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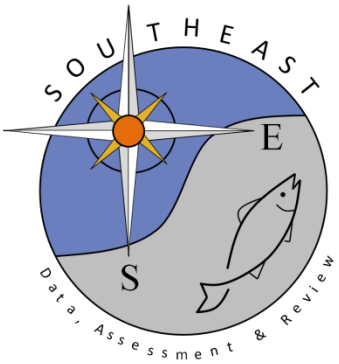

10. Coastal fisheries of Mexico

José Ignacio Fernández*, Porfirio Álvarez-Torres, Francisco Arreguín-Sánchez, Luís G. López-Lemus, Germán Ponce, Antonio Díaz-de-León, Enrique Arcos-Huitrón and Pablo del Monte-Luna

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1. INTRODUCTION

Small-scale fisheries in Mexico account for about 97% of the marine fleet. These fisheries cover about 70% of the continental shelf, which accounts for 10% of the exclusive economic zone (EEZ), and occur scattered along both coastal regions: the Pacific Ocean, and the Gulf of Mexico and the Caribbean (Figure 1). In this chapter, we first present an overview of the Mexican marine fisheries, emphasizing the most important small-scale fisheries in each region, and providing more detailed information when available. We refer to coastal, small-scale or artisanal fisheries as those that generate products for local consumption and marketing, use small-scale boats that operate with low capital investment, are labour intensive with limited autonomy and capacity, and usually undertake daily fishing trips. Other fisheries (midscale and industrial) are referred to when applicable.

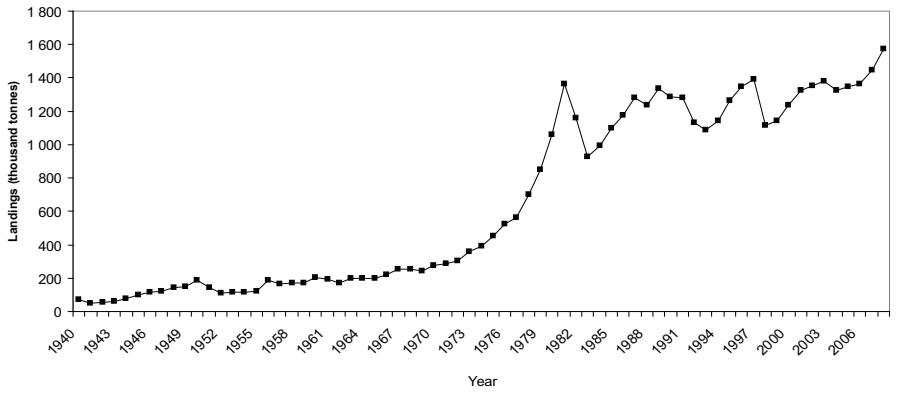
FIGURE 1
Map of the coastal area in Mexico surrounded by waters from the Pacific Ocean, Gulf of Mexico and the Caribbean Sea

Source: Beltrán-Turriago, 2007.

Total annual catch in Mexico has fluctuated in the last three decades around 1.3 million tonnes (Figure 2). Different governmental programmes provided the incentive for the development of the fisheries between the 1970s and the 1980s,

especially by improving technology and increasing fishing effort (Salas *et al*., 2007); more recently, catches range around 1 million tonnes (Figure 2).

FIGURE 2
Landing trends from 1950 to 2003 in Mexico



Source: CONAPESCA, 2002.

The development of Mexican fisheries has been different between regions, as landings from the Pacific contribute the most to the total national catch (77%), compared with those from the Gulf of Mexico (21%) and the Caribbean region (2%) (CONAPESCA, 2002). However, the Gulf of Mexico and the Caribbean region play an important role in terms of catch value and job generation. In these areas, a high proportion of total catch comes from the artisanal (small-scale) fleet that targets highly profitable species; other proportions of the landings come from multispecies fisheries that are mainly seasonal.

Landings from the Pacific have fluctuated more over the last two decades than those from the Gulf of Mexico/Caribbean region (Figure 3). This occurred mostly during the early 1990s when El Niño-southern Oscillation (ENSO) events caused declines in abundant sardine stocks. Catches in the Gulf of Mexico and the Caribbean Sea peaked by 1993–1994, the shrimp and the octopus fisheries contributing the most to the overall catch.

