FRESENIUS ENVIROMENTAL BULLETIN, vol. 16, núm. 11A, 2007, pp. 1331-1334.

Environmental Planning for Clam Aquaculture at the Largest Bay of Northwest Mexico - Enviromental aquaculture Mexico.

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ENVIRONMENTAL PLANNING FOR CLAM AQUACULTURE AT THE LARGEST BAY OF NORTHWEST MEXICO

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SUMMARY

The coastal zone of Magdalena Bay, in Baja California Sur, Mexico, was studied, using GIS and ecological planning methods, as a potential area where clam culture could be developed. As a result, 7 sites were selected for their suitability; field work was necessary to assess the precise suitability of each site. By evaluating the results of our research we could determine the optimal places to develop clam culture in the bay.

KEYWORDS:
Environmental planning, Bahia Magdalena, clam culture, Mexico.

INTRODUCTION

There are more than 123 coastal lagoons in the Mexican coastal zone covering an approximate area of 12,555 km². The length of these lagoons represents between 30 % and 35 % of the 11,543 km of the Mexican coast. Magdalena Bay, Mexico, is the largest bay in the Baja California peninsula (Fig. 1). The Bay is a lagoon system with three main areas, the northernmost called Laguna Santo Domingo, the central part Magdalena Bay, and the southernmost Almejas Bay. The lagoon system has a total length of 250 km, covering an area of 2,200 km² that includes 1,453 km² of the lagoon basin and 747 km² of mangrove forest, sand dunes, and wetlands.

Currently Magdalena Bay is very important for the economy of the state of Baja California Sur, 50 % of the artisan fisheries activities are established in this zone. To avoid conflicts between environmental and business we studied and summarized the main biological, physical, chemical and socioeconomic aspects of Magdalena Bay, in order to determine where, and how, new clam culture projects must be established.

Aquaculture world production has maintained a sustained growth in several countries for the last 15 years generating both positive and negative impacts on social [1-3], economic [4], and natural systems [5, 6]. Mexico, being no exception, has developed these activities at similar rates going from 0 tons in 1984 to more than 62,000 tons in 2003 [7].

Moreover, it is expected that aquaculture activities will increase explosively in the coming years. If aquaculture activities flourish, as it is foreseen in this region, there will be direct conflicts with artisan fishing activities, ecotourism and tourist activities foreseen to be carried out in the region, and with the conservation of the environment, including sand dunes and mangrove fragile ecosystems.

MATERIALS AND METHODS

Magdalena Bay lagoon system is located on the occidental side of the state of Baja California Sur. This lagoon system is the most extensive and important of the whole peninsula and within Mexico. It is located between 24° 17′ and 25° 40′ N and 111° 30′ and 112° 15′ W. The system is made of wide areas of wetlands especially in Laguna Santo Domingo and in Almejas Bay.

Because of the physiography of the system it is regarded as a natural shelter for marine flora and fauna, and for small fishing boats. This zone is influenced by the California Current and by water that comes from the Equator, being a transition zone characterized by high productivity [8]; it is warm and dry, classified as a semiarid climate by Coppell system. The annual average temperature is of 20 °C, with a maximum of 41 °C in July-August, and a minimum of 4 °C in January-February. The mean total annual average temperature is of 125 mm [9]. In the warm season water temperature column varies between 23 and 28 °C, while in the cold season it varies between 16 and 23.6 °C. Maximum salinity, ranging from 37.3 to 39.2 ups, is found in channels in the lagoon system, while minimum salinity, from 34.0 to 34.5 ups, is registered in channels connecting the system to the Pacific Ocean characterizing it as antiestuarine [10, 11]. Tides are semi-diurnal mixed. Maximum and minimum dissolved oxygen level at the mouth of Magdalena Bay are of 6.85 and 3.68 mL/L respectively; con-

centration of chlorophyll a fluctuates from 1.2 to 5.1 mg/m³; phosphates vary from 3.09 to 0.62 μm, and water velocity from 0.24 to 1 m/s [9].

