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# Capacity building to achieve sustainable fisheries management in Mexico

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ABSTRACT

Achieving sustainable fisheries management is an enormous challenge and involves the enhancement of scientific and technological management capacities worldwide. The improvement of this capacity building (CB) is particularly crucial to developing countries with massive fisheries such as Mexico. To understand the current status of CB in Mexico, the contemporary development of its academic research system was examined by undertaking a bibliographic review of specialized literature, including research institutions and postgraduate programs. The resulting information was considered as Mexican CB indicators and its theoretical and spatio-temporal analysis revealed capabilities are increasingly supporting research topics related to advancing sustainable fisheries development. However, because the recent and tumultuous development of the Mexican academic research system, much of the knowledge accumulated centers on commercial resources, and the renovation of the system itself is geographically inconsistent. In this paper, some key insights on how to improve Mexican CB process are highlighted.


## 1. Introduction

Since the publication of the Agenda 21 (1992) and the Code of Conduct for Responsible Fisheries (CCRF–1995), sustainable management approaches have been internationally adopted as an effective means to achieve socially and ecologically balanced fisheries (Garcia et al., 2003). By reversing the order of management priorities, such as focusing on the ecosystem rather than the target species, sustainable fisheries management represents a holistic management approach and emphasizes an understanding of the complex and reciprocal interactions between humans and marine resources (Pikitch et al., 2004). Both the Agenda 21 and the CCRF also recognized the urgent need for improved scientific and technological management capacities to facilitate the transition to sustainable fisheries. In this way, the term capacity building (CB) was proposed to describe the capabilities of each country in achieving the efficient and effective pursuit of environmental goals in cooperation with other nations (Chircop, 1998). According to Agenda 21 (Chapter 36), CB should have a job-specific focus that aims to fill knowledge gaps and provides skills that would assist individuals in environmental development work (UNCED, 1992a).

Nevertheless, CB within sustainable fisheries management has met enormous political and economic challenges (FAO, 1995), and there is no universal strategy in place (BID-PNUD, 1990). These challenges occur even in consolidated fishery systems in developed countries, such as Iceland or Norway, which have been fishing intensively for centuries (Roberts, 2007) as well as in sites of high ecological value, such as Antarctica, where international agreements have called for the adopting of a precautionary approach to minimize risks associated with unsustainable practices in conditions of uncertainty (CCAMLR, 2010). In developing countries, however, overcoming these challenges is particularly important because these nations are among the most important fish producers in the world; they make up 14 of the 20 countries that produce more than 1,000,000 metric tons annually (FAO, 2007) and contributed more than two-thirds of the global wild fish production in the last decade (Arnason et al., 2008). The challenge is that these massive fisheries mostly began from the 1970s onwards, therefore their recent fisheries regimens have limited training and institutional capacities. The limitations are also caused by the rapid turnover of several contrasting resource management policies that were rooted in the difficult conditions frequently faced by these kind of countries (Espinoza-Tenorio et al., 2010b), in which fundamental domestic debates are usually limited to political and moral priorities (e.g. improving the material conditions of life often is regarded as a central goal), rather than technical and economic choices (Bailey and Jentoft, 1990).

Mexico has a significant fishing industry (17th largest in the world in 2007), and Mexico has implemented sustainable fisheries development principles since the 1990s (Aguilar et al., 2000; Alcalá,

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2003; Espinoza-Tenorio et al., 2010b). Here, we review the process of capacity building (CB) that has occurred in Mexico since these sustainable management efforts began, and we discuss the effects of CB on commercial fishing in the nation. Positive policy outcomes of this process include the initiation of major institution-building efforts (Rivera-Arriaga, 1998), an increase in public and scientist participation in natural resources planning (Hernández and Kempton, 2003), and improvements in the policy framework (OECD, 2005; Pitcher et al., 2009). However, academic and scientific capabilities have improved only marginally due to a lack of strong political and economic support (Ortiz-Lozano et al., 2005; Salas et al., 2007). For example, only 1.1% of Mexico's fish production is used for research, representing only 0.0001% of the Gross Domestic Product (GDP) in 2007 (Csirke et al., 2005). In Australia, a developed country with a similar GDP but much smaller fishing industry, the proportion is twice as large (DAFF, 2010). According to Guzmán-Amaya et al. (2008), the Mexican Fisheries Institute, the agency required to provide official information on the national fisheries, appears to have been gradually abandoned by the federal government, and its research responsibilities and funding have been transferred to other government agencies. Thus, fisheries research is now supported mainly by funds from the National Council of Science and Technology (CONACyT) as part of a new arrangement in which half of the funding is provided by the industry and/or the states and the other half is provided by the research council (DOF, 2002). Under this new policy, a large amount of government research has moved to federal and private institutions. The priorities and interests of these institutions do not always match the needs of local fisheries management, and the continually evolving funding system has created inconsistencies in some local governments. Without a long-term organizational program, research on sustainable fisheries management cannot be expected to receive the same level of support as other political priorities like social security, the petroleum industry, agriculture, and forestry services.

How does CB help to promote sustainable fisheries management in Mexico? What are the goals of CB? What is most important from a management perspective, and how can management be improved? These are crucial questions about Mexican fisheries management, and they are addressed by this study under the assumption that the current management regime is the result of a series of international agreements, economic crises, and other historical contingencies (Gaichas, 2008). To understand the current status of CB for Mexican fisheries and to determine possible ways to improve it, we analyze the development of the Mexican academic research system from its inception in the mid-20th century to the beginning of the 21st century, when national political changes resulted in the strengthening of institutions through the Law of Science and Technology (2002). Historical analyses of the Mexican academic research system are difficult, however, due to a chronic lack of data.[1] To overcome this limitation, we reviewed commonly used indicators in studies of education and training for integrated resources management (Chircop, 1996, 2000; Cicin-Sain et al., 2000; Smith, 2002; Ceccon and Cetto, 2003). The information gathered was analyzed in a theoretical and temporal manner to describe the type of management knowledge generated by domestic and international research, and the academic profiles of the professionals, scientists, and institutions involved in fisheries resource management were examined. The spatial patterns of CB within the four official Mexican fishery zones were also described because knowledge of regional planning capacities is important for achieving sustainable development (Pikitch et al., 2004). In fact, in a heterogeneous country like Mexico with such large and complex marine ecosystems, this knowledge is vital for the development of multi-species fisheries (Rivera-Arriaga and Villalobos, 2001).

The methodological approach followed in this study highlights the need for sustainable resource management in the context of the current management situation. We use our theoretical, temporal, and spatial findings to discuss how current CB efforts might be improved to promote sustainable fisheries according to management needs, institutional needs, and regional needs.

## 2. Methods

The term "Capacity Building" (CB) is frequently used in the context of sustainable development to describe the education and training of academics and researchers in universities and research centers (Cicin-Sain et al., 2000). A fundamental goal of these professionals is to influence environmental policy choices and modes of implementation for the development of options based on an understanding of environmental opportunities and limits as well as knowledge of the needs of the country's people (UNCED, 1992b). This is a long-term process in which both academics and researchers participate in the creation of new courses and updated training materials, as well as the nationwide implementation of new training programs.

