordering the Atlantic Gulf. Production in Yucatán was only ~1 metric ton/year between 1989-2001, and is not shown on the graph.

Aquaculture

Bivalve cultivation in Mexico goes back to the beginning of the century when the pearl oyster, *Pinctada mazatlanica*, was cultivated (Baqueiro and Castagna 1988). It was not until the mid 1970s that the department of aquaculture was formed and special attention was given to resources with aquacultural potential, there having been only a minor previous effort to develop oyster aquaculture in 1954 (Ramírez and Sevilla 1965).

OYSTER FISHERY

In 1989 oyster production in Mexico reached a historic high 59,600 metric tons, after which production plummeted to 25,800 metric tons in 1993; production has increased slightly in recent years. Historically, the states of the Gulf of Mexico have supplied 88-92% of national production volume. However, this has represented no more than 65% of national value, due to the high value of oysters produced in aquacultural facilities on the Pacific, which corresponded to only 6.7% of the national production volume in 1997 (Figure 10.7).

State contributions to oyster production have changed radically. Veracruz led oyster production until 1996; currently, Tabasco produces the most oysters followed by Veracruz, Tamaulipas and Campeche (Figure 10.8). These levels of production do not reflect the potential for production represented by lagoonal/coastal area of each state. There are 274,736 ha of lagoons in Tamaulipas, followed by Campeche with 198,500 ha, Veracruz with 193,300 ha and

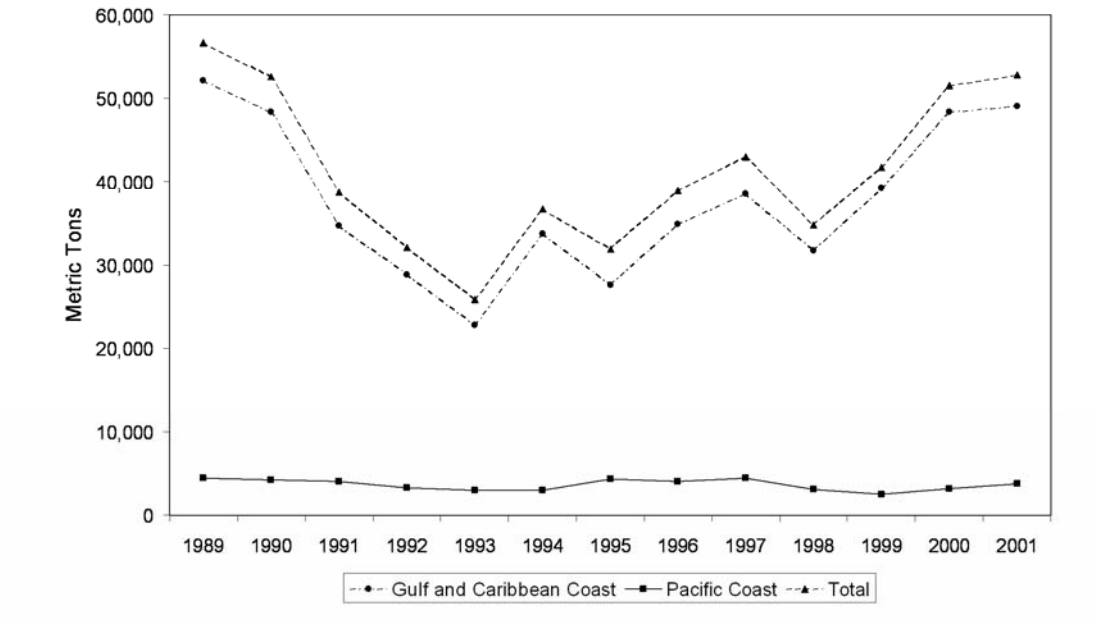


Figure 10.7. Annual variations in the production of oysters on the coasts of Mexico.

