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Fishery And Culture Of Selected Bivalves In Mexico: Past, Present And Future

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FISHERY AND CULTURE OF SELECTED BIVALVES IN MEXICO: PAST, PRESENT AND FUTURE[1]

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ABSTRACT This paper reviews the culture of selected bivalves of Mexico. Most species are utilized locally, but there is potential for some exports. The culture and fisheries of bivalves are often hampered by lack of information and restrictive regulations. *Pinctada mazatlanica* was grown for pearls and pearl shell production in the early 1900s. The methods used for its culture are reviewed. The culture of a few commercial species has shown encouraging results. Over 10,000 kilometers of coastal area with more than 1.5 million hectares of coastal lagoons and bays, plus a subtropical climate, give Mexico a great potential for the development of mariculture.

KEY WORDS: culture, bivalves, Mexico, *Pinctada mazatlanica*

INTRODUCTION

Mollusks are highly valued in Mexico where an abundance and diversity of species can be found all along Mexican coasts.

Most species are exploited locally in artisanal fisheries. There are nine commercial species in the Pacific and California, one in the Caribbean, and one in the Gulf of Mexico (Table 1). Some of these species have been intensively fished for many years with little or no management. Their beds are often overexploited, which together with the degradation of coastal water quality, has made them very scarce.

Though aquaculture in Mexico can be traced back to prehispanic times when the Aztecs reared the "axolotl", a neonatal stage of a salamander, very little has been done in the field of molluscan aquaculture.

THE FISHERIES

History

The use of mollusks for food in coastal communities can be traced back to prehispanic times with the presence of countless shell deposits or middens along both coasts (Schenck and Gifford 1952, Lorenzo 1955, Fieldman 1969, Foster 1975, Reygadas et al. 1984). The diversity of species varies widely and few species can be found throughout Mexico's entire distribution range. These same species are still utilized by coastal people today.

On the Pacific coast of Baja California, the pismo clam, *Tivela stultorum,* predominates in shell deposits. The bay scallop, *Argopecten circularis,* the mother of pearl oyster, *Pinctada mazatlanica,* oyster, *Pteria sterna,* cross-barred chione, *Chione undatella,* and California chione, *C. californiensis,* prevail in the Gulf of California. On the rest of the Pacific coast, the oysters, *Crassostrea palmula* and *C. fisshery,* and the mangrove cockle, *Anadara tuberculosa,* are found. In the Gulf of Mexico only the American oyster, *Crassostrea virginica,* and the mud clam, *Rangia cuneata,* are found in shell middens.

Overview of Techniques

Harvesting methods are primitive. Shellfish are gathered by hand along the shoreline at low tide or subtidally by free diving and by digging with bare hands or forks. On the Gulf of Mexico coast, *Rangia cuneata* is fished with a long pole net from outboard motor boats.

In the Gulf of California, bivalves are gathered by divers, free diving down to 3 m depth and scuba or hooka diving down to 30 m (Figure 1).

Most bivalves are sold fresh in the shell or shipped inland on ice. Scallops and pen shells are shucked in the field (Figure 2) for the adductor muscle which is sold fresh on ice to local markets and frozen for export, primarily to the U.S.A. The Pacific mussel and pismo clam from the Pacific coast of Baja California are the only bivalves canned.

Harvest Statistics

The bulk of the annual harvest of mollusks comes from the Pacific coast (54% in 1977 to 81% in 1981). The Mexican mollusk production is composed of over 50 species, with 9 species exploited intensively (Table 1 and 2). On the Atlantic coast the mud clam, *Rangia cuneata,* has been traditionally intensively exploited along with the more recently exploited reef clam, *Codakia orbicularis.*

Clam production from the different coastal states varies with five states producing over 90% of total landings. Before 1975, production was restricted to five states, but more states have contributed to the harvest in the last decade with both traditional and a few new species.

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Figure 1. Fisherman unloading a bag of scallops into an outboard motor boat equipped with a hooka compressor.

Problems and Potential

The development of a mollusk fishery is hampered by the monoculture approach of fishermen and investors, who are interested only in well commercialized seafood species such as lobsters, shrimp, oysters and fish, ignoring other resources with potential national and international markets. There is a lack of technology for exploiting stocks which are now ignored or not caught by traditional fishing methods.

The lack of information for proper management has led to overexploitation and misuse of stocks.

There are underutilized species that could with proper management be harvested annually, creating employment in new areas.

There is potential for the culture of commercially important species; however, restrictive regulations and difficulty in obtaining necessary water concessions and culture permits have been major constraints for private investors.

CANDIDATE SPECIES FOR CULTURE IN MEXICO

Taxonomy

A candidate species for culture has to satisfy the following requirements:

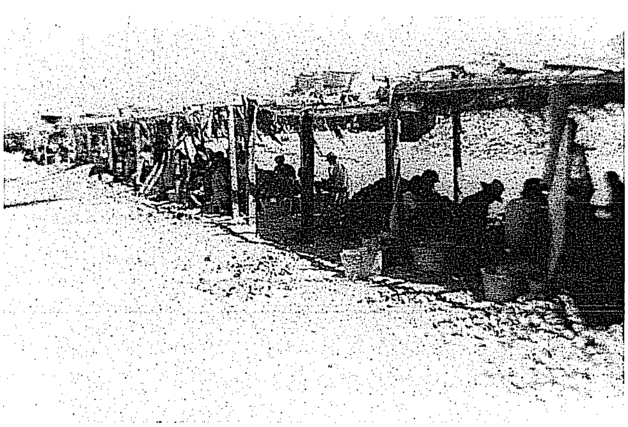

Figure 2. Shucking camp for scallops.

1. Market acceptability,
2. Competitive price, and
3. Availability of technology for its culture.

There are many species in Mexico that satisfy the first two conditions, along with high price, diminishing stocks and increasing demand. The following species are excellent candidates for culture:

Mangrove cockle *Anadara tuberculosa* (Sowerby 1833)
Pen shell *Pinna rugosa* Sowerby 1835
Atrina maura (Sowerby 1835)
Mother of pearl *Pinctada mazatlanica* (Hanley 1956)
Rock scallop *Spondylus calcifer* Carpenter 1857
Bay scallop *Argopecten circularis* (Sowerby 1835)
Red Clam *Megapitaria aurantiaca* (Sowerby 1831)
Black clam *M. squalida* (Sowerby 1835).