**Table 1**
Criteria used in the theoretical and spatio-temporal treatment of the information.

| | Criteria | Description |
|---|---|---|
| Theoretical | Research subject | Area of knowledge studied. Social studies refer to those involving policy or actor analyses, while biology science is divided according to the two main ecological levels involved in resources management: species and ecosystems |
| | Academic approach | The academic way of dealing with the complex processes involved in the fishing activity can be classified in disciplinary (fisheries or environmental) and integral (interdisciplinary, multidisciplinary, or transdisciplinary) |
| | Methodological approach | The methodology chosen to solve a fishing problem depends on the state of knowledge of a resource. Diagnosis and planning studies deal, respectively, with the causes and the processes of decision-making |
| | Spatial scale | The scale chosen to suitably represent fishing processes that operate on local or national-regional extents |
| | Type of management approach | Technical and general aspects refer, respectively, to physical interactions between humans and the natural environmental, and the purely human dimension that co-ordinates the decision-making (Smith, 2002) |
| Temporal | Evolution of the fisheries management system | Five irregular historical phases from 1940 to 2009 regarding the development of the main policies involved in the Mexican fisheries management (Espinoza-Tenorio et al., 2010b) |
| Spatial | Official marine zonification | Exclusive Economic Zone divided in the four official Mexican fisheries regions |

[1] There is a lack of information about fundamental aspects of fisheries, such as the number of Mexican academics, the number of graduate students, and historical statistics about fisheries science students. Even specialized Mexican organizations, such as the National Association of Universities, Higher Education Institutions, and the National Researchers System, do not record such information about the academic research system.

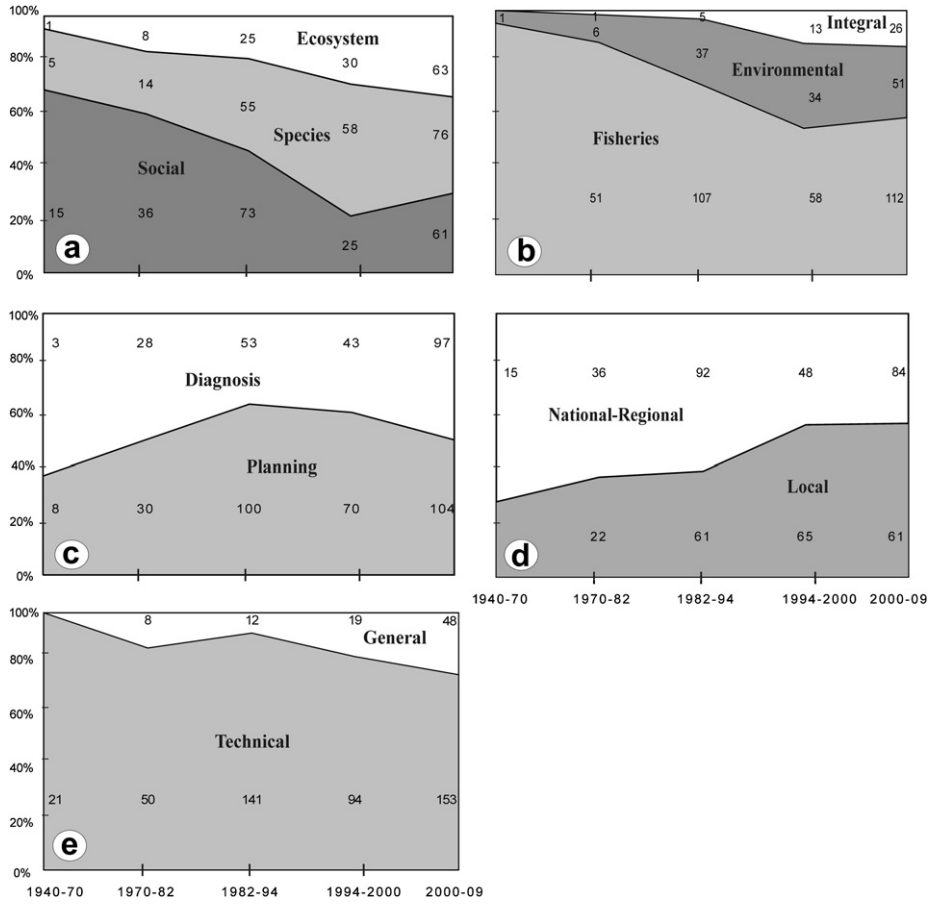


**Fig. 1.** Historical changes in the Mexican literature (theses and papers) concerning fisheries management research according to the proportions of the (a) research subject; (b) disciplinary approach; (c) methodological approach; (d) spatial scale; and (e) type of management approach. Temporal phases according to Espinoza-Tenorio et al. (2010b) (Sources: Libraries websites, Appendix A).

To describe the development of the academic and research system that supports fisheries management in Mexico, specialized literature, institutions, and postgraduate programs were examined in this study in a theoretical and spatio-temporal manner (Table 1). Specialized literature was identified through an electronic search of international online resources, Mexican websites, and libraries. Two types of publications were used: professional theses and journal articles. Because the thesis is still the main type of document produced during any degree program (diploma, bachelor's, master's, and PhD) in Mexico, this type of gray literature was used in two ways: first, to depict academic profiles of Mexican professionals involved in fisheries resource management, and second, to describe the type of domestic management knowledge generated by their thesis research. This study screened documents published between 1940 and 2009 from the websites of 21 major Mexican universities and research centers specializing in marine and coastal studies (Appendix A). Certain limitations of the study should be noted: (1) some scientists trained in Mexico may now be working in other countries while still publishing research about Mexican fisheries, and (2) research on Mexican fisheries by inhabitants of other countries still helps to build knowledge (and thus capacity) for Mexican fisheries management because the research publications are accessible to Mexican institutions.

Scientific journal articles were used as indicators of high-quality and multidisciplinary research on the management of aquatic resources in Mexico. The articles were obtained by searching the websites of national indexed journals from CONACyT and international academic databases such as SCIRUS and Google Scholar Beta. Keyword searches of titles and abstracts were used to identify relevant literature. The keywords used were "Mexico" (*México*) (with derivatives such as "Mexican") and "fisheries" (*pesquerías*), plus any of the following: "management" (*manejo*), "planning" (*planeación*), and "capacity building" (*construcción de capacidades*). To discriminate between domestic and international research, the origin of the research was identified using the author's institution. The articles selected for review must have at least one author at a Mexican institution.

The websites of the universities and research centers were used to track academic research institutions and postgraduate programs focusing on marine management. The institutions were divided into three categories: governmental (non-autonomous institutions supported by the federal government),[2] public (autonomous institutions that are basically supported by federal funds), and private (organizations that operate with international and domestic private funds).