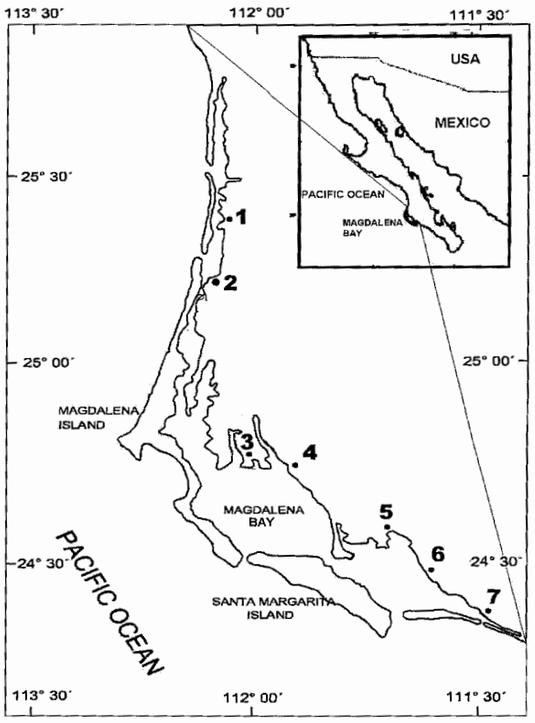

FIGURE 1 - Magdalena Bay location and selected clam culture sites. Sites are described in Table 2.

From 2001 to 2003 the main characteristics of the area were determined: climate, soil, geology, orography, morphology, and hydrology; after analyzing the bibliography and the data sets of the meteorological stations of the region as well as official charts, field stages of work were developed to corroborate the information.

Marine and costal characteristic, including tide effects, morphology of the coastal zone, and accessibility for marine water intake and waste water treatment and disposal were obtained through the analysis of satellite images and field stays of work. The availability of services for each potential clam culture zone, including roads (paved and not paved), electricity, phone and internet availability, human populations and potential workers, were also established by field surveys.

In order to assess the suitability of each potential site for sustainable clam culture activities inside Magdalena Bay, we applied the modified index of Lagunas & Ortega [12]:

$$CCS=\frac{ACS\ (0.1) + NMST\ (0.3) + AVD\ (0.15) + MCAS\ (0.15) + AAPD\ ((0.3) + MSK\ (0.1)\times 100}{2.45}$$

Where:
CCS = Clam Culture Suitability
ACS = Accessibility
NMST = Number of Months with Suitable Temperature for the Clam Culture
AVD = Average Depth
MCAS = Marine Current Average Speed
AAPD = Annual Average Phytoplankton Density
MSK = Marine Substrate Kind

The index of Lagunas & Ortega is the result of empirical field studies developed by the authors of this paper and by the careful assessment of the ecological, environmental, socioeconomic and facilities characteristics of the places where the optimal clam aquaculture activities are currently developed. In order to standardize the values obtained by this index, it is divided by the empirical value of 2.45. This way values obtained range from 0 to 100. The rank values are shown in Table 1.

TABLE 1 - Rank value used to assess clam aquaculture suitability.

Variable	Characteristics	Rank value
ACS	Site without roads available and without sea connection	0
	Site only with sea connection	1
	Site only with road connection	2
	Site with roads available and with sea connection	3
NMST	Less than 5 months with suitable temperature	0
	Between 6 to 9 months with suitable temperature	1
	More than 10 months with suitable temperature	2
AVD	From 1 to 5 m in average	1
	From 6 to 10 m in average	2
	More than 10 m	3
MCAS	Annual average more than 31 m/s	0
	Annual average between 21 to 30 m/s	1
	Annual average between 11 to 20 m/s	2
	Annual average between 1 to 10 m/s	3
AAPD	From 67% to 100% of water turbidity	0
	From 34% to 66% of water turbidity	1
	From 11% to 33% of water turbidity	2
	From 1 % to 10% of water turbidity	3
MSK	Rocky	0
	Clay-slime	1
	Sandy	2

RESULTS AND DISCUSSION

After the bibliographic revision and the analysis of satellite images, which were digitalized in a GIS in which we included climate, vegetation, soil, geological, and geomorphological characteristics, 7 potential places were identified where clam culture activities could be performed with the lesser impacts and with more success probability; the sites selected were Santo Domingo, Adolfo Lopez, Estero San Buto, Estero Chisguete, Punta Cayuco, Puerto Chale, and Rancho Bueno, which are shown in Figure 1.