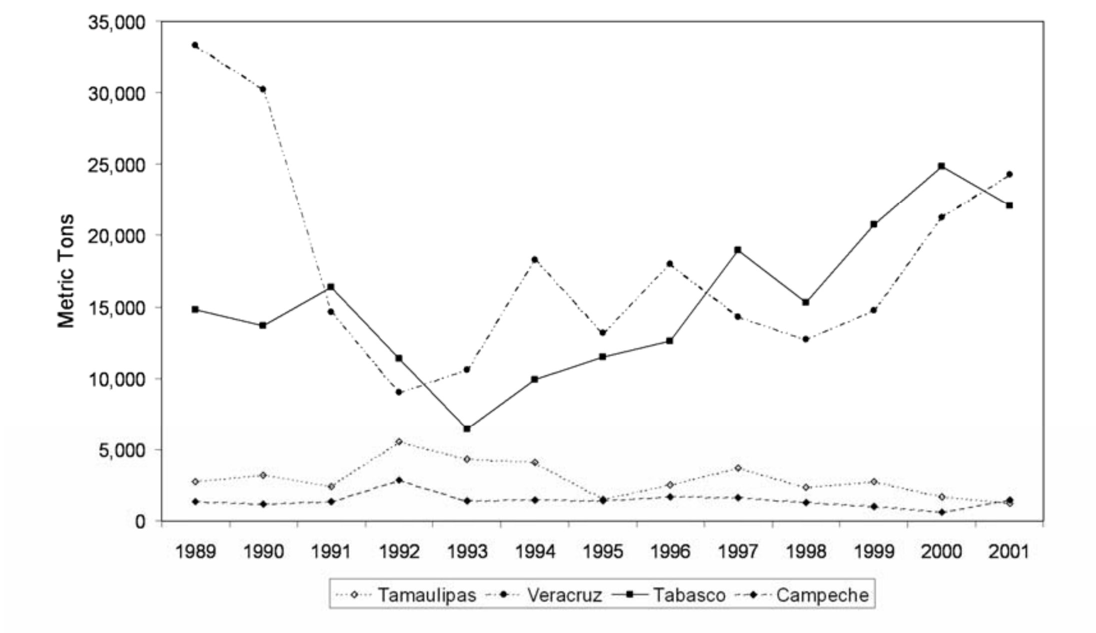


Figure 10.8. Variations in oyster production from states bordering the Atlantic Gulf. Production in Yucatán and Quintana Roo was only ~1 metric ton/year between 1989-2001, and is not shown on the graph.

Tabasco with 27,400 ha. The fact that 50% of Gulf oyster production comes from Tabasco with only 4% of total lagoonal area is an example of the production potential that exists in the Gulf of Mexico, which could possibly be increased to 500,000 metric tons. If oyster production in the Gulf of Mexico was developed to its full potential (based on the amount of surface area in the lagoons) and the value of that production reached the production value in the Pacific, value of the Gulf fishery would increase from the 1997 total value of 37.6 million pesos (~3.7 million USD) to 2000 million pesos (~20 million USD; Figure 10.9a, b). Production in of Tabasco is not optimally developed, and it could be increased three to five times, without causing sectorial conflicts, and up to ten times in intensive systems.

Some factors that limit the economic development of the oyster fishery are the public health issues associated with managing oysters and bringing them to market, as well as the lack of industrial processes that would increase the value of the product. But, generation of a quality product in sufficient amounts would guarantee market demand and allow continuous operation of the associated industrial plants.

History of the Fishery

Oysters have been used for food by the settlers of Mexico from Prehispanic times, as documented by the presence of oyster shell middens on both coasts. They were also commonly consumed by people in the interior (Lorenzo 1955, Fieldman 1969, Foster 1975, Reigadas *et al.* 1984), and, being considered a food for the kings, were taken fresh to Moctezuma in Tenochtitlan (Del Campo 1984).