For the spatial analysis, the National Institute for Fisheries zoning map was selected because it represents the official fisheries administrative arrangement and displays the major marine

[2] The term "governmental" was used because the name of the National Institute for Fisheries Research has changed several times since its creation. INIBP was its first name, but other acronyms like INP and INAPESCA have been used.

ecological and socioeconomic features (INAPESCA, 2009). The accumulated knowledge by region indicates the location of the academic and scientific institutions and their postgraduate programs, as well as the study area of each thesis and publication. In general, researches focus on their own local areas, but some may specialize in regions away from their own institutions. This can occur in areas near a border where research centers and universities coexist.

## 3. Results

The current Mexican CB effort can be understood through an analysis of the development of the fisheries management academic research system, from its inception in the mid-20th century to the beginning of the 21st century. According to our research (Espinoza-Tenorio et al., 2010b), this development can be divided into four early phases during which the academic and research foundation was constructed (1940–2000) and an additional recent period (2001–2009) in which national political changes resulted in significant institutional strengthening.

### 3.1. Academic and research basis

Before the 20th century, fishing in Mexico was limited to artisanal activities in the coastal zone and exploitation by foreign fleets on the open sea. These activities were studied and managed by the Secretary of Sea and War, two non-specialized academic institutions (*Instituto de Biología*, and *Escuela Nacional de Ciencias Biológicas*), and one specialized marine research center (*Estación de Biología Marina del Golfo*) (Cifuentes-Lemus and Cupul-Magaña, 2002). The basis for institutional fisheries research as we know it today was established in four later periods, described below.

#### 3.1.1. "Mexican miracle": fishery pre-development (1940–1970)

The fisheries system received a strong governmental impetus during this phase. However, it was not until 1962 that an academic research system for fisheries was founded through the creation of the first national institute of fisheries research, *Instituto Nacional de Investigaciones Biológicas Pesqueras*, and its 11 sub-stations, which provided official technical and scientific advice to the fisheries sector. Additionally, three public research centers, three universities, and the first private marine graduate school were established at major fishing ports (Fig. 3). Dominated by social studies on fishing subjects (Fig. 1a; b), the Mexican academic research system began to construct a fisheries administration system through general assessment (Fig. 1c) of commercialization, institutional organization, and human training. Political components, such as laws and national and regional agreements (Fig. 1d), were also important in encouraging the commercialization of high-value resources, such as sardines, yellowfin tuna, and shrimp. Recently graduated natural scientists conducted disciplinary studies of potential fisheries (technical aspects), albeit to a lesser extent than social researchers (Fig. 1e). The study of shrimp fisheries in the northern Mexican Pacific motivated the first collaborative research efforts with the U.S. in 1942. However, all research efforts remained focused on specific resources or geographic areas until 1969, when the first structured national research program supported by the Food and Agriculture Organization (FAO) was instituted (Cifuentes-Lemus and Cupul-Magaña, 2002).

#### 3.1.2. Rapid growth of fisheries and markets: institutional basis (1971–1982)

National fisheries research experienced a political boost after the establishment of a 200-mile Exclusive Economic Zone and a period of economic prosperity in Mexico in the 1970s (Alcalá, 2003; Soberanes, 1994). Consequently, the Secretary of Public Education and the newly created Mexican science foundation CONACyT (founded in 1970) led the decentralization of national research through the founding of seven public marine research centers, four state universities, and one federal technical institute (Fig. 2), most of them located along Mexico's northern Pacific coast (Fig. 3). Also at that time, that the first coordinated international research effort was promoted in the Gulf of Mexico (MEXUS–1977), and postgraduate studies in marine sciences were initiated with the funding of four programs.

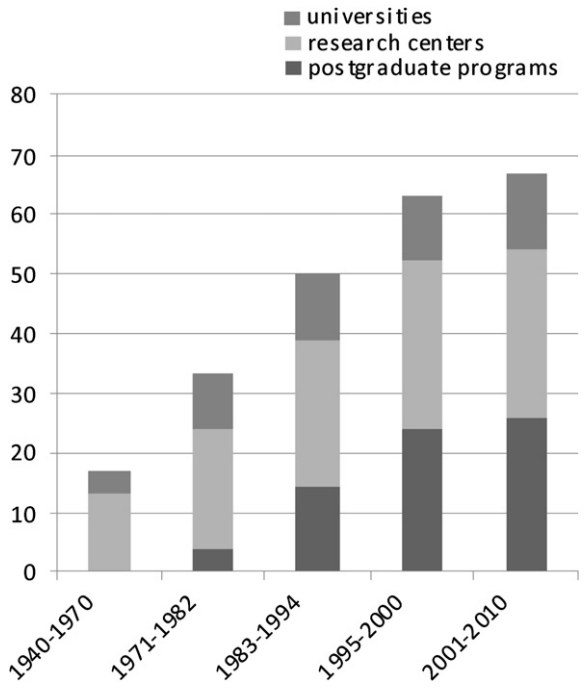


**Fig. 2.** Development of academic and research institutions destined for Mexican fisheries management research: (a) government and public research centers, (b) public universities, and (c) PhD and Master programs. (Sources: Cifuentes-Lemus et al., 1986; Cifuentes-Lemus and Cupul-Magaña, 2002; Libraries websites, Appendix A).

Research goals changed from encouraging fishing activity to regulating fishing activity, due to concern about the first evident impacts on marine ecosystems, such as oil spills and by catch caused by the industrial fleet. The social sciences, which continued to dominate the research arena, reorganized their research topics to incorporate studies on planning (Fig. 1c; d), including studies of institutional frameworks and the legal and economic aspects of fisheries management. With increasing participation of the natural sciences (Fig. 1a), management research became diversified (Fig. 1b) and expanded its efforts to include the systematic identification of new local fishery species (e.g., anchovy, shark, lobster, urchin) and studies investigating the decline of certain resources, such as sea turtles. Because of intense fishing activity in the late 1960s, the sea turtle became the first marine resource to be studied with the goal of integrated use.

#### 3.1.3. From prosperity to crisis: hands-off government (1983–1994)

During this phase, the academic and research system suffered severe administrative adjustments with no significant improvements because of multiple economic crises that limited the national budget (Guzmán-Amaya et al., 2008). Because of the economic