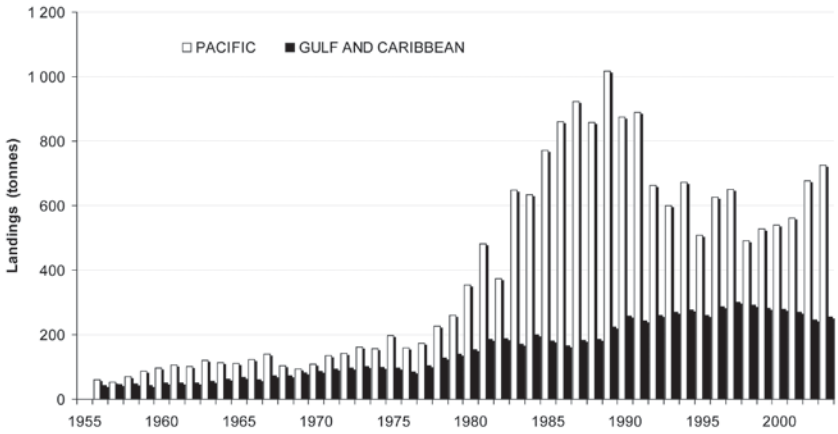
2. DESCRIPTION OF FISHERIES AND FISHING ACTIVITIES

Small-scale coastal fisheries can be described in terms of the catch of a variety of target species, plus several incidental species. Target species comprise 28% of the catches in the Gulf of Mexico and the Caribbean, as registered in statistical yeardocuments. Although subsistence fisheries are widespread, most artisanal fisheries can be characterized as small- to medium-scale commercial, since a significant fraction of the catch is sold to local markets or to middlemen for both domestic and overseas markets.

According to statistical yeardocuments (CONAPESCA, 2001), there are 56 412 small artisanal vessels in the Pacific shores: 1 609 in Baja California;

3 633 in Baja California Sur; 7 234 in Sonora; 11 828 in Sinaloa; 4 442 in Nayarit; 2 938 in Jalisco; 791 in Colima; 5 171 in Michoacán; 4 744 in Guerrero; 5 090 in Oaxaca; and 8 932 in Chiapas.

FIGURE 3
Landing trends from the Pacific Ocean and Gulf of Mexico and Caribbean Sea of main species targeted by coastal fleet in Mexico



Source: SEMARNAP, 2004.

On the other hand, there are 43 392 small artisanal vessels in the Gulf of Mexico and Caribbean shores: 6 662 in Tamaulipas; 15 898 in Veracruz; 9 601 in Tabasco; 5 362 in Campeche; 4 981 in Yucatán; and 888 in Quintana Roo (CONAPESCA, 2001).

Despite the differences in small-scale fisheries on both coasts, the per capita investment in fishing gear and boat equipment is generally low in both cases, compared with semi-industrial fleets. However, fishing technology has been improved during the past two or three decades as increases in both boat motorization and the use of more efficient fishing gears have occurred. These changes are the result of investments applied in these fisheries in Mexico, similar to investments in technology that have occurred in many other countries in Latin America and the Caribbean during the same period (Salas *et al*., 2007). Regardless of these improvements, productivity has not increased accordingly, since near-shore fishery resources are fully exploited, overexploited (Díaz de León *et al*., 2004) or fished down (Salas *et al*., 2004). Increasing fish demand and marketing of fish products has led to an excess of fishing capacity, resource depletion, waste of economic and human resources, and poor returns on investments. In addition, fishers have been faced with increases in frequency and intensity of natural phenomena in coastal areas such as hurricanes, tropical storms and red tides, which have impacted the resources and limited their fishing operations, thus affecting fishers' profits (Díaz de León *et al*., 2004; Salas *et al*., 2006).

2.1 Fisheries technology

Mexican artisanal fisheries vary in their degree of technology. The simpler side has fishers operating from the shore or from propelled wooden canoes using cast nets or beach seines. However, most fishing vessels are made of fibreglass and are 6 to 10 m long. In some regions, the outboard-powered small vessels are called *panga*.

Some fisheries, like the shrimp fishery that operates in coastal waters, use fixed gears which block migrations to the sea (*tapos*) and use small vessels to load the catches and take them to shore. In Tamaulipas and Veracruz, fishers use small vessels and 'V' shaped fixed nets (*charangas*) and they store the catch until it is taken to shore.

In some cases, such as the octopus-grouper fishery in Yucatán and the lobster fishery, several fleets of varying size and capacity target the same species. The larger vessels generally use fishing methods and gears which incorporate the same level of mechanical support for extraction, such as winches for grouper or traps for lobster. These vessels have the ability to expand their operations to deeper areas, usually targeting species of larger size, or other species like octopus. These fisheries can be sequential, as different types of vessels operated by different stakeholders target various life stages of the exploited populations, resulting in social interactions that are not always explicitly considered in management. Even though it is generally forbidden by regulations, diving is also a common fishing method in the Gulf of Mexico and the Caribbean, targeting species like lobster, conch and octopus.

2.2 Gulf of Mexico and Caribbean fisheries

A variety of species are targeted in the Gulf of Mexico and the Caribbean. However, only a dozen of them represent the highest contribution in volume and profit; other species are caught incidentally or in a complementary manner. A summary of the characteristics of the vessels used, as well as the usual crew employed by the fleet that undertake fishing operations in the Gulf of Mexico and the Caribbean region, are presented in Table 1. Appendix I presents a complete list of species targeted in the area.