Records of oyster harvests are the oldest fishing records in the country. From 1940-1953, national production reached an annual average of 7,277 metric tons, of which 23% was sold without shell. From 1952-1963, the annual average surpassed 15,000 metric tons (Ramírez and Sevilla 1965). During 1980s, production increased from 40,000 to 50,000 metric tons, but them declined due to diseases that appeared in oyster beds in Laguna Tamiahua, Veracruz, in 1990.

Methods of Extraction

Oyster extraction methods have not changed much since primitive times. In general, they are collected during low tide with the aid of a sharp instrument. Extraction from deeper areas is carried out from rowing or outboard motor boats.

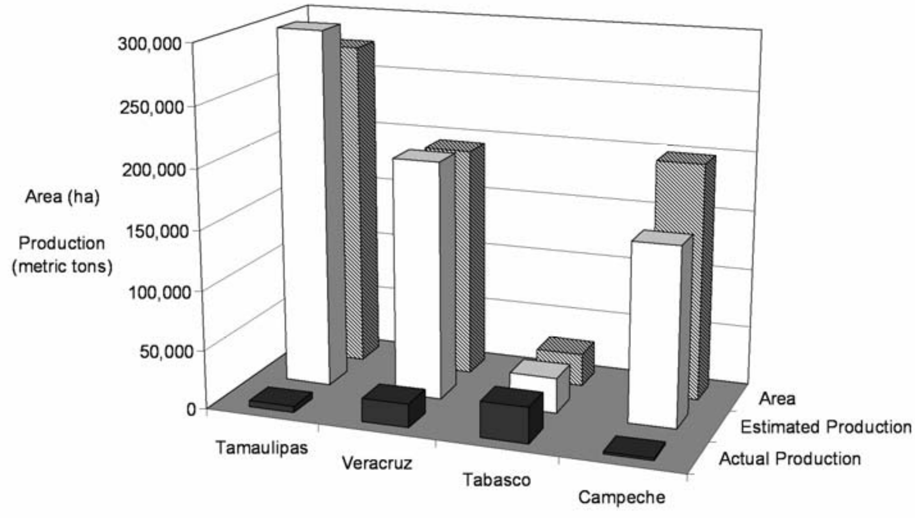
Species Composition & Volume

The oyster fishery is composed by six species of commercial importance. On the Atlantic coast there are two native species (*Crassostrea virginica, C. rhizophorae*) and on the Pacific coast, three native species are exploited (*C. palmula, C. corteziensis, C. iridescens*) as well as *C. gigas* that has been introduced for use in intensive aquaculture.

Oysters are mainly sold fresh, with or without shell and on ice. Only 0.01% is smoked or canned in Tamaulipas and Tabasco. Gulf of Mexico production comes mainly from natural beds, with a few areas where some semi-cultivation practices are used.

Mechanisms of Management & Administration

Until 1994, oysters were one of the five fishery species reserved for exploitation by cooperatives. Of the 88,015 fishing cooperatives in the country, 561 hold oyster extraction permits (CONAPESCA 2001). For *C. virginica* on the Gulf of Mexico coasts, there is a closed