Technology is often the real constraint. Although the general techniques for larval culture developed by Loosanoff and Davis (1963) can be applied to most bivalve species with minor modifications, the specific requirements for every species are different. Culture techniques used for one species in one location are not easily transferred to other species in other places. The general biology and requirements of each species to be cultured should be known to apply the appropriate techniques.

Biology and Ecology

The biology of only a few species has been studied to a limited extent. The growth rates and reproductive cycles of *Megapitaria aurantiaca, M. squalida, Dosinia ponderosa* (Baqueiro and Stuardo 1977), *Argopecten circularis* (Baqueiro et al. 1981), *Anadara tuberculosa* (Baqueiro et al. 1982), *Chione undatella* (Masso and Baqueiro 1984), and *Glycymeris gigantea* (Mucino and Baqueiro 1984) have been determined through studies of natural populations and some studies of marked and caged animals (Table 3). *Pinna rugosa, Argopecten circularis* and *Pinctada mazatlanica* have been studied under culture conditions. Diaz (1972) cultured *P. mazatlanica* in wire cages suspended from rafts, measuring a 9.4% monthly mortality for adults and 6.6% for two to three month old juveniles. Arizpe and Felix (1980) measured growth rate and mortality of spat to two year old *P. rugosa* reared in suspended plastic cages. A 3% mortality occurred in the first year and 1.5% in the second. Growth rate was defined by Von Bertalanffy's equation:

$$L_t = 23.14(1 - e^{0.189\,(t-0.631)})$$

Commercial size of 204 g was attained in two years. Shell length could be converted to weight by the equation:

$$W = 0.0054 \times L^{3.39}$$

Felix et al. (1978) reared spat of *Argopecten circularis* in cages obtaining growth of 3.7 mm per month and 40% mortality in 6 months. A maximum size of 39.5 mm was reached.

TABLE 1.

Bivalves exploited in Mexico and their potential.

Species	Level of Exploitation[a]	Price to Fishermen[b][x]	Aquaculture Potential[c]
California Province (Pacific coast of Baja California)			
Mytilus californianus	C	x 0.30 kg	2
Hinnites multirugosus	C	o 6.00 Kg	1
Tivela stultorum	C	+ 1.60 Kg	3
Panamic Province (Pacific coast and Gulf of California)			
Anadara tuberculosa	C	x 0.07 each	1
A. grandis	L	x 0.15 each	2
A. multicostata	L	x 0.15 each	2
Glycymeris gigantea	P	x	3
Ostrea angelica	P	+	4
Modiolus capax	L	x 0.15 Kg	4
Choromytilus paliopunctatus	P	x 0.15 Kg	4
Mytella strigata	L	x 0.15 Kg	3
Pinna rugosa	C	o 3.00 Kg	1
Atrina maura	C	o 3.00 Kg	2
Pteria sterna	F	o 6.00 Kg	2
Pinctada mazatlanica	F	o 6.00 Kg	2
Pecten vogdesi	C	o 3.00 Kg	2
Argopecten circularis	C	o 2.75 Kg	1
Lyropecten subnudosus	C	o 6.00 Kg	2
Spondylus calcifer	C	o 6.00 Kg	2
S. princeps	C	o 6.00 Kg	2
Laevicardium elatum	L	x 0.15 each	4
Tivela byronensis	L	x 0.15 Kg	4
Trachycardium spp.	L	x 0.15 Kg	4
~~*Megapitaria squalida*~~	~~C~~	~~x 0.15 each~~	~~1~~
M. aurantiaca	C	x 0.15 each	1
Chione spp.	L	x 0.15 Kg	4
Peryglypta multicostata	P	x 0.15 each	4
Ventricolaria isocardia	P	x 0.15 each	4
Caribbean Province (Gulf of Mexico and Caribbean coast)			
Rangia cuneata	C	x 0.08 Kg	1
Asaphis deflorata	L	x 0.25 Kg	4
Chione cancelata	P	+ 1.50 Kg	4

[a] C = commercial exploitation, F = fishing prohibited, L = local use, P = potential; [b]x = whole with shell, + = whole without shell, o = adductor muscle; [c]1 = culture recommended, biology known, 2 = culture recommended, biology unknown; 3 = culture not recommended, biology known; 4 = culture not recommended, biology unknown. [x]dollar exchange rate: 1 U.S. dollar per 200 pesos.

The information so far gathered shows the feasibility of bivalve culture, but many questions on their biology and requirements remain to be answered:

—Optimal densities
—Temperature, salinity, light, pH and oxygen requirements
—Food requirements
—Predators, parasites and diseases.

All these experimental cultures have depended upon natural spawnings of bivalves, but a commercial enterprise could not rely on a source of spat that would be very unpredictable and erratic (Tripp 1978). A commercial endeavor with the bay scallop failed due to unpredictable and erratic setting. Commercial cultures of these species require conditioning, spawning, and larval rearing techniques so that consistent numbers and quality of seed could be produced for culture.

Market

Table 1 shows demand for scallop muscle and similar products and for whole clams in the shell. All of these products are consumer fresh or frozen. The higher priced products have both a national and international market, primarily export to the U.S.A. Scallops are shipped as frozen adductor muscles, and clams are sold as fresh and frozen whole clams. The pismo clam and the Pacific mussel are canned for sale in Mexico or export to the U.S.A. and Japan.

TABLE 2.

Mexican mollusk production by coastal states, 1977–1981 (metric tons).