One of the most important fisheries in the Gulf of Mexico targets grouper and related species. The demersal species associated with reef areas (Veracruz) and rocky areas (Yucatán) are usually reported in a group called *escama*. This situation can obscure the organization of catch records and the assessment of stocks, further complicating the implementation of management strategies that properly regulate the effort allocated to different stocks. The demersal fishes included in the '*escama*' group include the following: groupers (*Epinephelus flavolimbatus, E. morio, E. itajara, E. adscencionis, E. drummondhayi, E. nigritus, Mycteroperca bonaci, M. microlepis, M. venenosa, M. interstitialis*); snappers (*Lutjanus bucanella, L. vivanus, L. synagris, L. analis, L. griseus, L. jocu, Ocyurus chrysurus, Rhomboplites aurorubens*), porgies (*Calamus bajonado*); grunts (*Haemulon plumieri*); banded rudderfish (*Seriola zonata*); hogfish (*Lachnolaimus maximus*); and tilefish (*Lopholatilus chamaeleonticeps*) (Monroy *et al*., 2000a). At certain locations in the Gulf of Mexico, between 35% and 70% of the total catch of *escama* is made up of the red grouper (*E. morio*).

TABLE 1
Summary of characteristics of boats and gears employed in the fisheries that operate in the Gulf of Mexico and the Caribbean region

Species	Type and size of gear	Type and size of boat	Number of boats	Average crew size
Octopus	*Alijos* (small boats) carrying *jimbas* (wooden stick with several lines and baits)	3–4 m long, fibreglass boat, carried by a 7–9 m long boat with outboard engine (15–75 hp) or by a 12–22 m long vessel acting as mother ship for the *alijos*. Around 10 *alijos* for mid-size vessels and 2 *alijos* for small vessels	Around 3 500 small vessels, and 500 mid-size vessels	1–4 for small boats, 10–12 for mid-size vessels
Shrimp	V-shaped nets 15 to 50 m wide (*charangas*), cast nets, gillnets	4–6 m long, fibreglass boat with outboard engine (15–100 hp)	Around 4 000 small boats in Tamaulipas-Veracruz At least 200–400 vessels in seabob fishery	1–4
Mullets	450–1 500 m long gillnets, 2–3.75 in mesh size	4–6 m long fibreglass boat, with outboard engine (15–75 hp)	No records	1–4
Grouper	Longline with 1 500–2 000 handlines or short longlines	3–4 m long, fibreglass boat, carried by a 7–9 m long boat with outboard engine (15–75 hp) or by a 12–22 m long vessel acting as mother ship for the *alijos*	Around 4 000 small vessels, 500–600 mid-size vessels	1–4 for small boats, 4–12 for mid-size vessels
Spanish and king mackerels	Gillnets (300 m long, 3.5–4 in mesh size), beach seines (400–800 m), handlines	4–6 m long fibreglass boat with outboard engine (15–100 hp)	No records	1–4 in boats, up to 20 when using beach seines
Sharks and rays	Longlines, gillnets	4–6 m long fibreglass boat with outboard engine (up to 100 hp)	Around 3 665 small vessels	1–4
Lobster	Hooka system, artificial habitats (*casitas*) and traps in Yucatán; nets, diving and same as above in Quintana Roo	7–9 m long, fibreglass boat with outboard engine (between 50–75 hp) and mid-size vessels (10–22 m long)	998 small vessels and 16 mid-size vessels	1–3 for small vessels, 6–12 for mid-size vessels
Finfish	Gillnets, longlines, cast nets, handlines, beach seine nets	7–9 m long, fibreglass boat with outboard engine (15 up to 100 hp)	Up to 43 392 small vessels	1–4 for small vessels

In Tamiahua, Veracruz, the following species account for more than 50% of the total catches: spotted and silver weakfish (*Cynoscion nebulosus* and *C. nothus*); mojarras (*Eugerres* spp.); sheepshead (*Archosargus probatocephalus*); croaker (*Micropogon undulatus*); drum (*Pogonias cromis*); and red drum (*Sciaenops*

ocellatus). White mullet and mullet catches account for another 9%. In Laguna Madre, Tamaulipas (north of the Gulf of Mexico), spotted weakfish, croaker, sheepshead and drum (together, 28% of catches) are caught with gillnets (Gómez and Monroy, 2000).

Some fish species can also be caught in lobster traps (González-Cano *et al*., 2000), namely grouper (*Epinephelus morio*), hogfish (*Lachnolaimus maximus*), cabrilla (*Serranus cabrilla*), and snappers (*Lutjanus* spp.). Other crustaceans, such as crabs and lobster (*Scyllarides nodifer*), are also caught incidentally and are consumed locally. On the other hand, white shrimp are caught in nets used to catch seabobs in shallow waters of the Campeche Bank. In this zone no artisanal fishery for white or pink shrimp in shallow marine waters is allowed, although it occurs frequently enough to be considered a serious problem. In Tamaulipas and Veracruz, small fishes and crabs of several species are caught in the *charangas*, although a list of such species has not been published (Fernández *et al*., 2000). In Yucatán, shrimp are caught in the estuaries using nets called *triangulos*, which are operated manually (Salas *et al*., 2006).