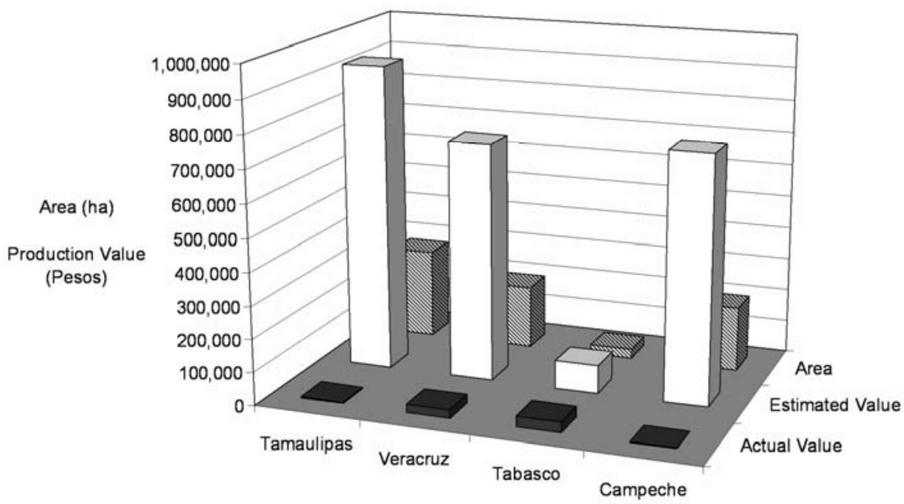


Figure 10.9. Actual and estimated production volume (top, metric tons) and actual and estimated production value (bottom, pesos) of oysters in the Gulf of Mexico, with the lagoonal surface area available for production in each state. Estimated volume (metric tons) was determined based on the current production in lagoons in Tabasco and its relationship to lagoonal surface area of each of the other states. Estimated value (pesos) was determined from the potential production volume in each state and the present value of oyster production in the Mexican Pacific.

season from May 15 to July 30, and a minimum size of 8 cm long of the shell for both species (*C. virginica, C. rhizophorae*).

Aquaculture

The first oyster aquaculture was established out on the Atlantic coast where fishing was well established but it was abandoned at the end of the 1960s and had not been attempted again until recently in the coastal lagoons of Tabasco. Ten percent of production from the states of Campeche and Tamaulipas, 20% from Veracruz and 90% from Tabasco, comes from improved beds (Polanco *et al.* 1988).

Management of the Environment

In the 1970s, many oyster beds were the target of many activities designed to support and improve their growth and survival. A major activity in this category was the dredging of the passes and channels into the numerous coastal lagoons to increase the exchange of marine water.

As mentioned above, on the Gulf of Mexico coast the most common cultivation practices are limited to bed improvement. A common practice in Laguna Tamiahua and Laguna de Términos is spreading oyster shells to increase settlement areas. In the state of Tabasco, bed improvement is also practiced as well as and spat collection, that, upon reaching 3-5 mm in length are placed on previously prepared beds (Palacios *et al.* 1983). Bed improvement is only a secondary activity in the Pacific.

History of Oyster Aquaculture

The first biological studies on the oyster were made in 1930 and were focused on the study of taxonomy, biology and ecology of Mexican oyster beds. In the same year commercial oyster fishing appeared officially, extracted by divers using diving masks ("gafas") and sold in 35 kg sacks (Rangel-Dávalos 1990).

It was not until the 1950s that oyster cultivation officially began in Mexico, with natural oyster bed protection, improvement and cultivation programs. The first practices were bed improvement and spat transplants (Palacios and García 1988). Other work followed subsequently such as that by Sevilla (1959), in Guaymas, Sonora, who carried out the first tests on oyster cultivation and studies to determine the best collector for settlling spat. Ramírez and Sevilla (1965) proposed to increase national oyster production to large scale through technical cultivation. Sevilla and Mondragón (1965) determined the biological cycle of *Crassostrea virginica* in Laguna Tamiahua, Veracruz. In the 1970s, numerous studies on oyster cultivation techniques were conducted in the Gulf of Mexico. Lizárraga (1977) tried various cultivation techniques in some ponds in Tabasco, Nayarit and Sinaloa. Casas (1976) studied aspects of oyster cultivation in relation to environmental parameters in the Laguna San Andrés, Tamaulipas. Iracheta (1972) was the first to introduce small-scale commercial oyster farming in Tabasco.