	1977	1978	1979	1980	1981	%
Baja California	1425	1547	1545	1665	1483	18
Baja California Sur	1053	2028	2742	5875	5117	39
Sonora	89	254	55	118	230	2
Sinaloa	1216	1555	1225	954	1775	15
Nayarit	1	7	58	0	150	1
Jalisco	4	1	0	0	141	1
Colima	0	0	0	62	11	1
Michoacan	0	0	0	0	0	0
Guerrero	22	9	37	0	42	1
Oaxaca	17	0	0	36	20	1
Chiapas	55	60	330	674	80	3
Pacific coast total	3882	5461	5992	9384	9049	78
Tamaulipas	27	0	0	0	0	1
Veracruz	460	614	1023	963	870	9
Tabasco	0	12	0	0	0	1
Campeche	1290	1023	915	1027	1188	12
Yucatan	0	0	0	0	0	0
Quintana Roo	0	0	0	0	0	0
Atlantic coast total	1777	1649	1938	1990	2058	22
National total	5659	7110	9930	11373	11107	

HISTORY OF MOLLUSK CULTURE IN MEXICO

Commercial Endeavors

No commercial culture is being carried out in Mexico at present, but the first record dates back to 1904 in Baja California Sur when a technique was developed to rear the mother of pearl, *Pinctada mazatlanica,* by J. Gaston Vives (Estrada 1916, Townsed 1916, Diguet 1919). Detailed information on this technique was not mentioned by the authors since the whole process was patented. In 1919 the "Compania Criadora de Concha Perla, S.A." obtained a contract from the Federal Government to renew its license with provisions to instruct fisherman in culture, to provide them with up to five million spat of 2 cm length each year, and to manufacture and sell at cost all "protective shields" for oysters. In exchange the company received the right to all waters around Espiritu Santo Island, free import of equipment required for the industry, and the use of private police to guard against poachers.

This contract was expected to renew operations of a firm that had been in operation since 1904, but was destroyed by vandals during the Mexican revolution in 1914. At the time

TABLE 3.

Detected growth of some commercial species.

Species	Growth (mm/month)	Source
Megapitaria squalida	5.5 (+) 3 (−)	Baqueiro and Stuardo, 1977
M. aurantiaca	4.5 to 6 (+) 3 (−)	Baqueiro and Stuardo, 1977
Dosinia ponderosa	2.3 (+) 2 (−)	Baqueiro and Stuardo, 1977
Anadara tuberculosa	4 to 6 (+)	Baqueiro et al., 1982
Chione undatella	2 (+)	Masso and Baqueiro (in press)
Argopecten circularis	2 to 4 (+)	Baqueiro et al., 1981
	3.7 (−)	Felix, 1978
Pinna rugosa	10 (−)	Arizpe and Felix, 1984
Glycymeris gigantea	5 (+)	Musino and Baqueiro (in press)

(+) from natural populations, (−) from experimental cultures.

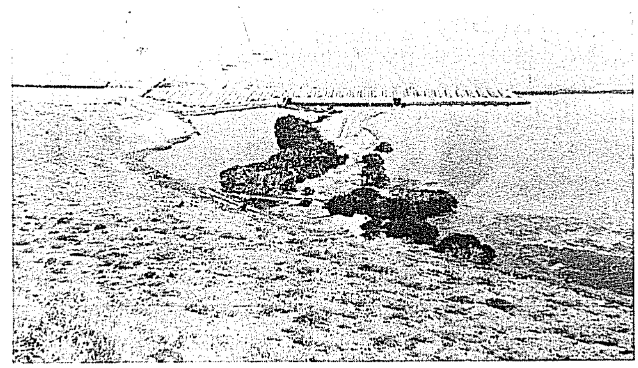

Figure 3. Aerial view of artificial lagoon and nursery canals with palm roofs to prevent over heating of juvenile pearl oyster, *Pinctada mazatlanica.*

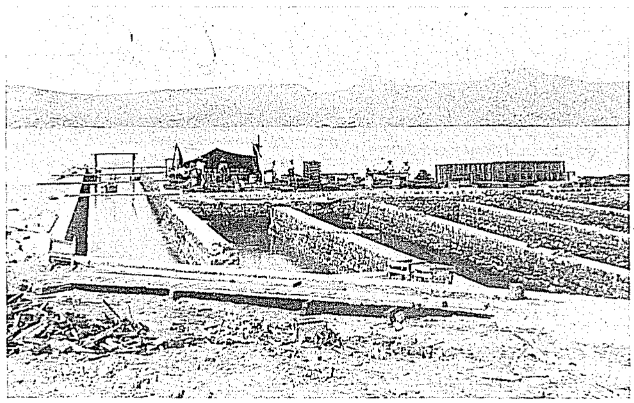

Figure 4. Nursery canals for the culture of juvenile pearl oysters, *Pinctada mazatlanica*. Note sluice gate to control tide flow and the passage of predators.

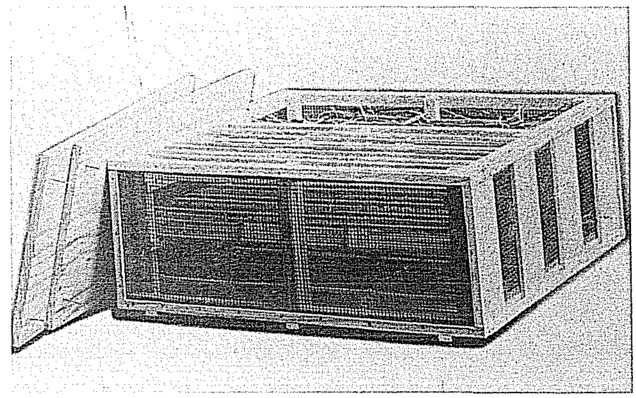

Figure 6. Collectors of hatchers showing wire mesh sides, inner compartments and solid board top that aided flotation.

of its destruction, the firm produced five million pearl oysters of one to three years of age, utilizing over 500 spat collectors and employing 400 workers.

The technique is described in detail in the contract and patents but was never made public. Mr. J. Gaston Vives Jr., surviving son of Mr. J. Gaston Vives Sr., furnished all available information on the Company and allowed us to describe the technique used by a once flourishing mother of pearl culture industry.

Spat were collected by means of "hatchers" which were wooden frames covered with galvanized wire mesh, the top of the hatcher being a solid board to provide shade and flotation (Figures 5 and 6). These cages or boxes were 3 m long, 2 m wide and 1 m high. Inside these hatchers were wooden trays (nests) where shells, branches and other objects were placed as cultch for the spat. The hatchers were floated just below the water surface from March to June. In each hatcher approximately 50 adult mother of pearl oysters were placed. Ten to twenty thousand spat one to two cm long were collected from each hatcher.

Spat were picked by hand from the hatcher nests and laid on the bottom of "nursery canals" (Figures 7 and 8). These consisted of 36 masonry canals, 25 m long, 5 m wide and 3 m deep, connected at opposite ends to form a zigzag pattern with one end opening to the sea and the other to an artificial lagoon made by a dyke 500 m long, 11 m wide and 10 m high (Figures 3 and 4). Both ends opened through a sluice containing wire mesh screens to control the water level and exclude predators. The canals were shaded by palm roofs to prevent overheating at low tide.