2.3 Pacific coast fisheries

Several fisheries based in the Pacific region could be considered as a single group (or species) since they are very specialized (e.g. seaweeds, kelp, octopus, lobster and crabs). Other species, such as the abalone, conch, clams, mussels and sea urchins, are hand-picked by divers using boat-based air compressors (called 'Hooka'). In these fisheries it is not very common to report incidental catch, although some complementary species are captured by the divers. Table 2 depicts a summary of the characteristics of some of the fisheries in the Pacific region and Appendix II includes a complete list of species targeted in the region.

The Pacific littoral fisheries are similar to the fisheries for shrimp in coastal waters, with fishers using fixed gears blocking migrations to the sea (locally called *tapos*) and small vessels to collect catches and take them to shore. There are also active fishing gears to catch shrimp in shallow water, such as cast nets and *suripera* (a quasi-trawlnet).

One of the most specialized fisheries in the area is the one for sharks, as it requires different fishing strategies and gears than those used for finfish. However, some fleets that target finfish using gillnets and longlines also catch sharks. There is high species richness for sharks in the Mexican Pacific and almost all are sold commercially when caught.

In the squid fishery, which primarily targets the giant squid (*Dosidicus gigas*), some species appear as bycatch, for example, the common Pacific squid (calamar común del Pacífico, *Loligo opalescens*), the dart squid (calamar dardo, *Loliolopsis diomedeae*), *Lolliguncula* spp., *Illex* spp., *Ommastrephes* spp., and *Symplectoteuthis* spp. These are also caught as bycatch by industrial shrimp trawlers.

TABLE 2
Summary of vessels and gear characteristics of the fisheries in the Pacific littoral

Fishery	Type and size of gear	Type and size of boat	Number of vessels
Seaweed	SCUBA diving, Hooka	5–7 m fibreglass vessels, outboard engine	59
Kelp	Hand-picked	Small fibreglass vessels, outboard engine	613
Abalone	SCUBA diving, Hooka	Small fibreglass vessels, outboard engine	878
Conch	SCUBA diving	Small fibreglass vessels, outboard engine	
Clams	SCUBA diving, Hooka, hand-picked on low tide	Small fibreglass vessels, outboard engine	200
Mussels	SCUBA diving, Hooka, hand-picked on low tide	Fibreglass vessels, outboard engine	55
Giant squid	Poteras	Small fibreglass vessels, outboard engine	2 000
Octopus	SCUBA diving, Hooka	Small fibreglass vessels, outboard engine	1 188
Shrimp	Castnets, *suripera* or *dragona*, seine	Small fibreglass vessels, outboard engine (55 hp)	12 339
Lobster	Metal, wood and plastic traps (Californian type)	5-7 m fibreglass boats, outboard engine (40–75 hp)	1 110
Crabs	'Chesapeake trap', maximum dimensions 60 x 60 x 40 cm	Small vessels, fibreglass, outboard engine	2 700
Stone crabs	Traps	Small vessels, fibreglass, outboard engine	760
Sea urchin	SCUBA diving, Hooka	Up to 7 m fibreglass, outboard engine	615
Sea cucumber	SCUBA diving, Hooka	Small fibreglass vessels, outboard engine	7
Groupers	Gillnets, line	7 m fibreglass boat, outboard engine (45–60 hp)	
Croakers and drums	Gillnets 100–500 m long, 3–6 in. mesh size	Small fibreglass vessels, outboard engine	
Snappers	Bottom gillnets 200–300 m long, 82.55 mm mesh size, line, handline	Small fibreglass vessels, outboard engine	
Jacks	*Almadraba*, beach net, lines (*currican*)	Small fibreglass vessels, outboard engine	
Flounders	Bottom gillnets, trawling, lines	Small fibreglass vessels, outboard engine (115 hp)	
Mullets	Gillnets 2.5–3.5 in. mesh size	Small fibreglass vessels, outboard engine	848
Tilefishes	Handlines, gillnets	Small fibreglass vessels, outboard engine	500 in BCS, 33–380 in the west coast BC
Snooks	Gillnets; handline, SCUBA diving, harpoon	Small fibreglass vessels, outboard engine	
Mackerels	gillnets 500 m long, 2.5-3.5 in mesh size	Small fibreglass vessels, outboard engine	
Coastal sharks	Longline 1 500–3 000 m long, 500–1000 hooks; up to 750 m long and 350 hooks	Small fibreglass vessels, outboard engine	4 973
Rays	Bottom gillnets 4–10 in. mesh size	7-8 m overall length, fibreglass outboard engine (75 hp or more)	
Sailfish	Fishing rod	Sport fishing fibreglass vessels, outboard engine	966
Dolphinfish	Fishing rod	Sport fishing fibreglass vessels, outboard engine	966
Marlin	Fishing rod	Sport fishing fibreglass vessels, outboard engine	966

BCS = Baja California Sur; BC = Baja California.