In the 1980s, interest in oyster cultivation continued. Palacios (1983) cultivated *C. virginica* semi-intensively in Laguna San Andrés, Tamaulipas, obtaining good results with a suspended cultivation method. García-Valdez (1987) compared *C. virginica* oyster growth, when cultivated on the surface in Nestier-type boxes and on the bed in nylon mesh sacks, in the Boca del Río-Mandinga lagoon system, Veracruz. Rentería (1987) studied the feasibility of cultivation of *Crassostrea corteziensis* in Boca Camichín, Nayarit, with rafts and a suspended cultivation method. Navarrete (1989) studied gonad evolution and fixation of *C. virginica* in the Boca del Río-Mandinga lagoon system, Veracruz. From 1988 to 1989, a project of "Producción aquacultural de *C. virginica*"was carried out in Boca del Río- Mandinga lagoon system, Veracruz (Amador 1989; Amador *et al.* 1991). Rihaní (1989) cultivated *C. virginica* in Nestier-type boxes in Ría Lagartos, Yucatán.

Interest in oyster culture would have disappeared if not for the efforts of some researchers, such as Castro *et al.* (1990) who studied the growth of *C. virginica* in wooden boxes, Aldana-Aranda (1990) who conducted several studies on the cultivation of *C. virginica* in the Yucatán Peninsula, with favorable results, and Cabrera (1993) who assessed the growth and survival of two populations of *C. virginica* cultivated in San Felipe, Ría Lagartos, Yucatan, also with good results.

Oyster production in the Gulf of Mexico, which is sustained completely by bed improvement, which is considered in world statistics as aquaculture production, has an outstanding average of 40,000 metric tons per year. However, as of 1997, this activity was considered "improved fishing" and not cultivation, and does not now appear as part of aquaculture in world statistics. Only Pacific production, which does not represent even 10% of the country's production, is recorded as production by aquaculture in world statistics (FAO 1999). The abandonment and loss of interest in promoting oyster cultivation in our country has been so great that there is no oyster cultivation to speak of in the Gulf of Mexico.

Proposal for Development

With the purpose of promoting integral development of the oyster fishery in the Gulf of Mexico, the creation of technology packages is proposed. These packages would enable organized fishermen and investors to produce first class oysters that comply with international health regulations, as well as industrialized products for all the national and international market niches.

An integral study plan is proposed that would 1) determine the present state of the fishery and the factors that limit its development; 2) identify the potential for development on the entire coastline; 3) identify management technology and appropriate cultivation techniques in each area; 4) create methods for sanitary handling and packing; and, determine how industrialized products could be created and marketed.

CEPHALOD FISHERY

Squid catch in the Gulf of Mexico is incidental to shrimp fishing, with a maximum of 441 tons in 1992 (Figure 10.10). Octopus fishing is almost exclusive to the Gulf of Mexico, in particular the states of Campeche and Yucatan (Figure 10.11), which contribute 93% of national production. Fishing is carried out mainly in small vessels and is limited to August and December, and closed during the remainder of the year when octopi reproduce.

SHELL TRADE

Shells constitute a group within fishing statistics, with an annual average of 1,000 metric tons and valued at over 300 million pesos, and therefore make a significant contribution to export volume. The main shell producers are Baja California Sur and Baja California. Exported shells

