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Environmental impact reduction through ecological planning at Bahia Magdalena, Mexico

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Abstract: *For analyzing basic marine and coastal characteristics we selected the potential sites where shrimp culture could be developed in a large coastal zone, Bahía Magdalena, Baja California Sur, Mexico. Based on our analysis, 6 sites were preselected and field stages of work were then developed to assess the precise suitability of each site in order to develop the proposed aquaculture activities. In ranking the suitability we were able to recommend the most appropriate places to develop shrimp culture in this region. Also, knowing the exact biological, physico-chemical and social environment, we determined the best species to cultivate, the recommended total area and the methodology to be used to lessen the environmental impact and to obtain the maximum profitability. Our methodology could be used not only to select appropriate sites for shrimp culture in other coastal lagoons, but it also could be applied to assess the suitability, in a quick and accurate way, of any other production activity in coastal zones.*

Key words*: Environmental impact, Ecological planning, Bahia Magdalena, Shrimp culture, Mexico*
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Introduction

The world production of cultivated shrimp has maintained a sustained growth in several countries for the last 15 years and has generated both positive and negative impacts on social (Bailey, 1988; Primavera, 1991; Lebel *et al.,* 2002; Saksena *et al.,* 2006), economic (Kautsky *et al.,* 1997), and natural systems (Paez-Osuna, 2001; Macintosh, 1996). Mexico's production of cultivated shrimp has developed at a similar rate going from 0 ton in 1984 to more than 62,000 tons in 2003 (SAGARPA-CONAPESCA, 2003).

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

In the coastal zone of Mexico there are more than 123 coastal lagoons, 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's 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 one of the most important in Mexico. It is located between 24° 17´ and 25° 40´ N and 111° 30´ and 112° 15´ W (Fig. 1). It has three main areas, the northernmost called Laguna Santo Domingo, the central part Bahia Magdalena, and the southernmost Bahia Almejas, with a total length of 250 km, covering an area of 2,200 km² that includes 1,453 km² of water body and 747 km² of mangrove forest, sand dunes and wetlands.

The system encompasses wide areas of wetlands especially in Laguna Santo Domingo and in Bahia Almejas. Due to the system's physiography 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. It is a transition zone characterized by high productivity (Parrish *et al*., 1981). It is warm and dry, classified as a semiarid climate by the Coppell system.

Today, Magdalena Bay is very important for the economy of the state of Baja California Sur as 50% of the artisan fisheries activities of the state are developed in this zone.

In order to avoid conflicts of shrimp culture with other productive activities and conservation priorities within the area, we study and summarize the main biological, physical, chemical and socioeconomic aspects of Magdalena Bay, in order to determine where, and how, new shrimp culture projects must be established.

Materials and Methods

Chlorophyll and phosphate were analyzed by spectrophotometric methods described by Strickland and Parsons (1968).

From 2001 to 2003 we determined the main characteristics of the area: 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 maps, field stages of work to corroborate the information were developed.

Marine and coastal characteristics, 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.