When the pearl oysters reached 3 to 4 cm in length, they were scattered on the bottom of the canals and provided with stones and shells for byssal attachment and protection.

After 6 to 8 months when the oysters reached about 5 cm in length, they were transplanted to prepared bottoms on the open sea. Live oysters were transported from the nursery to the growing grounds in specially designed cages (Figure 9) that were towed by sailboats. One hundred twenty hectares of sandy sea bottom around Espiritu Santo Island were covered with stones and shells to provide firm substrate by byssal attachment by the pearl oysters. This was done by hard-hat divers (Figure 12).

To protect the mother of pearl oysters from predators, a tin shield ("protective shield") (Figure 10) was cemented to the upper shell by a glue made from the sap of two local

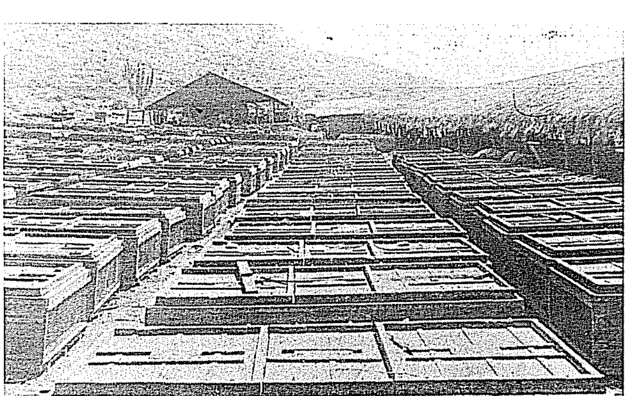

Figure 5. Hatchers, collecting boxes for spat of pearl oysters, stowed between seasons.

Figure 7. Workers picking pearl oyster spat from inner compartments of hatchers.

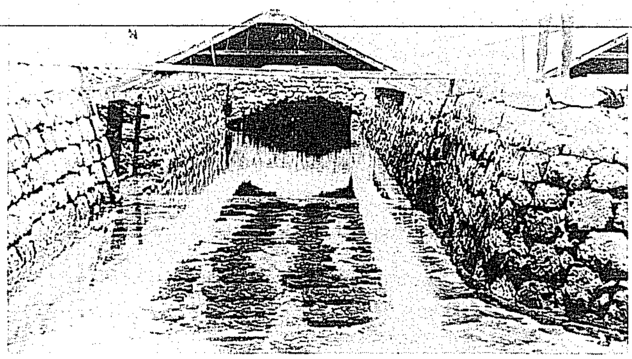

Figure 8. Nursery canal with wire mesh trays on the bottom, holding pearl oyster spat.

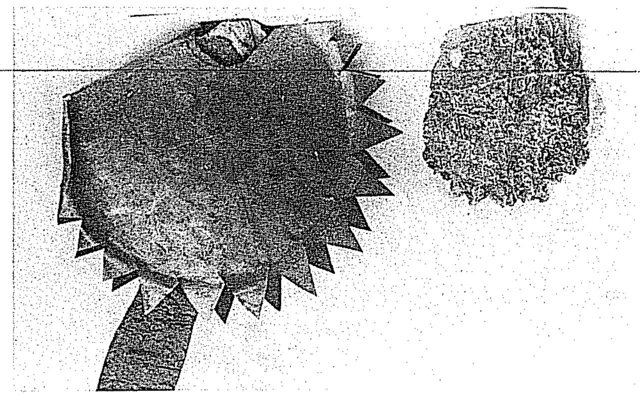

Figure 10. Juvenile pearl oyster with protective tin shell to prevent predation. Note wooden slab that acted as rudder on its fall from the boat and opening for attachment of the byssus.

species of trees. On top of the shield was a cork or small wooden slab which held the oyster in a straight up position during its descent to the bottom and until it had attached by its byssus.

A "protective pavilion" (Figure 11) was also developed to use soft sands and muddy bottoms. It was constructed of a concrete slab 60 cm long, 30 cm wide, 15 cm high, covered by a galvanized wire-mesh cage. Fifty to 60 oysters were placed in each cage where they grew for two years with only a 30% mortality. The cages and nursery boxes were reconditioned with a galvanic bath every season for reuse.

The oysters were grown for two to three years for the nacre or mother of pearl shell and the pearls. Oysters were harvested by divers. At the time of the company's demise, 1.5 million shells were produced annually.

A repletion program was initiated with the mud clam, *Rangia cuneata,* that had been heavily exploited in the Gulf of Mexico. The discovery in 1970 of abundant stocks of juveniles led to the practice of bed management. Overcrowded beds of small clams were thinned by transplanting clams to overexploited or depleted commercial beds. This has sustained a stable fishery at Pom and Atasta lagoons, Campeche (Figure 13).

Based on two years of government-sponsored experi-

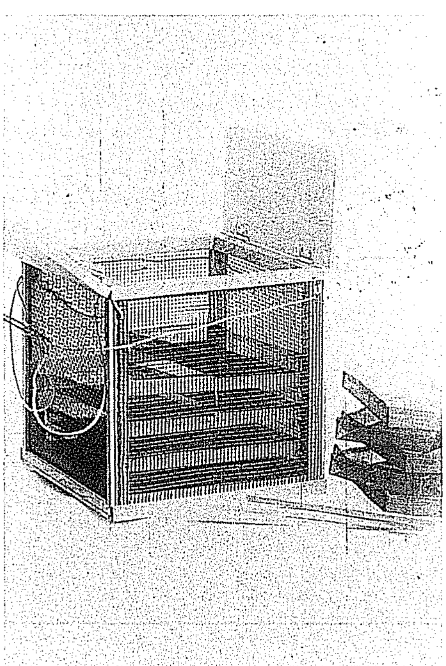

Figure 9. Transportation cage. Pearl oysters on wire mesh trays were placed in transportation cages and towed by sailboats to the rearing grounds.