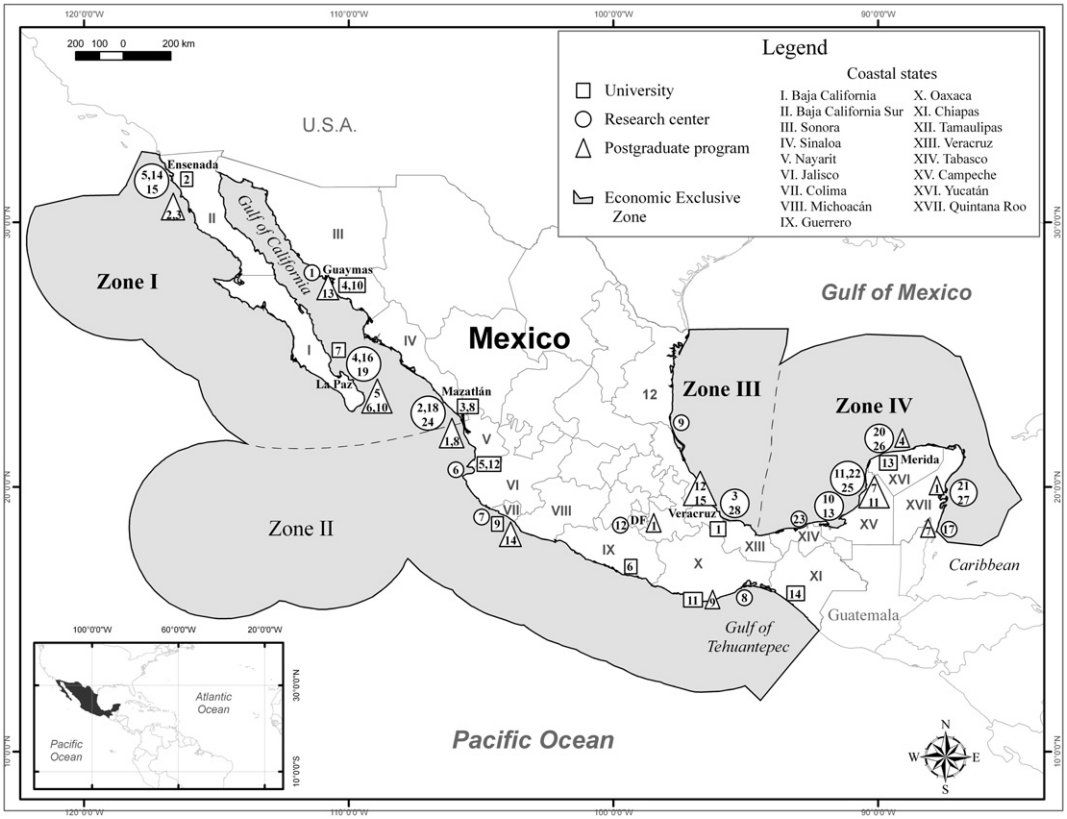


**Fig. 3.** Spatial distribution in Mexico of institutions destined for fisheries management research. The three types of institutions (government and public research centers—circle; universities—rectangle; and PhD and Master programs—triangle) were chronologically numbered: (a) *government and public research centers = Sub-stations of the INIBP, 1964–1970–current INAPESCA: (1) *Guaymas—before Instituto de Pesca del Pacífico, (2) *Mazatlán—before Estación de Biología Marina, (3) *Veracruz—before Estación de Biología Marina del Tecnológico de Veracruz, (4) *La Paz, (5) *Ensenada, (6) *Bahía Banderas, (7) *Manzanillo, (8) *Salina Cruz, (9) *Tampico, (10) *Ciudad del Carmen, (11) *Lerma; (12) Departamento de Ciencias del Mar y Limnología, DF, 1967–current ICMYL, and its (13) Sub-station Cd del Carmen-UNAM, 1970; (14) IIO-UABC, Ensenada, 1973; CONACYT centers: (15) CICESE, Ensenada, 1973, (16) CIBNOR, La Paz, 1975, (17) Centro de Investigaciones de Quintana Roo, 1979–current ECOSUR station Chetumal, (18) ICMYL Sub-station Mazatlán, 1971, (19) CICIMAR-IPN, La Paz, 1976, (20) CINVESTAV-IPN, Mérida, 1980; ICMYL Sub-station (21) Puerto Morelos, 1984; ECOSUR-CONACyT stations included artisanal fisheries research in 1994: (22) Campeche and (23) Villahermosa; (24) CIAD Mazatlán, 1993; (25) EPOMEX-UAC, Campeche, 1990; CRIP-INP: (26) *Yucalpetén and (27) *Puerto Morelos; (28) Unidad de Investigación de Ecología de Pesquerías-UV, 2000–current ICIMAP; (b) universities= (1) Estudios Superiores en Ciencia y Tecnología del Mar-SEP, Veracruz, 1958–current ITMar, (2) Facultad de Ciencias Marinas-UABC, Ensenada, 1960, (3) Escuela de Ciencias del Mar-UAS, Mazatlán, 1970; (4) Escuela de Ciencias Marítimas y Tecnología de Alimentos-TEC (private), Guaymas, 1967; (5) Escuela de Oceanografía-UAN, San Blas, 1970–current Facultad de Ingeniaría Pesquera; (6) Escuela Superior de Ecología Marina-UAG, Acapulco, 1972; (7) Departamento de Biología-UBCS, La Paz, 1976; (8) ITMar-SEP, Mazatlán, 1977; (9) Escuela Superior de Ciencias Marinas–UCol, Manzanillo, 1981; (10) ITMar-SEP, Guaymas, 1984–current Instituto Tecnológico de Guaymas; (11) UMar-Oaxaca state, Puerto Angel, 1992; (12) ITMar-SEP, Bahia Banderas, Nay, 1993–before an extension of ITMar-Mazatlán; (13) UMDI–UNAM, Sisal, 2004; (14) UNICACH-Chiapas state, Tonalá, 2009; and (c) PhD and Master programs= (1) ICMYL–1973; (2) CICESE–1980; (3) UABC–1990; (4) CINVESTAV–1990; (5) CICIMAR–1993; (6) CIBNOR–1994; (7) ECOSUR–1994; (8) CIAD–1995; (9) UMar–1996; (10) UABCS; (11) EPOMEX (Master); (12) ITMar, Veracruz (Master) and (13) Guaymas (Master); (14) UCol (Master); (15) and ICIMAP–2004. (Sources: Cifuentes-Lemus et al., 1986; Cifuentes-Lemus and Cupul-Magaña, 2002; Libraries websites, Appendix A).

climate, the previous research trends continued (Fig. 1), and the research topics were only expanded to include more local species such as clams and sailfish. The federal government halted the construction of new academic institutions and began to strengthen national research programs through the regional and administrative restructuring of four public research centers and three universities (Fig. 2), focusing on southern Mexico (Fig. 3). In addition to regulating the expansion of postgraduate programs (10), in 1984 the federal government implemented the National Researchers System to promote high-quality research through the publication of journal articles. The first two articles on economics and planning were published in 1983 in international (McGuirre, 1983) and Mexican (Fuentes, 1983) journals, and publications on ethnographic diversity in fishing communities (Alcalá, 1985, 1986; Bretón and López, 1989) and integrated management (De la Lanza, 1992) were also beginning to be published during this time. Moreover, domestic environmental research was boosted by the North American Free Trade Agreement in 1994 and by the awarding of the first non-governmental grant (*Fondo Mexicano para la Conservación de la Naturaleza*).