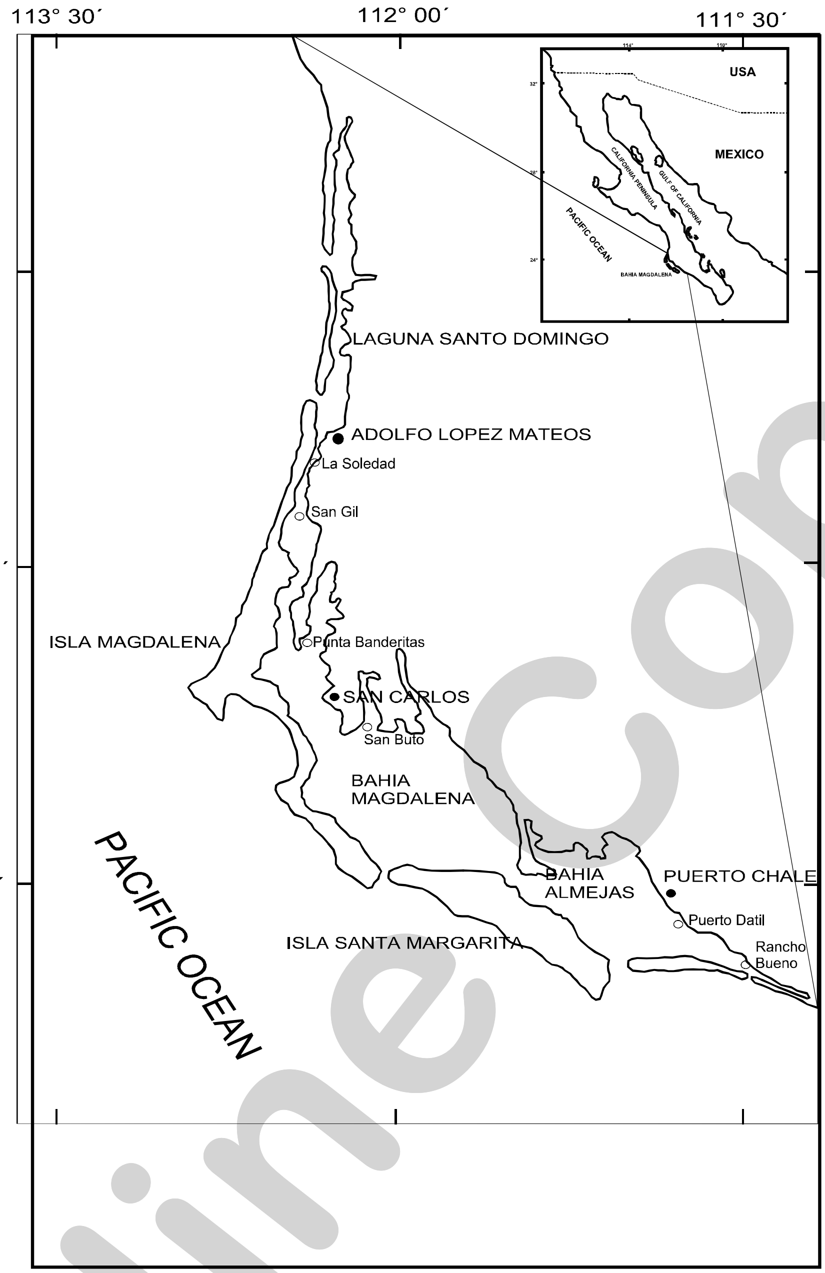

Fig. 1: Magdalena Bay location and selected shrimp culture sites

For purposes of managing the information provided by the NOAA-AVHRR, LANDSAT TM and ETM satellite images were stored in the ArcGis 8.3 GIS program. Satellite images were used to precisely locate the potential areas, and to determine the vegetation cover, orography, morphology and hydrology.

The availability of services for each potential shrimp culture zone was established by field surveys, including roads (paved and not paved), electricity, phone and internet availability, human population and potential workers.

In order to assess the suitability of each potential site for sustainable shrimp culture activities, we applied the modified index of Lagunas and Ortega (Maravilla-Chavez *et al.,* 2006):

$$SCS = \frac{\sum VC+BWC+NMST+ST+TO+SS+SA}{15} \times 100$$

Where: SCS = Shrimp culture suitability, VC = Vegetation cover, MWC = Marine water circulation, NMST = Number of months with

Table - 1: Main characteristics and SCS values obtained for each selected site

Site	NMST	VC	ST	MWC	ORG	SS	AS	SCS
La Soledad	1	1	2	0	1	1	3	60
Islote San Gil	1	0	1	0	0	1	0	20
Punta Banderitas	1	1	2	1	1	2	3	73
Estero San Buto	1	0	2	0	0	1	3	46
Puerto Dátil	1	3	3	1	1	2	3	93
Rancho Bueno	1	0	2	2	1	1	3	66

NMST = Months with suitable temperature for shrimp culture, VC = Vegetation cover, ST = Soil texture, MWC = Marine water circulation, ORG = Orography, SS = Soil salinity, AS = Accessibility to services, SCS = Shrimp culture suitability

suitable temperature for the shrimp culture, ST = Soil texture, ORG = Orography, SS = Soil salinity, AS = Accessibility to services.