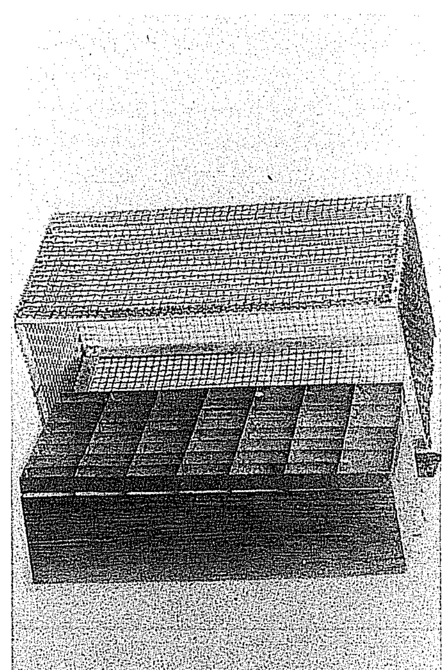

Figure 11. Concrete block with compartments for individual pearl oysters and protective wire-mesh cage. Used on sandy and muddy bottoms.

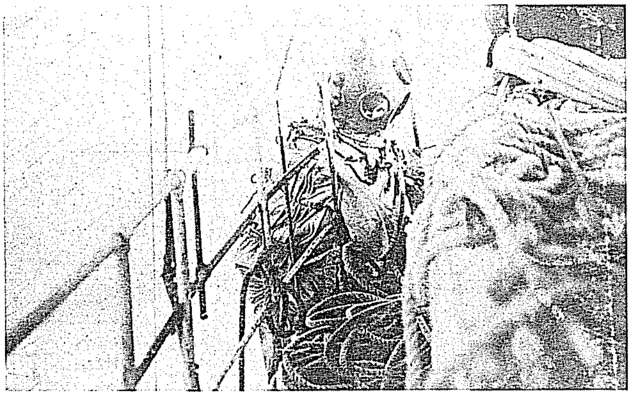

Figure 12. Hard hat divers were used to prepare bottoms with stones and lay culture devices.

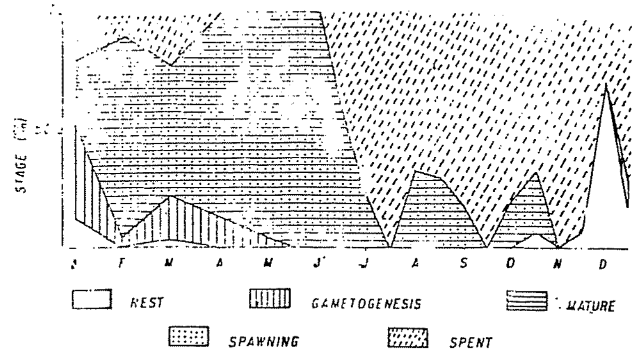

Figure 14. Reproductive cycle of *Rangia cuneata* from Pom lagoon, Campeche, during 1974. Adapted from Rogers and Garcia-Cubas (1981).

mental culture of the bay scallop, *Argopecten circularis,* a commercial farm was started in La Paz, Baja California Sur (Figure 13). This scallop venture relied on collection of spat from natural sets. Poor settlement during the second year of operation forced this enterprise to close.

Culture Research

Research on the culture and biology of mollusks has been sparse and erratic (Baqueiro 1984). Diaz (1972) reared *Pinctada mazatlanica* in suspended wire cages and baskets. In the same locality, Martinez (unpublished) planted *Pinna rugosa* juveniles to study growth and survival. Results were inconclusive due to lack of continuity.

In 1977 the Fisheries Department, through its aquaculture office in La Paz, Baja California Sur, began research on larval abundance, collecting devices, and on growth and survival of several species under different culture conditions (Tripp, 1978).

Felix et al. (1978) studied growth and survival of bay scallops, *Argopecten circularis,* in suspended plastic cages. Arizpe and Felix (1984) determined growth and survival of pen shells, *Pinna rugosa,* in suspended cages and fenced bottom cultures.

There are two commercial hatcheries on the Pacific coast (Figure 13) where pen shells, *Pinna rugosa* and *Atrina maura,* have been reared experimentally from egg to commercial size. They are reared to 10 mm after settlement and then transferred to either open tanks or to suspended cultures, using in both cases Nestier® plastic trays to hold them for three to four months before being planted on the bottom (Flores, per. comm.).

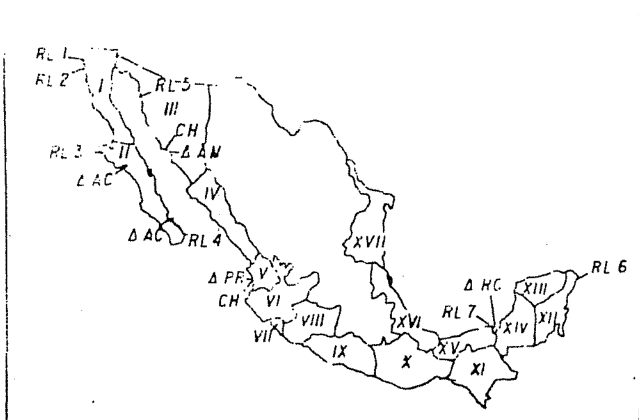

Figure 13. Map of Mexican coastal states: I–Baja California, II–Baja California Sur, III–Sonora, IV–Sinaloa, V–Nayarit, VI–Jalisco, VII–Colima, VIII–Michoacan, IX–Guerrero, X–Oaxaca, XI–Chiapas, XII–Quintana Roo, XIII–Yucatan, XIV–Campeche, XV–Tabasco, XVI–Veracruz, XVII–Tamaulipas. △ Localities where clams are or have been cultured: AC–*Argopecten circularis,* AM–*Atrina maura,* PR–*Pinna rugosa,* RC–*Rangia cuneata.* CH–commercial hatcheries: 1–Kino Bay, 2–San Blas. RL–research laboratories: 1–Ensenada, 2–Erendira, 3–Tortugas Bay, 4–La Paz, 5–Puerto Penasco, 6–Puerto Morelos, 7–Del Carmen Island.

GAMETOGENESIS AND SPAWNING IN MEXICAN CLAM POPULATIONS

A three-year gametogenic study of *Rangia cuneata* has been reported for a single locality in the Gulf of Mexico (Rogers and Garcia-Cubas 1981) (Figure 14). More species have been studied on the Pacific coast. *Anadara tuberculosa* (Flores 1971, Baqueiro et al. 1982) (Figure 15) and *Pinna rugosa* (Noguera and Gomez 1972, Coronel 1981) (Figure 21A, B) were studied in different localities at different times; *Mitella strigata* (Estevez 1975) (Figure 17A, B) presented different reproductive trends in response to different climatic conditions between localities.