### 3.1.4. Adoption of the sustainable development approach (1995–2000)

During this phase, important administrative and legal adjustments were made to the fishery administration in an attempt to balance exploitation and conservation in light of international environmental commitments signed during the previous phase (Hernández and Kempton, 2003; Micheli, 2002). These adjustments to environmental research occurred mainly within postgraduate programs. The increase in specialized postgraduate programs (10) continued during this phase, and a new General Regulation of Postgraduate Studies (1996) gave more autonomy to existing programs and restructured, among other things, the faculties implementing postgraduate studies (e.g., the Program for Improvement of Faculty). Although no new universities were created within the country, three research centers were

**Table 2**
Fisheries management research literature in Mexico from 1940 to 2009 according to the management research subject.

| Research subject | | | Theses | Articles | Total |
|---|---|---|---|---|---|
| Biological | Species | Yellowfin tuna[a] | 32 | 5 | 37 |
| | | Marine turtles[b] | 34 | – | 34 |
| | | Shrimp[c] | 19 | 4 | 23 |
| | | Minor pelagics[d] | 12 | 2 | 14 |
| | | Abalone[e] | 12 | 1 | 13 |
| | | Elasmobranchs[f] | 11 | 4 | 15 |
| | | Urchin[g] | 7 | 2 | 9 |
| | | Lobster[h] | 5 | – | 5 |
| | | Billfishing[i] | 7 | 2 | 9 |
| | | Other fishes (≤5)[j] | 20 | 5 | 25 |
| | | Other mollusks (≤5)[k] | 11 | 4 | 15 |
| | | Other crustaceans (≤5)[l] | 2 | 1 | 3 |
| | | Incidental capture[m] | 12 | 1 | 13 |
| | | Others[n] | 3 | – | 3 |
| | | *Subtotal* | 187 | 31 | 218 |
| | Ecosystem | Coastal lagoon | 11 | 4 | 15 |
| | | Coastal zone | 9 | 6 | 15 |
| | | Bay | 11 | 1 | 12 |
| | | Gulf | 4 | 3 | 7 |
| | | Reef | 4 | 2 | 6 |
| | | Pelagic zone | 3 | – | 3 |
| | | Submareal | 2 | – | 2 |
| | | *Subtotal* | 44 | 16 | 60 |
| Social | Policy | Administration | 62 | 5 | 60 |
| | | Planning | 49 | 3 | 47 |
| | | Instrument | 40 | 5 | 34 |
| | | *Subtotal* | 151 | 15 | 166 |
| | Actors | Fishing | 44 | 7 | 51 |
| | | Other economic activities | 40 | – | 40 |
| | | Research | 2 | 3 | 5 |
| | | Government | 4 | 2 | 6 |
| | | *Subtotal* | 90 | 12 | 102 |
| | | Total | 472 | 74 | 546 |

(Sources: Libraries Websites, Appendix A).

[a] *Thunnus albacares*.

[b] Fishery until 1990, currently incidental capture or conservancy: *Lepidichelys olivacea*, *L. kempi*, *Chelonia mydas mydas*, *C. agassizi*, *Eretmochelys imbricata imbricate*, *Caretta caretta*, *Dermochelys coriacea schiegelli*.

[c] *Litopenaeus stylirostris*, *L. vannamei*, *Farfantepenaeus californiensis*, *F. aztecus*.

[d] Sardines–7 (*Sardinops cauruleus*, *Opisthonema libetate*, *O. bulleri*, *Cetengraulis mysticetus*), california anchovy–7 (*Engraulis mordax*).

[e] *Haliotis fulgens*, *H. corrugata*.

[f] e.g., *Carcharhinus falciformis*, *C. limbatus*, *Sphyrna lewini*, *Prionace glauca*, *Rhinoptera steindachneri*.

[g] *Strongylocentrotus franciscanus*, *S. purpuratus*.

[h] *Panulirus interruptus*, *P. argus*.

[i] *Xiphias gladius*, *Istiophorus albicans*.

[j] e.g., *Lutjanus* spp, *Katsuwonus pelamis*, *Micropogonias megalops*, *Cynoscion Othonopterus*, *Epinephelus morio*, *Scomberomorus concolor*, *Totoaba macdonaldi*.

[k] Sea snail–5 (*Strombus gigas*, *Astrea undosa*, *Hexaples nigritus*, *Plicopurpura pansa*), octopus–3 (*Octopus* spp), clams–2 (*Argopecten circularis*, *Tivela stultorum*), oysters–1 (*Crassostrea* spp), jumbo squid–2 (*Dosidicus gigas*), unspecified–3.

[l] Blue crab–2 (*Callinectes* spp), arched box crab–1 (*Calappa convexa*).

[m] Mammalian fauna–8 (*Eschrichtius robustus*, *Zalophus Californianus*; *Tursiops truncatus*), fishes–4 (*Coryphanena* spp; *Calamus pennatula*), seastar–1 (*Pisaster ochraceus*).

[n] sea cucumber–3 (*Parastichopus parvimensis*, *Isostichopus fuscus*).

established in southern Mexico (Fig. 3). Thus, academic research institutions trained groups of scientists to increase studies on planning strategies (Fig. 1e), and interdisciplinary approaches began to garner more attention (Fig. 1b). Studies on protected areas, management plans, and ecological ordinances for local resources and ecosystems become more common (Fig. 1a; d), as did studies on protected species, such as marine mammals and sea turtles. Moreover, in specific regions such as the Gulf of California, private research was consolidated by international conservation agencies, including Pro Natura and Conservation International.

### 3.2. Capacity building to face the 21st century

Over the course of 47 years (1962–2009), knowledge about the management of intensive fisheries within Mexico was represented by a total of 472 theses and 74 journal articles. Much of the knowledge on management objectives has been gathered about species that are within exclusively industrial fisheries, such as yellowfin tuna and minor pelagics, or that are shared with the artisanal fleet, such as shrimp and elasmobranchs (Table 2). However, benthic artisanal fisheries have also been the subject of a significant number of studies. The largest number of ecosystem studies focus on coastal systems, such as lagoons and bays. In the realm of social research, much of the studies focus on technical aspects of fishery policies, such as administration, planning, and instruments used. Studies on industrial, artisanal, and recreational fishing and economic sectors, such as the petrochemical industry, tourism, and urban development, are also represented. At the beginning of the 21st century, researchers focused again on fisheries assessment (Fig. 1c). However, in contrast to the studies conducted 30 years ago, more diversified approaches are now being used (Fig. 1a), mainly on local research subjects (Fig. 1d).

Much of the research on types of management (Table 3) has focused on technical management, such as environmental monitoring of resources and ecosystems, and on the information technology concerned with the creation, analysis, and use of databases. To a lesser extent, scientific activities in academic fields are primarily focused on the topics of society (e.g., the types of fishing cooperatives), technology (e.g., production systems engineering), law (e.g., legal aspects of marine conservation), and planning (e.g., environmental education). General management issues have been the least studied, although these studies are

**Table 3**
Fisheries management research literature in Mexico from 1940 to 2009 according to different types of marine management approaches (following Smith, 2002).

| | | | Theses | Articles | Total |
|---|---|---|---|---|---|
| Technical | Information management | Environmental monitoring | 101 | 20 | 124 |
| | | Information technology | 93 | 6 | 100 |
| | | Surveillance of uses | 12 | 5 | 15 |
| | Information assessment | Social | 36 | 5 | 45 |
| | | Technology | 35 | 1 | 38 |
| | | Environment | 27 | – | 27 |
| | | Economic | 26 | 1 | 27 |
| | | Risk | – | 1 | 1 |
| | Professional practice | Law | 45 | 1 | 45 |
| | | Planning | 28 | 9 | 35 |
| | | Surveying | 4 | – | 4 |
| | | Natural/social sciences | 2 | – | 2 |
| | | Accounting | 1 | – | 1 |
| | | Engineering | – | – | – |
| | | *Subtotal* | 410 | 49 | 459 |
| General | Technical management coordination | | 35 | 13 | 48 |
| | Strategic planning | | 15 | 5 | 20 |
| | Policy | | 7 | 5 | 12 |
| | Organization management | | 5 | 2 | 7 |
| | | *Subtotal* | 62 | 25 | 87 |
| | | Total | 472 | 74 | 546 |

(Sources: Libraries Websites, Appendix A).

increasing (Fig. 1e). This general type of management approach has been the focus of studies on decision-making and technical coordination, such as biological research programs, management plans, and ecological ordinances. Policy and planning matters have also been studied, for example, through the design of management scenarios and the evaluation and recommendations of policies. Studies on the nature of management organizations were rarely mentioned.