2.4 Seasonality

Multispecies catches occur due to the seasonality of stock abundances; fishers target species that are most abundant at any given time. In addition, multigear fleets often switch target species with changes in resource abundance or regulations (Salas *et al*., 2004). One example of this involves the giant squid fishery. This fishery is a single-species fishery in the central region of the Gulf of California during the periods of high abundance of squid. But when the abundance of this resource decreases, the fleet switches primarily to finfish. The same applies with lobster and octopus fisheries along the Yucatán coast.

Seasonal effort shifting from one target species to another is common in many small-scale fisheries of Mexico. Seasonal effort and changes in catch patterns are due to three main factors: (i) closed seasons; (ii) changes in stock abundance (or resource availability in coastal areas); and (iii) changes in relative prices of harvested species. A summary of the main seasonal allocation of effort of Mexican small-scale fisheries is presented below.

Octopus: Caught in the Yucatán shelf during last five months of the year as a result of a closed season, mostly determined by the seasonal recruitment of *Octopus maya*, the Mexican four-eyed octopus (Solís-Ramírez *et al*., 1998).

Shrimp: In Tamaulipas and Veracruz, brown shrimp (*Farfantepenaeus aztecus*) are more abundant from April to July for the artisanal fishery operating in the lagoons. Seabob (*Xiphopenaeus kroyeri*) is more abundant at the beginning of the second part of the year. Seasonality of the fishery is affected by the closed season (late May to mid-July in Tamaulipas and Veracruz and May to October in Campeche). Juvenile pink shrimp are found in greater numbers in shallow waters off the western seashore of the Yucatán Peninsula from June to September and white shrimp are abundant from May to early September in lagoons of the southern Gulf; both species are caught illegally in those areas (Fernández *et al*., 2000). In Yucatán, shrimp are caught by men and women in estuarine areas. Shrimp are caught between October and February in Chabihau (Cabrera, 2003); in Celestun, the abundance of the four species (*Farfantepenaeus aztecus, F. brasiliensis, F. duorarum* and *F. notialis*) in the estuarine area varies throughout the year, so the area provides alternatives to fishers all year round (Defeo *et al*., 2005).

Grouper: Due to reproduction-linked aggregations, groupers are more vulnerable to fishing from January to March. A closed season has been established between mid-February and mid-March. By the end of July fishing effort allocated initially to grouper and related species shifts mostly to the octopus and lobster fisheries, and catches diminish to a third of the maximum (Monroy *et al*., 2000a; Salas *et al*., 2006).

Spanish and king mackerel: These species migrate regularly along the Gulf´s shores, from south to north in spring–summer and from north to south in autumn–winter (Mendoza, 1968; Doi and Mendizabal, 1978; Schultz *et al*., 2000). As a result, two seasonal abundance peaks can be found, occurring at different times according to location along the migration's path. Spanish mackerel is

more abundant in Tamaulipas in April and September to October, in March and October in Veracruz, in March and October–November in Tabasco, and in January and November in Campeche, Yucatán and Quintana Roo. For the king mackerel these peaks occur in June and August in Tamaulipas, May and August in Veracruz, May and October for Tabasco, in December to February in Campeche, in December and January in Yucatán, and in December and February in Quintana Roo (Schultz *et al*., 2000).

Sharks and rays: In many species caught by this fishery, abundance varies according to migratory movements occurring mostly during winter, when several species are caught (Cid *et al*., 2000; Fuentes-Mata *et al*., 2002).

Spiny lobster: Although migratory movements dependent on age and size have been described (González-Cano, 1991), their effect on availability has not been clearly defined. Seasonality of the fishery is determined mainly by management, with a closed season from 1 March to 31 June (González-Cano *et al*., 2000). Catches are usually higher from July to September.

2.5 Non-target species and bycatch

Because of the low selectivity and diversity of fishing gears and methods in the small-scale fisheries, the catches contain a considerable number of different species. It is important to notice here, however, that most of the products harvested by the small-scale fleet are sold and rarely discarded. In multispecific fisheries, as many stocks are diminishing and catch-per-unit effort continues to decline, fishers tend to keep those resources that can be traded in such a way that the travel costs can be compensated and a profit generated from every fishing trip. This condition, however, does not apply in the case of the shrimp fishery. A list of non-target species harvested incidentally is presented in Appendix III for artisanal fisheries and in Appendix IV for shrimp trawl bycatch.

3. FISHERS AND SOCIO-ECONOMIC ASPECTS

The statistical yeardocument report indicated that 268 727 persons were employed in fisheries in Mexico in 2001 (CONAPESCA, 2001). In 1999, the National Institute of Statistics, Geography and Information (INEGI) reported 154 379 persons employed directly in fisheries and aquaculture and 83 058 employed in jobs directly related to them.