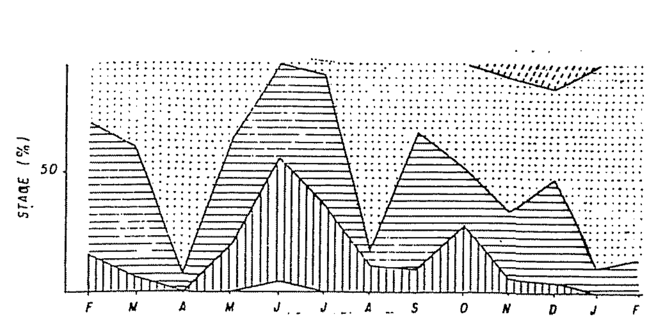

Figure 15. Reproductive cycle of *Anadara tuberculosa* from La Paz, Baja California Sur, during 1978–1979 (Baqueiro et al. 1984).

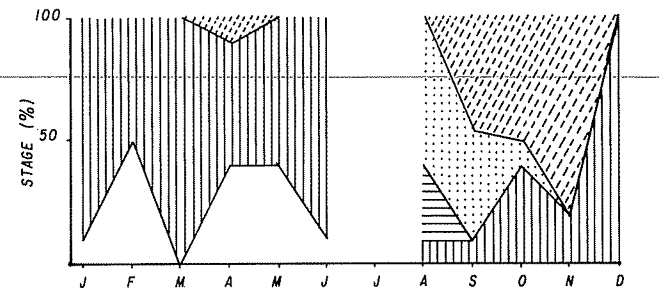

Figure 16. Reproductive cycle of *Mytella strigata*. a) Nuxco, b) Chautengo, Gro. during 1974 (Estevez 1975).

Populations in open tropical waters or in coastal lagoons from the desert area of Baja California Gulf Coast are exposed to a very stable environment without strong seasonal fluctuations. Gametogenesis continues throughout the year, which is reflected in constant spawning with two or three peaks a year (Figures 14, 17A, B, 18B, 19, 21B). Populations that inhabit coastal lagoons or shallow bays on the Pacific coast of Baja California, where the seasonal effect of climate can be felt, have a well defined reproductive period with gametogenesis either throughout most or all year (Figures 15, 16a,b, 17a,b, 18b,c, 19).

Both groups can present either a clear post-spawning and rest period after a spawning peak or have a very quick gonad recovery with no clear post spawning or rest period.

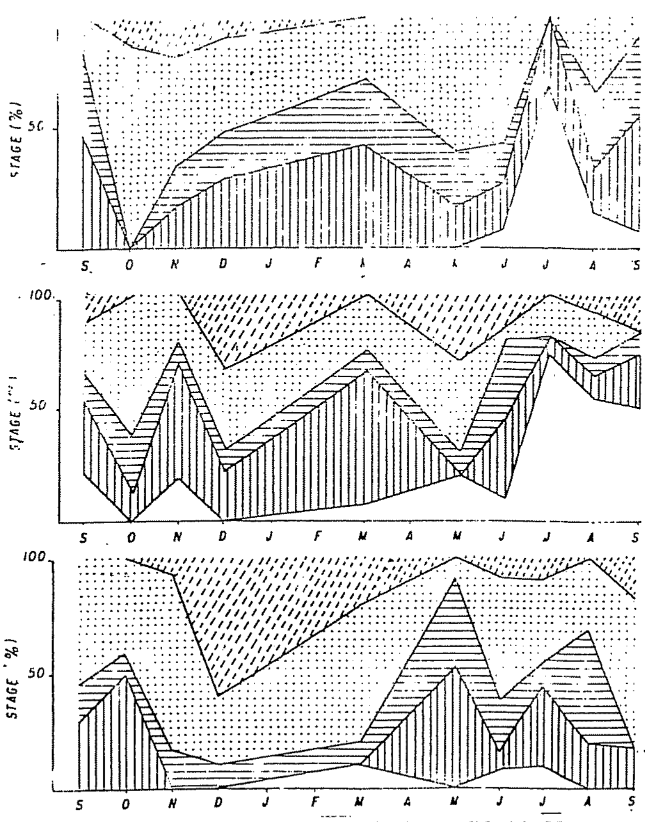

Figure 17. Reproductive cycle of *Megapitaria squalida* (a), *M. aurantiaca* (b) and *Dosinia ponderosa* (c) from Zihuatanejo, Gro. during 1974–1975 (Baqueiro and Stuardo 1971).

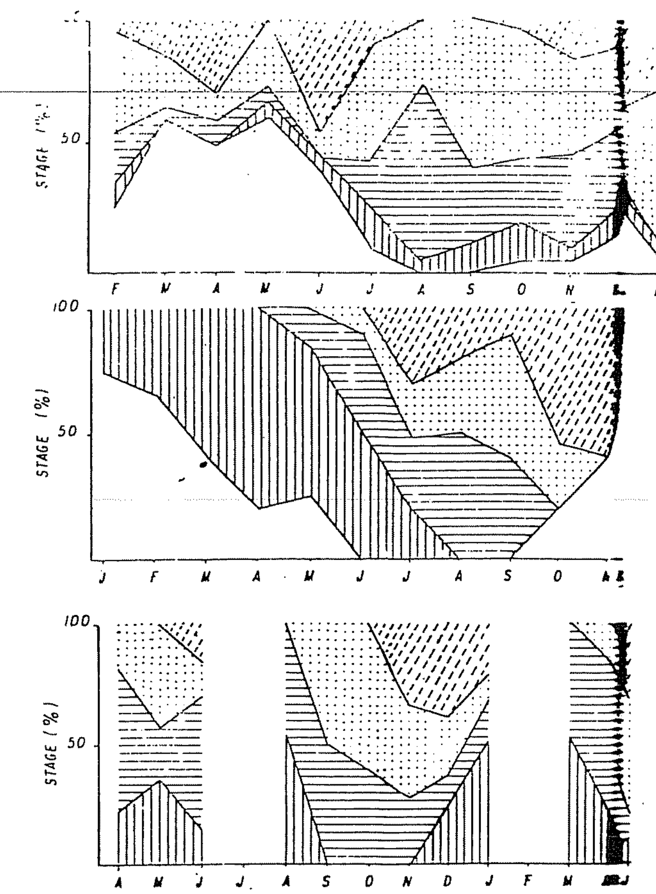

Figure 18. Reproductive cycle of (a) *Chione undatella* from La Paz Bay, Baja California Sur during 1978–1979 (Masso and Baqueiro 1984); (b) *Pinctada mazatlanica* from Mazatlan, Sinaloa during 1967 (Sevilla 1969); (c) *Glycymeris gigantea* from Concepcion Bay, Baja California Sur during 1979–1980 (Mucino and Baqueiro 1984).