High-quality research on fisheries management has been published in four national and 18 international journals. The 47 publications on biological research subjects are distributed across 14 natural science journals, including *Ciencias Marinas* (27), *Hidrobiológica* (4), Fisheries Research (4), Ecological Modeling (2) and 10 other journals with one publication in each. Fewer social science articles (27) were published in eight journals. Disciplinary social science publications (5) were limited to international journals, such as Maritime Anthropological Studies and Human Organization. Most of the articles on social research subjects (22) were distributed in six interdisciplinary, international journals, with Ocean and Coastal Management alone featuring 15 articles. Only four papers were published in two interdisciplinary, national journals (*Investigaciones Geográficas* and *Universidad y Ciencia*). Moreover, 80% of the articles were produced in Mexican institutes. The remaining articles were mainly produced at locations in the Gulf of California by USA universities (16.2%), the names of their authors indicating either an USA (67%) or Mexican (33%) origin. Of the articles "made in Mexico," 45% were from personnel at CONACyT public centers such as CICESE and CIBNOR, 36% were from researchers at universities such as UNAM and UABC, 18% from government centers mainly localized in La Paz and Mazatlan, and 1% from employees of NGOs such as The Nature Conservancy.

In general, theses and papers share a similar thematic focus, although there are important differences. One difference involves the research scale. The majority of journal articles (66%) covered topics of national or regional interest, whereas theses demonstrated a more balanced distribution of scales (local = 52%; regional/national = 48%). Journal articles demonstrated more of a balance between general (51%) and technical (49%) approaches than did theses, which had fewer studies on general management (15%). Moreover, multidisciplinary and integral management approaches are most often published in recent international papers concerning the economic valuation of resources (Avila et al., 2009), integrated management tools (Yañez-Arancibia and Day, 2004; Ortiz-Lozano et al., 2005), and interdisciplinary research (Espejel et al., 2005). Because sea turtle hunting was permanently prohibited by the federal government in 1990, theses concerning turtles as a fishery resource were published only before that year. The most recent papers, in contrast, focused exclusively on sea turtle conservation issues.

For the management of fisheries, national CB in terms of research and education infrastructure consists of 42 specialized institutions, plus ten organizations that handle fisheries management only occasionally. None of these institutes are social research institutions that specialize in fisheries. Many of them manage natural sciences and are composed of public (15) or government (13) research centers, not private ones. Only fourteen of the institutions are state (8), federal (5), or private (1) universities. Twenty-six postgraduate programs are in place, most often within public research centers (Fig. 3).

#### 3.2.1. Spatial trends

As Fig. 3 shows, Mexican CB has an irregular spatial distribution. One spatial trend is the concentration of mostly academic and research institutions emerged in 1970s and single-species biological approaches around the Gulf of California. In contrast, anthropological and interdisciplinary studies have concentrated mostly on local fishing in southern Mexico, where many of the research institutes were constructed in the 1990s. The Mexico's Pacific Ocean dominates in regional capacity. Much of the research and educational institutions (25) and postgraduate programs (13) exist on the Pacific coast, and 78% of the published literature focuses on Pacific marine ecosystems. However, with 16 institutions concentrated in four cities (Mazatlán, La Paz, Guaymas, and Ensenada), it is the North Pacific (Zone I) that features 51% of all literature on artisanal and industrial fishery planning for minor pelagics, abalone, jumbo squid, and shrimp. Protected marine species such as gray whale (*Eschrichtius robustus*), the Gulf of California harbor porpoise (*Phocoena sinus*), and the California sea lion (*Zalophus californianus*), as well as environmental education and the conservation of marine protected areas, are popular subjects in Zone I.

The Central and South Pacific (Zone II) share marine resources with Zone I, such as shrimp, yellowfin tuna and sailfish, as well as environmental impacts, such as the deterioration of coastal lagoons. Zone II is the largest and most socially diverse region in Mexico (Seingier et al., 2011a,b). Nevertheless, only 13% of the fisheries management research publications originated in this area. This research has mainly been led by non-local institutions because, without the large public research centers found in other zones, the research infrastructure in Zone II is restricted to nine institutes and three recently established postgraduate programs. The main research focus in this zone is coastal resources, such as lobster and urchin, and the conservation of sea turtles. Ecosystem approaches have been marginally applied in specific protected areas or in coastal lagoon systems.

Zones III and IV share a focus on shrimp fisheries and the environmental impacts of shrimp trawling, oil spills, and tourism. Zone III, situated on the northern side of the Gulf of Mexico, currently averages the smallest number of published studies (5%) on domestic fisheries management and the smallest number of academic research institutions (4). Like Zone II, the Gulf of Mexico has three new postgraduate programs. The resources studied in Zone III include species associated with estuaries, such as fishes and crabs, whereas environmental research has been focused on endemic sea turtles, such as Kemp's Ridley sea turtle (*Lepidochelys kempi*), and the implementation of MPAs. Unlike Zone III, the southern Gulf of Mexico and the Caribbean (Zone IV) are the source of the largest number of diversified studies on marine animal populations, such as sea turtles, sea snails, red grouper, octopus, and mackerel. Zone IV features five postgraduate programs and 12 research institutions, two of which are multidisciplinary research centers (EPOMEX and UMDI-Sisal).

## 4. Discussion

Some of the relevant theoretical frameworks are still being developed (Garcia et al., 2003), but it is known that improving sustainable management in Mexico requires addressing scientific management capacities, which may be summarized according to the theoretical, temporal, and spatial outputs from this study in three key points: (1) the type of management knowledge needed, (2) updating capacity building, and (3) regional capabilities.