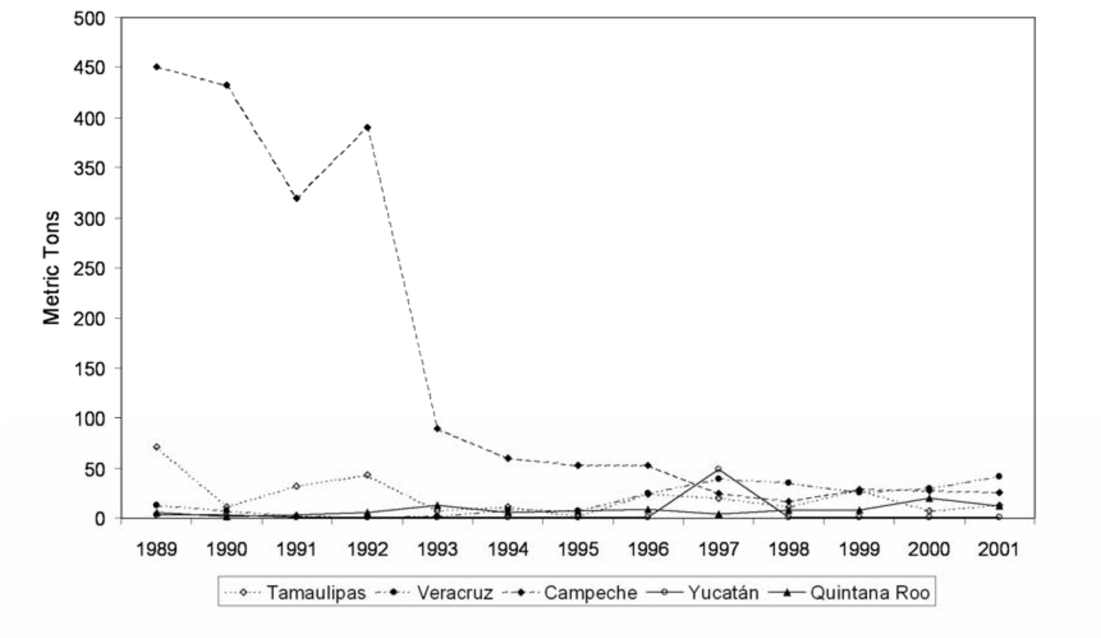


Figure 10.10. Variations in squid production from states bordering the Atlantic Gulf. Production in Tabasco was < 2metric tons/year except in 1989, when it peaked at 7 metric tons, and is not shown on the graph.

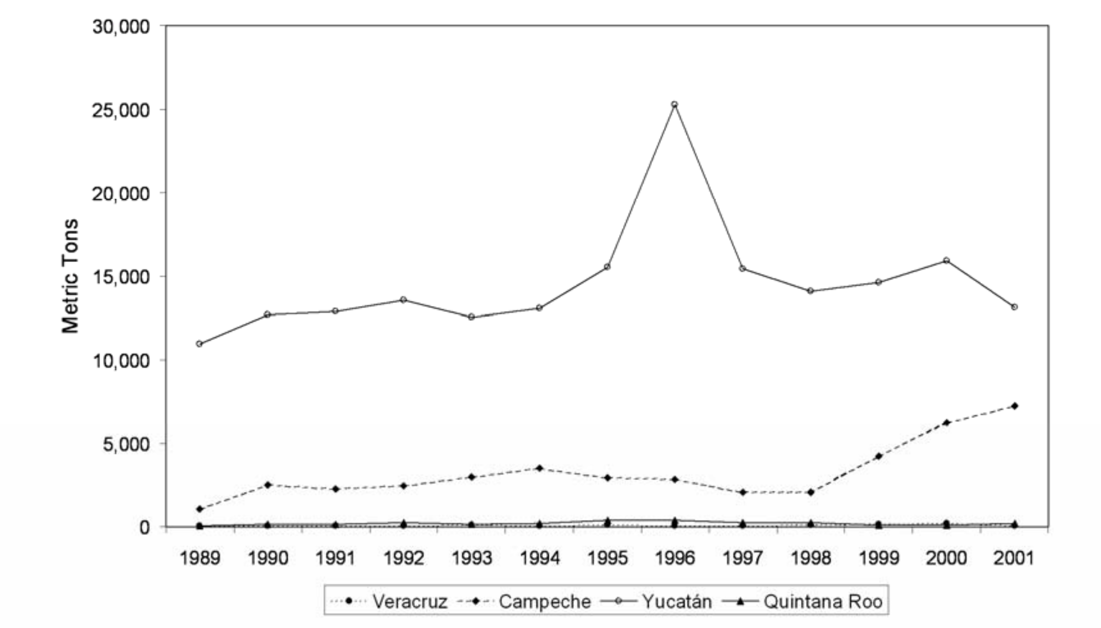


Figure 10.11. Variations in octopus production from states bordering the Atlantic Gulf. Production in Tamaulipas and Tabasco was < 2metric tons/year, and is not shown on the graph.