BIOLOGY AND CULTURE OF *ARGOPECTEN CIRCULARIS* AND *PINNA RUGOSA*

The bay scallop, *Argopecten circularis,* and pen shell, *Pinna rugosa,* are two species whose biology and culture have been most studied. A pilot scale culture and at least one commercial culture of *A. circularis* has been carried out (Ortiz 1979).

Both species are found in the Panamic province. *Argo-*

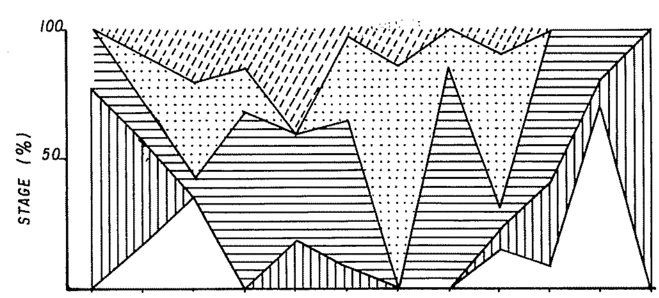

Figure 19. Reproductive cycle of *Argopecten circularis* from La Paz Bay, Baja California Sur during 1978–1979 (Baqueiro et al. 1981).

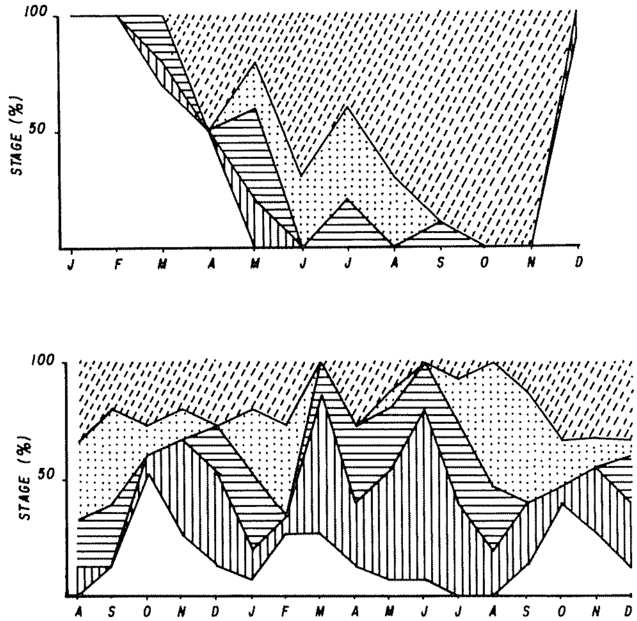

Figure 20. Reproductive cycle of *Pinna rugosa* from La Paz Bay (a) during 1969 (Noguera and Gomez 1972), (b) during 1980 (Coronel 1981).

pecten circularis has a range from Cedres Island, Baja California throughout the Gulf of California to Paita, Peru (Keen 1971). It is found on sea grass or intertidal algal beds to depths of 135 m, but is more abundant between 1 and 6 m depth in coastal lagoons and well protected bays. *Pinna rugosa* ranges from southern Baja California, Gulf of California to Panama on a wide variety of bottom types from sandy-mud to boulders in both open sea and coastal lagoons in depths of 2 to 45 m, but is more abundant in protected bays with good oceanic water circulation on muddy-sand bottoms.

The growth, reproduction and reproductive cycles of natural populations of *A. circularis* were studied by Baqueiro et al. (1981) and Yoshida and de Alva (1977). Larval abundance in plankton and settlement in different types of collectors were determined by Tripp (1978). Growth and survival in plastic cages were studied by Felix et al. (1978).

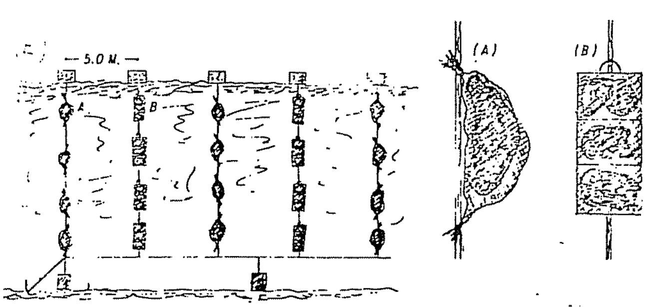

Figure 21. Collectors used to catch spat of *Argopecten circularis* and *Pinna rugosa*. a) Plastic net bag with brush branches, b) Plastic mesh basket with shells, c) Long line of collectors (Felix et al. 1978).

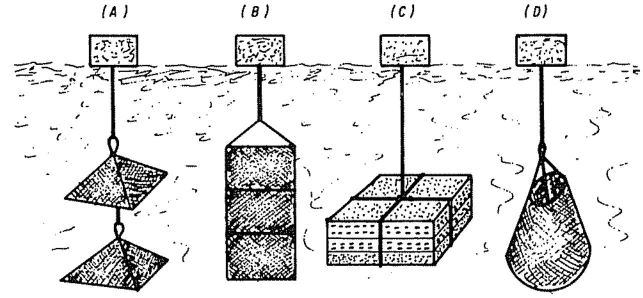

Figure 22. Different structures for rearing *Argopecten circularis* and *Pinna rugosa* juveniles. a) Modified lantern, b) Three layer basket, c) Nestier® trays, d) Net bag (Felix et al. 1978).

This species has a very active gametogenic cycle (Figure 19) which shows a fast recovery from spawning. The availability of ripe gonads during most of the year allows a long reproductive season with three peaks a year. This permits an almost constant recruitment, and natural sets-of-spat-can be collected at three peak times a year.

Growth rate of natural populations varied from 2 to 4 mm a month. In cage culture the growth rate was 3.7 mm a month in the first eight months after which growth ceased, perhaps due to overcrowding in the cages.