According to the statistical yeardocument of 2000 (CONAPESCA, 2001), there were 104 028 persons involved full time in fisheries in the Gulf of Mexico and Caribbean seashores: 15 153 in Tamaulipas; 32 277 in Veracruz; 21 499 in Tabasco; 12 307 in Campeche; 19 711 in Yucatán; and 3 081 in Quintana Roo. These numbers include artisanal and industrial fishers as well as 1 203 involved in aquaculture and other jobs directly related to the sector. In most cases, those registered by INEGI as employed in fisheries satisfy the criterion of obtaining most of their income from fisheries or related activities. Despite these records, there is no accurate information published that estimates the number of people involved in each of the most important fisheries in the country, nor does discrimination by type of fleet exist.

Gómez and Monroy (2000) report that in the Laguna Madre there were 1 233 small vessels operating in the finfish fishery. According to the same authors, there were 3 111 fishers operating in the northern Veracruz finfish fishery with 2 408 small vessels.

The number of fishers per vessel varies according to the type of fishery and the region. For instance, in Tamaulipas, Veracruz, Tabasco and Campeche the average number of fishers by registered small vessel is 2.2, while in Yucatán and Quintana Roo the average is 3.7 fishers per vessel.

The Pacific littoral presents a north-to-south decreasing gradient in the number of fishers per vessel. This is due mainly in part to the fact that the Gulf of California (north) is a highly productive area, reflected in the economy through the presence of industrial fleets targeting mainly tuna, sardine and shrimp. In comparison, the rest of the Pacific shores are dominated by artisanal fisheries. The southern Pacific shores also experience higher indices of poverty.

According to statistical yeardocuments (CONAPESCA, 2001), there are 149 522 persons involved full time in fisheries in the Pacific seashores: 6 444 in Baja California; 11 027 in Baja California Sur; 22 638 in Sonora; 39 681 in Sinaloa; 10 627 in Nayarit; 5 001 in Jalisco; 2 281 in Colima; 8 527 in Michoacán; 11 071 in Guerrero; 13 755 in Oaxaca; and 18 470 in Chiapas. These numbers include artisanal and industrial fishers as well as 15 969 persons involved in aquaculture and other related activities.

The proportion of people working in fishing by state in the Pacific is as follows: Baja California (4.67%); Baja California Sur (5.21%); Sonora (13.53%); Sinaloa (24.36%); Nayarit (7.94%); Jalisco (3.70%); Colima (1.50%); Michoacán (7.22%); Guerrero (11.37%); Oaxaca (9.07%); and Chiapas (11.42%).

In the Gulf of Mexico and Caribbean, distribution of people employed in fisheries is as follows: Tamaulipas (0.55%); Veracruz (0.47%); Tabasco (1.14%); Campeche (1.8%); Yucatán (1.2%); and Quintana Roo (0.34%) (data comes from INEGI, 1999 and CONAPESCA, 2001). Dependence on fishing is more evident in small fishing communities. For example, Méndez (2004) reports 67% of households are dependent on fisheries in Celestún, Yucatán.

No official statistics give a clear idea of part-time employment in fisheries in the Gulf of Mexico. Chenaut (1985) reports that many fishers along the Yucatán coast were originally peasants; they engaged in fisheries when they were displaced from agriculture. Many of these retained some of their agricultural activities. However, this situation should be considered a special case. The same author reports that in the neighbouring Quintana Roo, the dependence of communities on fisheries is higher because the land in the north of that state is unfit for agriculture. Fishing traditions date back many years in many locations along the Mexican coast; Alcalá (1986) reports a figure of 500 years for some communities.

3.1 Average annual income level

There are big differences between the incomes derived from fisheries among regions and types of fisheries. The average monthly income derived from fisheries

in municipalities of the five states around the Gulf of California for the period 2000–2001 was 2 714 Mexican pesos (MXN) (1 US$ = 11.50 MXN), while in the Gulf of Mexico states the average was 624 MXN. In Tamaulipas, the average monthly income was 702 MXN, 471 MXN in Veracruz, 579 MXN in Tabasco, 475 MXN in Campeche, 526 MXN in Yucatán, and 989 MXN in Quintana Roo. It is worth noting that the states with the highest average income have the most valuable fisheries: shrimp (Tamaulipas) and lobster (Quintana Roo) (data processed from INEGI, 1999). Nadal (1996) reported that 14% of fishing units (employed in industrial fisheries) received 43% of the total income while 67% of them (those employing 1–15 fishers per unit) received only 2.8%.

In many small fishing communities the lack of basic services such as running water, education and electricity has been reported (e.g. Melville, 1984; Rodríguez, 1984; Cheanaut, 1985; Alcalá, 1986; Cesar and Arnaiz, 1998; Méndez, 2004). Even in communities with basic services, the low income and the low average wages create low living standards for many artisanal fishers.