After the 7 sites were selected, we performed one week field stays of work in each of them. The CCS value for each site was obtained after we analyzed all the specific

characteristics of the environmental and socioeconomic features considered in the formula for each place (Table 2). As we can see the best site to develop clam culture is located in Estero San Buto where optimal conditions were found with a CCS value of 90.

According to the characterization of this site we recommend that the species to be cultured are the Catarina scallop (*Argopecten ventricosus*), the Lion paw scallop (*Nodipecten subnodosus*), the Pen shell (*Atrina maura*), and the Chocolata clam (*Megapitaria squalida*).

TABLE 2 - Main characteristics and CCS value obtained for each selected site.

SITE	ACS Accessibility	NST Number of Months With Suitable Temperature for the Clam Culture	AVD Average depth	MCAS Marine Current Average Speed	AAPD Annual Average Phytoplankton Density	MSK Marine Substrate Kind	CCS Clam Culture Suitability
1 Santo Domingo	1	2	1	1	1	1	57
2 Adolfo Lopez	3	2	1	1	1	1	65
3 Estero San Buto	2	2	2	2	2	2	90
4 Estero Chisguete	2	2	3	1	1	1	73
5 Punta Cayuco	1	2	1	1	2	1	69
6 Puerto Chale	3	2	1	1	1	2	65
7 Rancho Bueno	2	2	1	1	1	2	65

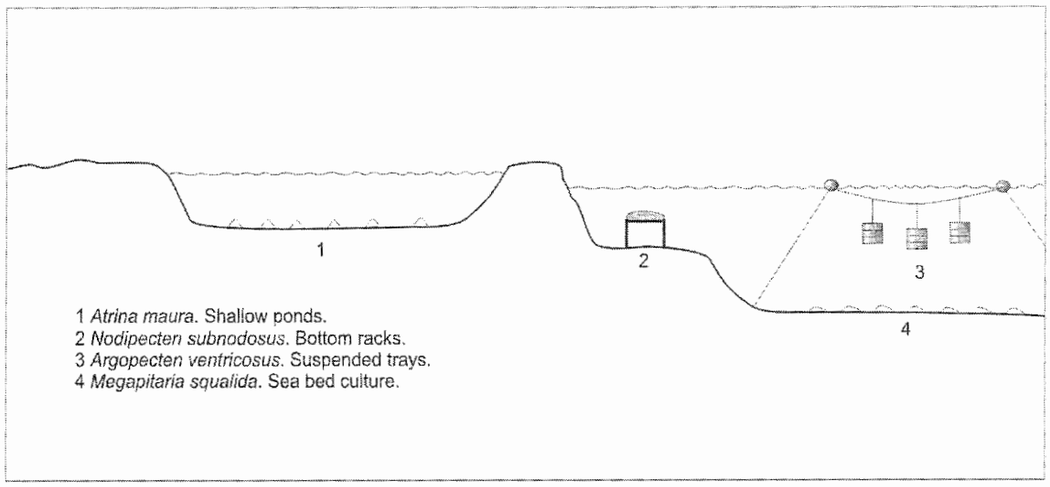

FIGURE 2 - Recommended polyculture.

We recommend to establish policulture facilities for these local species, without intensive culture activities, thus avoiding the nourishment excess and the pollution caused by the own detritus of the cultured individuals (Fig. 2). There exist 150 ha in Estero San Buto suitable to establish this recommended policulture, being possible to hire workers in the locality for it; an average annual harvest of 2,312 tons of the different species is estimated.

CONCLUSIONS

Knowing the precise biological, physicochemical and social environment, we can determine the best species to cultivate, the recommended total area to use, and the methodology to be employed to produce the lesser environmental impacts and to obtain the maximum profitability. Our methodology could be used not only to select appropriate sites for clam culture but also to assess the suitability, in a quick

and accurate way, of any other aquaculture activity in coastal zones.

ACNOWLEDGEMENTS

This study was supported by the Centro de Investigaciones Biológicas del Noroeste, by the CONACyT-SEMARNAT Project 2002-C01-0844, and by the Universidad Autónoma de Baja California Sur, PROMEP, SEP. We thank the two anonymous reviewers whose pertinent opinions were important to write a better version of this manuscript.

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Received: October 04, 2007
Revised: February 12, 2007
Accepted: April 17, 2007

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