are mainly the mother of pearl from the shells of the Gulf freshwater clam, and are used to manufacture creams, clam shell for buttons and abalone and mother of pearl for jewelry. Conch and scallop shells are also important as exports for ornamentation, both as individual shells and as manufactured products. In Mexico, shells are also used as a food supplement for birds, building materials, handicrafts and jewelry (Baqueiro 1990).

POLLUTION

During the 1950s, the Secretaría de Industria y Commercio (Department of Trade and Industry), through the Instituto Nacional de Investigaciones Biológico Pesqueras (National Institute for Fishery Biology Research), developed a plan with the aims and objectives of determining problems with oyster resources in the Gulf. Petroleum pollution problems in Veracruz and the indefinitely closed season that resulted in the state, caused overexploitation of the resource in the remaining producer states Tamaulipas, Tabasco and Campeche (Rangel-Dávalos 1990).

Pollution is the factor that has had the greatest impact on natural oyster beds and their exploitation in Mexico. Basically, it comes from the petroleum industry, urban settlements and the agricultural and cattle industries.

Pollution from petroleum extraction, caused by spills, crude oil leaks from platforms and mud flows from oil web drilling are spread by tides and currents, have had an impact on oyster production, due to their harmful effect on the organisms themselves and production areas, limiting their development, reducing productive bed size or contaminating the oyster with elements that when consumed, are harmful to human health (Arriaga-Becerra and Rangel-Dávalos 1988).

Pollutants from urban, industrial and agricultural zones that are transported into the diverse coastal zones due to the great quantity of water that flows out from the rivers into the Gulf of Mexico have a considerable affect the development of organisms that inhabit them. Sewage contaminated water not only contains great quantities of fecal matter but also waste from food and pesticide processing facilities. These have caused an increase in pathogenic agents in estuarine areas and adjacent marine zones (Weibel *et al.* 1974).

Because bivalves are sedentary and filter great volumes of water (5 L/h), they become reservoirs of pathogenic agents from the discharge of sewage into coastal lagoons (Weibel *et al.* 1974). This is not only a problem for the bivalves, but also represents a human health hazard (Metcalf and Stiles 1965). Cases of gastroenteritis and infectious hepatitis have been reported after having consumed some species of bivalves collected from polluted marine waters (Rodríguez 1986).

PERSPECTIVES

With regards to the future of these fisheries, only adequate management could allow the volume extraction to be maintained at its present levels. However, extraction practices must change. Extraction must be suspended during reproduction, efforts must be made to locate feeding areas, and carnivorous species should be exploited using passive methods, which would allow access to beds not exploited at present by divers. Given that the state of health of many riverside populations is critical, to maintain extraction volumes or to recover their optimum values, recovery activities must be implemented such as closures, seeding and transplantation.

However, development of aquacultural production is very encouraging, for both bivalves and some species of gastropods that are suitable for cultivation. In particular, those bivalves for which the methodology for population improvement developed by Loosanoff and Davis (1963) that allows production of larvae in controlled conditions enabling management of genetic characteristics. There are low cost techniques and simple technologies to cultivate *Mercenaria* (Castagna and Kraeuter 1981) that could easily be adapted to the conditions of the Mexican Gulf and Caribbean.

The results achieved in the Centro Regional de Investigacions Pesqueras de Puerto Morelos (Regional Center for Fishing Research of Puerto Morelos) in the cultivation of the queen conch, *S. gigas*, (Cruz 1986; Baqueiro 1994) demonstrate the feasibility of production of young for their either cultivation or repopulation, with the feasibility of the cultivation of those species with direct development and carnivorous feeding habits still to be determined.

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