### 4.1. The type of management knowledge needed

The first key point, the type of management knowledge needed to improve sustainable management in Mexico, is critical because sustainable fisheries management requires the integration of

georeferenced ecological, environmental, and socioeconomic information not limited to that which has direct commercial importance (Smith, 2002). However, as in many other developing countries (Bailey and Jentoft, 1990), this knowledge is insufficiently generated in Mexico. Although current fishery studies include a better balance of social and natural research subjects (Fig. 1a), diagnosis and planning methodological approaches (Fig. 1c), and local/regional/national spatial scales (Fig. 1d), Mexican CB in fisheries management has continued to be restricted to generating and analyzing sectoral information on either a single species (Fig. 1b; Table 2) or the physical interactions between humans and the natural environmental (Fig. 1e; Table 3). This lack of information occurs because the federal government continues to favor research on the management of species that are economically important or protected (Csirke et al., 2005) rather than research on ecosystems and their interactions with social and economic processes. There is also a lack of support for research on human coordination for decision-making (Espinoza-Tenorio and Espejel, in press). Consequently, only a small number of studies consider management tools according to the current management situation and national context. Mexico is thus adopting international methodologies to process data needed for sustainable fisheries management (e.g., mass-balanced models, spatial multi-species models) without a robust academic discussion about how these tools may need to be adjusted before being applied to local situations.

To generate the knowledge needed for sustainable fisheries management in Mexico, research policies need to consider the availability of knowledge. Environmental research needs to increase the understanding of ecosystems and social processes, even for topics that have received a significant amount of attention, such as the Gulf of California, or species of high commercial or conservation priority such as yellowfin tuna or sea turtles (Table 2). In those regions where increasing the breadth of information is a priority (e.g., Central and South Pacific), we recommend continuing studies to explore viable management methods that are appropriate for local circumstances. For example, some new transdisciplinary studies are showing how local and traditional ecological knowledge can be useful to aid decision-making in fishing areas where people interact daily with ecosystems for their livelihood (Sáenz-Arroyo et al., 2005; Espinoza-Tenorio et al., 2010c; Moreno-Baez et al., 2010). On a national scale, recent initiatives such as the Mexican Fisheries Society (SMP, 2005) and the National Network for the Integrated Management of the Coastal Zone (Rivera-Arriaga, 2009) are also suggested to improve the accessibility of data and identify knowledge gaps through academic networks and shared databases.

### 4.2. Updating capacity building

Having discussed the types of management knowledge needed in order for Mexico to improve its sustainable management of fisheries resources, we now proceed to the second key point: updating capacity building.

With the help of academic and research institutions capable of leading independent and interdisciplinary research, a new generation of academics and scientists needs to be trained as generalists with interdisciplinary knowledge of complex multisectoral problems (Chircop, 1996; Smith, 2002). This scientific renovation is an enormous challenge for Mexico.

The academic system is so new that the third generation of professionals, formed in the 1980s and favoring single-species studies, is still dominant. The oldest centers of research activity, a relic of the popular research scheme adopted in 1970s, continue to present species-specific studies, and there are few interdisciplinary research centers emphasizing social research (EPOMEX, UMDI–Sisal, and UNICACH–Tonalá). The fourth generation of professionals is emerging (129 degree students in 2003) (ANUIES, 2003), but the antiquated academic arena has hindered training in sustainable approaches, and this material may not be encountered by a student unless enrolled in a new non-traditional postgraduate program. In addition, the National Researchers System, which manages the promotion of scientists, has a weak interdisciplinary agenda. For instance, sustainable development and risk analysis are “disciplines” evaluated by committees of pure social scientists; fisheries research areas are evaluated in a committee named “biotechnology and agro-science”.

Consequently, universities and research centers lack the space and economic support needed to foster a new generation of scientists, thus precluding research that uses a modern sustainable approach. The lack of government interest in research performed during previous phases (from 1982 to the present) has also limited the government institutions, where most fisheries researchers have served for many years (many are almost 65 years old and have 23 years of job experience) and the percentage of postgraduate personnel is very low (PhD = 5% and master’s = 29%) (Csirke et al., 2005). Fig. 2 illustrates the Guzmán-Amaya et al. (2008) characterization that interest in fisheries has been gradually abandoned by the federal government. Research centers and university programs did not increase in the past decade, in contrast to postgraduate programs. One explanation could be that that there are already enough centers and universities, but this raises the question of where all of the newly trained professionals will work. Replacement of retirees is not sufficient to employ all of the students that are being trained now.

To facilitate the communication of results and to foster national research discussions, the National Researchers System renovated its evaluation system in the 1990s following a bibliometric analysis of papers published in mainstream indexed journals. However, the lack of high-quality publications continues to be a national concern. According to CONACYT (2008), Mexican authors accounted for 0.77% of worldwide scientific articles during the period of 2003–2007, whereas the USA represented 32.65%, Spain 3.32%, and India 2.75%. Brazil was the highest-ranking Latin American country, representing 1.8% of total articles. Our bibliographic review found only 74 papers published since 1983, or 1.6 per year, showing that the lack of publication is especially critical in the case of fisheries management research. The majority of publications (45%) came from public centers, whereas only one of the smaller contributions came from a government center, though government centers have most of the fisheries information. This publication discrepancy between institutes was also mentioned by Csirke et al. (2005), who found that the National Fisheries Institute averages only 0.21 (indexed) and 0.37 (non-indexed) publications per year despite employing 189 researchers and 167 technicians in the largest network of research centers (13). This rate is slower than some smaller public centers, such as CICESE (0.12 and 0.77) and CIBNOR (2.25 and 0.98).

The lack of publications on sustainable fisheries management is likely caused by the lack of updated Mexican fishery journals. Few Mexican journals are interested in publishing interdisciplinary studies, and those that are interested (e.g., *Investigacion ambiental*, *Politica y Ciencia*) are not considered to be high-quality journals by CONACyT standards and are therefore omitted from its national index. The fact that it is an international journal (Ocean and Coastal Management) that is publishing most of the interdisciplinary articles indicates the lack of a domestic high-quality debate on sustainable fisheries management. The National Researchers System further underrates the importance of most local studies by

ignoring unpublished technical reports and non-scientific academic contributions to management research, both of which are methods currently used by local stakeholders. Certainly, many graduate students have produced simple but important theses, thus contributing to the increasing amount of ecosystem knowledge (Fig. 1a).

Another way to balance natural and social science research and interdisciplinary management is to integrate holistic approaches into postgraduate programs (Smith, 2002). In Mexico, most of the twenty-six programs in fisheries management are preparing to include interdisciplinary concepts in courses, and the most recent programs have been designed with these new research paradigms in mind (Espejel et al., 2005). Most of these programs are considered to be consolidated by the federal government, and the access to public funding is contingent on the program meeting criteria for faculty, students, institutional facilities, and research outcomes, such as student participation in projects and faculty productivity (CONACYT, 2009). In 2004, specialized postgraduate programs received 237 new students, of which 201 graduated. Of these, 77% were master's students, and 23% were PhDs (ANUIES, 2003). Alternately, university-based short-term courses are being offered in several Mexican towns (Jalapa, Veracruz; Melaque, Jalisco) at varying levels (e.g., graduate, undergraduate) (INECOL, 2007; DEDSZC, 2008). These courses cater to a variety of participants, such as resource users, students, and stakeholders.