Survival in cages was 40% in 8 months. In natural populations the production rate of biomass was estimated over a year to average 55.4 g/m^2/month, with a maximum of 119 g/m^2. Scallops in suspended cage culture obtained a maximum of 37.5 g/m^2/month.

Pinna rugosa has not been studied in its natural populations except for its reproductive cycle (Noguera and Gomez 1972, Coronel 1981). The growth rate for the first two years of *P. rugosa* kept in pens or suspended in Nestier® trays was determined by Arizpe and Felix (1984).

The reproductive cycle determined by Coronel (1981) (Figure 20b) shows an active gametogenesis throughout the year with ripe gonads from March to September and two reproductive periods, one from June to November-December and a secondary period from January to March. This differs from the findings of Noguera and Gomez

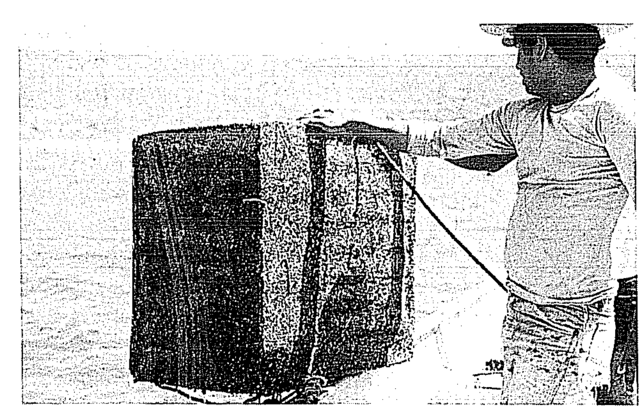

Figure 23. Multilayer rearing basket for suspension culture of *Pinna rugosa* (Arizpe and Felix 1984).

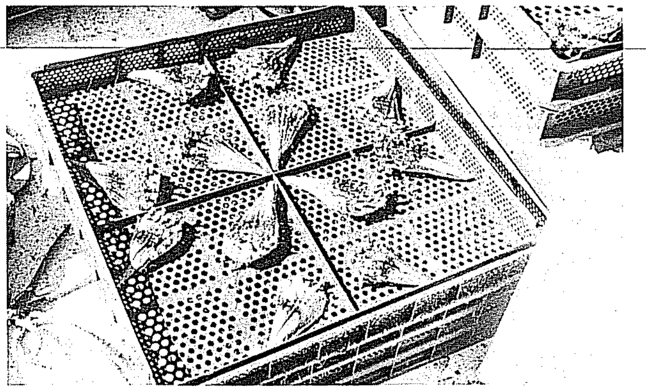

Figure 24. Two-year-old pen shell, *Pinna rugosa,* reared in Nestier® trays (Arizpe and Felix 1984).

(1972) (Figure 20a) where gametogenesis was restricted from March to June and setting from May to September. Both studies suggest a rapid conditioning period. Noguera and Gomez's data suggested a rest period which was not evident in Coronel's work.

Growth rate under culture conditions was 1 cm a month for the first two years. Arizpe suggested an optimum harvest age of 12 to 14 months.

Culture Techniques

Conditioning of *A. circularis* was attained in a laboratory in four weeks at 22°C, using running seawater and one daily supplementary feeding of 1.25×10^6 cells/ml of *Isochrysis* sp. Spawning was induced by thermal shock, raising the water temperature from 20° to 28°C in two hours. Metamorphosis of larvae started on the 20th day at 22°C.

For the pilot culture of *A. circularis,* spat are collected from the field with collectors made of plastic net bags filled with shells or branches (Figure 21). Larval abundance was determined by plankton tows, and collectors were dispensed when a high abundance was observed. When the spat reached 5 to 8 mm in size, they were scraped off the collectors and placed in Nestier® trays with mosquito net liners at 2000 spat per tray, occupying about 50% of the tray surface.

Trays were stacked in groups of five and hung from rafts or long lines at 1 m depth. Fouling was a major problem, requiring cleaning about every two weeks. Trays were scrubbed with a brush or sprayed with a water jet from a motor-driven pump. Mortality kept spat density equal or under 50% of total tray area. When the scallops reached 30 to 35 mm, their growth stopped and their shells thickened, increasing to width but not in length, and their meat condition was very poor.

Pinna rugosa spat are collected and handled like the bay scallop. Confinement in trays did not seem to have any adverse effects on them in the two years it took to reach commercial size (Figures 23, 24).

Pinna rugosa and *Atrina maura* from San Blas, Nayarit and Kino Bay, Sonora were collected ripe from the field and induced to spawn with thermal shock. Their larvae were reared in metamorphosis in 18 to 20 days. After metamorphosis they were kept in Nestier® trays in open tanks with running seawater or suspended from rafts and long lines until they reached 6 to 7 cm, after which they were transplanted to the bottom in protected ponds. Commercial size was reached in two years (Flores, per. comm.).

SUMMARY

Culture techniques have copied oyster culture in other countries. The slow growth and stunting of *A. circularis* show the need for research on culture methods. The lack of technical information has hindered the development of mariculture. Previous failures discourage others until a well proven technique can be demonstrated.

Legislation to protect water parcels or leases and culture stock is needed to enhance aquaculture in Mexico. A simplification of licensing and leasing regulations by assigning them to a single agency would be useful. At present it involves no less than four ministries to get an aquaculture permit and permits to use a body of water.

The present fisheries law states those given a permit to exploit a resource should improve it by aquaculture. The Fisheries ministry tries to accomplish this by providing training and counseling to fishermen. With an education program in aquaculture sponsored by the Education ministry from secondary school through college, aquaculture is expected to boom in the coming years.

The culture of a few commercial species has shown encouraging results. As techniques are developed, the advantage of a year-round growing season and available labor will certainly aid in the development of an industry which will provide jobs, income and food for both local use and export.

Many large species like the pen shell, rock scallop and red clam do not have to be grown to full size since they can be sold to foreign markets that demand small and medium size scallops and clams, taking advantage of the faster growth in their first years of life.

Over ten thousand kilometers of coastal area, with more than a million and a half hectares of coastal lagoons and protected bays, give Mexico a great potential for the development of mariculture. Since clams and scallops are among the easiest and the highest priced species to culture, their culture should be encouraged.

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