The rank values used were:

VC:

From 0 to 10% of the site covered by vegetation = 3
From 11 to 33% of the site covered by vegetation = 2
From 34 to 66% of the site covered by vegetation = 1
From 67 to 100% of the site covered by vegetation= 0

If the vegetation is mangrove, the numerical results are multiplied by 0.10.

MWC:

Marine body water with low natural circulation = 0
Marine body water with natural exchange = 1
Marine body water strongly influenced by open sea=2

NMST:

Less than 5 months with suitable temperature = 0
Between 6 to 8 months with suitable temperature = 1
More than 9 months with suitable temperature = 2

ST:

Sandy = 1, Sand–silt–clay = 2, Clay–silty = 3

ORG:

With hills and barriers = 0, Flat = 1

SS:

Hipersaline soil = 2, Soil not hipersaline = 1

AS:

Electricity and telephone = 1, Nearby human population = 2, Road access = 3

Results and Discussion

The annual average temperature is 20°C, with a maximum of 41°C in July-August, and a minimum of 4°C in January-February. The mean total annual precipitation is 125 mm. In the warm season water temperature 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 antiestuarinic (Alvarez *et al.*, 1975). Tides are semi-diurnal mixed. Maximum and minimum dissolved oxygen at the mouth of Magdalena Bay are of 6.85 y 3.68 ml/l respectively, concentration of chlorophyll fluctuates from 1.2 to 5.1 mg/m³, inorganic phosphates vary from 1.00 to 2.48 μM/l, and water velocity from 0.24 to 22.5 cm/s (Acosta-Ruiz and Lara-Lara, 1978).

After the bibliographic revision and the analysis of satellite images, which were digitalized in a GIS, we stored the information concerning the vegetation, geological, soil, and geomorphologic characteristics; we identified 6 potential places where shrimp culture activities could be performed with a lesser impact and with a higher degree of success. The sites selected where: La Soledad, Islote San Gil, Punta Banderitas, Estero San Buto, Puerto Datil y Rancho Bueno, which are shown in Fig. 1. After 6 sites here selected, we performed 6 field stays of work, spending one week in each of them. After we analyzed each site, including all the specific characteristics for the environmental and socio-economic features considered in the formula, we obtained the SCS values for each place (Table 1).

We determined that the best site to develop shrimp culture is located in Puerto Datil (Fig. 1). According to the characteristics of this site, we recommend that the species to be cultured are the brown shrimp (*Farfantepenaeus californiensis*) and the white shrimp (*Litopenaeus vannamei*). We recommend developing a biculture, separating the species seasonally: from May to October culturing white shrimp and from November to April brown shrimp. We also recommend, according to the site characteristics, and to avoid environmental impacts on the coastal zone, the use of supra-litoral ponds, with a maximum area of 150 ha, using 14 workers hired from the Puerto Adolfo Mateos town, and feeding the shrimps with the use of mobile trays which avoid the food pollution of the body water. According to our estimates, the total production of these 150 ha, following our recommendations, would be of 225 tons per crop.

When analyzing with GIS and ecological planning methods, despite the size of the area, it is possible to select suitable sites to develop a specific productive activity. Field work to analyze the pre-selected sites is mandatory to assess the precise suitability of each one of them. Following this methodology and using simple but useful indexes, one can accurately rank the site's suitability, including how to lessen the environmental impact, and obtain the maximum profitability in this activity. We believe our methodology can be used not only to select appropriate sites for shrimp culture in other coastal lagoons, but it also could be applied to assess the suitability, in a quick and accurate way, of any other marine species production activity in coastal zones.

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