Those states with large littorals and low populations, such as the whole Baja California Peninsula and Sonora in the Mexican northern Pacific, are characterized by the lack of basic services and the dispersion of fish landing locations. In some states such as Oaxaca and Chiapas in the southern Mexican Pacific, as well as northern Tamaulipas and Campeche, fishing communities are characterized by low standards of living.

Most fishers are native to the regions where they operate. However, there is a considerable seasonal migration in certain areas associated with local variations of resource abundance. Fernández *et al*. (2000) and Gómez and Monroy (2000) reported on the seasonal migration of fishers to Tamaulipas from other states (mostly Veracruz) when the shrimp and mullet fisheries are in periods of high abundance. Alcalá (1986) reports the presence of transient fishers from Veracruz to Tabasco. Cesar and Arnaiz (1998) report migrant fishers from Veracruz establishing fishing communities in northern Quintana Roo. In the Mexican Pacific, some groups move seasonally between Chiapas and the Gulf of California for the shark fishery.

3.2 Fishers' levels of education and roles of family members in coastal fisheries

Generally speaking, the educational level among artisanal fishers is low. Méndez (2004) reported that less than 25% of boys in a fishing community in Yucatán reached secondary school. A similar figure was reported in Michoacán, on the Pacific shore, where 28% of fishers studied some years of elementary school and only 31% finished this educational level; 21% reached secondary school and only 1% enrolled in college (Toledo and Bozada, 2002).

Concerning family participation in the fishery, most times women have marginal roles in the harvesting process but play significant roles in processing. Younger members of the family play auxiliary roles and act many times as apprentices (Chenaut, 1985; Alcalá, 1986; Méndez, 2004). This level of participation is reflected in the annual income of families in fishing communities.

INEGI (1999) reports that only 3.7% of the people registered as directly involved in fisheries and aquaculture are women, and 21% of them are working in administrative and control areas. Women, along with the elderly and children, are more involved with subsistence fisheries (Chenaut, 1985; Méndez, 2004).

3.3 Processing and marketing

Fishery products coming from artisanal small-scale fisheries are mainly fresh, iced, frozen and, in very limited cases, processed. National, local and international markets receive the products from these fisheries. Finfish and shark (up to a certain size) are usually sold whole. Most of the shrimp artisanal catches in the Gulf fisheries are of small sizes and are not suitable for international markets.

Octopus is processed (frozen) for the export market. Around 20 to 25% of catches were exported in 2001, but in 1997 nearly 14 000 of the almost 18 000 tonnes caught were sent to international (mostly Asian) markets (CONAPESCA, 2001). After 1996, when the north African octopus fishery collapsed, international demand rose, doubling the price of octopus paid to fishers in the Yucatán and Campeche fishery (Solís-Ramírez *et al*., 1998; Hernández *et al.*, 2000). However, prices were lower in consecutive years, and demand decreased (Salas *et al*., 2006).

Around 40 to 50% of lobster catches are exported (González-Cano *et al.*, 2000). Frozen lobster tails comprise around 30% of the exported volume, the rest being fresh and iced (CONAPESCA, 2001).

Close to 4 000 tonnes from approximately 8 000 tonnes of grouper catches are exported to the United States of America, frozen whole or in fillets. The rest is distributed in national markets and little is consumed locally (Monroy *et al*., 2000a).

Nearly 70% of shark is sold fresh, 22% frozen, and the rest dried-salted. Shark leather has been exported to the United States and Europe (294 tonnes in 1990, worth US$10 million). Although it does not appear in statistical yeardocuments since 1996, shark fins are exported to Asian markets (190 tonnes and US$2.5 million in 1987) (Cid *et al*., 2000).

The female gonads of mullets earn a price four to five times that of the rest of the fish (120 Mexican pesos per kg, around US$30 in 1994). Fresh mullets are consumed locally and only 4% are exported. Around 48% of female gonads are consumed locally, 24% are for the national market, and 28% are exported. Dried-salted mullets comprise 97% of the mullet products for the national market (Gómez and Monroy, 2000).

On the Pacific littoral, seaweed is dehydrated and sold mostly in national markets. Kelp is dehydrated and sold in national markets and exported. Both are used to extract alginates.

Abalone is sold fresh and iced in national (local) markets. It is also frozen or canned for national markets and exportation. Most species of conch are sold fresh and iced locally and are rarely canned. Conch is also used for handicrafts. Clams and mussels are mostly sold fresh and iced; they are rarely frozen or in brine.

Squid is mostly sold fresh and iced. Sometimes it is processed (canned), while octopus is sold mostly fresh and iced for the national market.

Most of the shrimp coming from artisanal catches are of small sizes, making them unsuitable for international markets. These shrimp are consumed at local and national levels. Large white shrimps caught in coastal waters are usually exported and a small amount is allocated to national markets.

More than 70% of lobster catches are exported, mostly frozen. At the national level, lobster is sold iced and fresh. Crab is mainly sold fresh and iced for the national market. Some large boats targeting crab and operating under a special licence process the meat into crabs sticks, which are cooked and exported.