### 4.3. Regional capabilities

The third key discussion point, regional capabilities for the support of sustainable approaches, helps to show how Mexican CB varies geographically. Major capacities are found in the North Pacific and in the southern Gulf of Mexico. The North Pacific has received significant academic attention because of its importance for domestic fisheries, its proximity to U.S. research institutes (e.g., University of Arizona, SCRIPPS) and its focus on international conservation. Actually, some social research papers come from Arizona and Colorado researchers working on social communities in the Gulf of California (McGuirre, 1983, 1991; McGoodwin, 1987, 1989).

The North Pacific zone contains the states with the highest average number of scientists; Baja California Sur has an average of 1.4/10,000 inhabitants, which is almost twice the national ratio (0.67/10,000 inhabitants) (Cariño-Olvera et al., 2004). Furthermore, the majority of postgraduate students (237 in 2004) is received in Zone I (ANUIES, 2003). In this way, although Mexico's northern Pacific states continue to primarily produce species-specific studies, these states are a center of regionalization enforcement, assuming regional cooperation between government and academic research institutes and non-governmental coalitions (Ezcurra et al., 2009).

The southern Gulf of Mexico and the Caribbean have CB efforts that emphasize marine conservation issues more strongly because these regions contain the most important coral reefs in Mexico (Rivera-Arriaga and Villalobos, 2001). Important collaborations exist between Mexican institutions in these regions and the Universities of Miami and Texas, and this is the area where more interdisciplinary research is being conducted. The newly-established UMDI–Sisal is also the sole university in Zone IV, making it appealing to specialized graduate students.

Zones II and III include the greatest number of states, some of which are also the poorest states in the country (Veracruz, Tabasco, Guerrero, Oaxaca, and Chiapas) (Seingier et al., 2011a,b). Artisanal fisheries in these regions help to alleviate local poverty (Alcalá, 1985, 1986; Espinoza-Tenorio et al., 2010a). Their economic instability has limited the development of a robust CB process in this zone, and only 18% of the fisheries management research publications have originated in these areas. This finding is likely related to the small number of underfunded, isolated academic research institutions (13), notwithstanding Veracruz's status as a pioneer in research and publications on fishery resources. Both zones have a mere six new postgraduate programs, none of which graduated students until 2003 (ANUIES, 2003). Although a considerable number of regionalization studies have been conducted in this zone (Yañez-Arancibia et al., 1999; Yañez-Arancibia and Day, 2004), few collaborative efforts have been conducted.

## 5. Conclusions

Mexican CB can help to promote more sustainable fisheries management strategies. The historical analysis of specialized literature, institutions, and postgraduate programs undertaken in this study reveals that fisheries management capabilities are increasingly supporting research topics related to advancing sustainable development. Thus, a new generation of scientists and institutions is emerging that makes use of interdisciplinary approaches to encourage collaboration and to refine research priorities to consider interactions between humans and the natural environment. Retrospective analysis reveals that the development of the Mexican academic and research system for fisheries management has been tumultuous under varying political and economic priorities within the government. After 47 years of managing with various resource management policies, much of the knowledge accumulated in this system centers on commercial resources, and the renovation of the system itself is incomplete and geographically inconsistent. Because of these shortcomings, the domestic CB process continues to support a management system based on single-species evaluations. This is not a pessimistic but a realistic statement; the issue is a global one. Nevertheless, Mexican CB for fisheries management is being updated, albeit gradually.

Whereas the priority in previous decades was to build a basic understanding of Mexican fisheries, the current challenge is to update the academic and research system while taking into account national and regional priorities. Therefore, to update this system and to generate additional research projects, the federal government must reconsider its role in designing medium- and long-term research strategies. Only in this way can the Mexican academic and research system reduce its vulnerability to changes in official fishery policies and effectively assist in sustainable fisheries management through capacity building. For instance, we suggest that the federal government meet the nation's research needs by updating the information at numerous research centers and selecting indicators, such as the one utilized in this study, for fundamental research on fisheries. This information could be stored in a database for use in the analysis of fisheries management strategies.

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## Appendix A

Library websites of the main Mexican Universities and Research Centers of natural and social sciences specialized in marine and coastal studies; Mexican marine indexed journals; and academic international Web-searchers. Date of consult, June to December of 2009.

| *Universities* | URL: |
|---|---|
| Instituto Politécnico Nacional (IPN) | http://azul.bnct.ipn.mx/tesis/index.php |
| Universidad Autónoma de Baja California (UABC) | http://sia.mxl.uabc.mx |
| Universidad Autónoma de Baja California Sur (UABCS) | http://altair.uabcs.mx/Altair/buscador/opac.asp? |
| Universidad Autónoma de Campeche (UAC) | http://www.uacam.mx/bib.nsf/pages/basesdatos |
| Universidad Autónoma de Nuevo León (UANL) | http://www.codice.uanl.mx/wfrmPalabraClave.aspx |
| Universidad de Sonora (USON) | http://www.biblioteca.uson.mx/ |
| Universidad Autónoma de Sinaloa (UAS) | http://148.227.21.3/tesis |
| Universidad Autónoma Metropolitana (UAM) | http://tesiuami.izt.uam.mx/uam/default2.php |
| Universidad del Mar (UMar) | http://bibliotecas.umar.mx/Principla/catalogo.html |
| Universidad Nacional Autónoma de México (UNAM) | http://132.248.67.65:8991/F/-/?func=find-b-0&local_base=TES01 |
| Universidad de Sonora (UNISON) | http://www.biblioteca.uson.mx/digital/tesis/dig_TesisWeb.asp |
| *Research Centers* | |
| Centro Interdisciplinario de Ciencias Marinas (CICIMAR), IPN | http://www.biblioteca.cicimar.ipn.mx |
| Centro de Investigaciones Biológicas del Noroeste (CIBNOR) | http://www.cibnor.mx/cgi/eacerv.cgi |
| Centro de Investigaciones y Estudios Superiores en Antropología Social (CIESAS) | http://www.ciesas.edu.mx |
| Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE) | http://biblioteca.cicese.mx |
| Centro de Investigación en Alimentación y Desarrollo (CIAD) | http://www.ciad.mx/biblioteca/ |
| Colegio de la Frontera Norte (COLEF) | http://www.colef.mx |
| Colegio de México | http://www.colmex.mx |
| Colegio de la Frontera Sur (ECOSUR) | http://www.ecosur.mx/sibe |
| Colegio de Michoacán (ColMich) | http://www.colmich.edu.mx |
| Colegio de Sonora (ColSon) | http://aleph.colson.edu.mx:8991/F/-/?func=find-b-0&local_base=SON01 |
| *Mexican marine indexed journals* | |
| Hidrobiológica | http://148.206.53.230/revistasuam/hidrobiologica |
| Ciencias del Mar | http://www.cienciasmarinas.com/index.php/cmarinas/issue/current |
| Investigaciones Geográficas | http://www.igeograf.unam.mx/instituto/publicaciones/invest_geog.html |
| Universidad y ciencia | http://www.ujat.mx/publicaciones/uciencia/ |
| *International web-searchers* | |
| SCIRUS | http://www.scirus.com/srsapp |
| Google scholar Beta | http://scholar.google.com |
| *Federal founds to research projects* | www.conacyt.fondos |

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