Practically all production of sea urchin is frozen and mostly exported; sea cucumber is dried and mostly exported. Most marine fishes are sold whole or in fillets and are fresh, iced and frozen for national markets. A small amount of groupers and snappers are exported frozen, whole or in fillets. In several cases, gonads earn the highest prices and some species, such as mullets, are targeted mostly for the gonads. Some species (i.e. mullets) are dried-salted or smoked and sold in national markets.

3.4 Conflicts between fishers and other coastal activities

Allocation of marine resources has always been a complex issue to address in fisheries. This issue is further complicated when deciding who will be granted access to the most profitable resources, such as shrimp, lobster, abalone and conch, in Mexico. By decree these resources were allocated to members of fishing cooperatives in the 1970s and 1980s, restricting access by the members of the organizations once they got the concession of the resources. By the 1990s this decree was changed and the access was opened to other participants. However, preference was given to those who have historical rights over the resources as long as they were able to demonstrate they were efficient in the production system.

Another potential source of conflict in fisheries is the interaction of small-scale fisheries with industrial fisheries, especially in the cases where the same resources are targeted by both fleets. This is the case for the shrimp fisheries in Mexico, as juvenile shrimp are caught by artisanal fishers in the estuaries, while the adults are caught in marine areas. Juvenile shrimp can be overfished, reducing the stock available for population reproduction and as a fishing stock for the industrial fleet. The shrimp fishery is one of the most important fisheries in economic terms in Mexico and the conflict between artisanal and industrial fishers is a growing concern for fisheries managers (Fernández *et al*., 2000). Similar types of interactions occur within the octopus and grouper fisheries, although the conflicts have not been as drastic as those reported in the shrimp fishery. However, octopus artisanal fishers along the interstate border of Campeche and Yucatán have been clashing periodically over access to fishing grounds.

Other conflicts arise between fisheries and conservation. One case in particular involves interactions between harvesters and marine mammals in the Gulf of California. In the upper Gulf of California there is a marine reserve aimed

to primarily protect the *vaquita* (*Phocoena sinus*) and the *totoaba* (*Totoaba macdonaldii*), which are threatened by shrimp trawl fishing activity and the use of gillnets by the artisanal fishery. Moreover, there is restricted access to the core area of the reserve for all fleets which is not respected by the artisanal fishers (Morales-Zárate *et al*., 2004; Lercari, 2006).

Conflicts between commercial and recreational fisheries are also present. For instance, commercial fishers claim access to the dolphinfish stock normally reserved for sportfishers. Commercial fishers claim that there is enough biomass of the stock to allow their participation, but sportfishers argue that reduction in individual sizes could cause a negative impact on the tourist sector.

Prohibiting fishing around oil platforms is a growing problem for fishers in the Campeche Bank as the area has been banned to fishing operations. Pollution from oil extraction activities is also a growing concern. Social disruption in fishing communities as a result of oil worker immigration has been noticeable in the Ciudad del Carmen, Campeche (Rodríguez, 1984).

Resort developments and tourism-related activities have been interfering with fishing activities in a high degree in the northern coast of Quintana Roo (Cesar and Arnaiz, 1998) and several places along the Pacific coasts, such as Huatulco, Acapulco, Manzanillo, Puerto Vallarta, Mazatlàn and Los Cabos, among others.

4. ASSESSMENT OF FISHERIES

The National Institute of Fisheries has developed assessment of the stocks of the most important fisheries in Mexico; this assessment is periodically updated (INP, 1998, 2000). As a means to unify methods that facilitate comparisons and understanding of the results by the fishing community and all fishing sectors, these assessments have been based on biomass models and in several cases uncertainty and risk analysis have been included. This data includes information from the most important artisanal fisheries considered in those analyses. An important contribution for knowledge of the status of small-scale fisheries from the Gulf of Mexico is reported in Flores *et al.* (1997). A summary of some of the methods employed for stock assessment of several fisheries are listed below and the status of the main fisheries by region is integrated afterwards.

Arreguín-Sánchez and Pitcher (1999) analysed changes in catchability by size of the grouper fishery, comparing fleet trends through time. Several studies on reproduction have been conducted for grouper, including Brulé *et al*. (2003). Monroy *et al*. (2000a) and Giménez-Hurtado *et al*. (2005) applied an age structured model to assess the grouper fishery. Age-structured models have also been employed to assess the octopus fishery (Solís-Ramirez *et al*., 1998; Arreguín-Sánchez *et al*., 2000; Hernández *et al*., 2000), the shrimp fishery (Castro and Arreguín-Sánchez, 1991; Fernández *et al.*, 2000), and sardine in the Gulf of California (Morales-Bojórquez *et al*., 2003). Cohort analysis has been used to assess the lobster fishery.

Age-structured models have been used in many fisheries because of the importance of considering age-related events (migrations, individual growth,

reproduction and sex shifts in protogynous hermaphrodite species like red grouper), which facilitate the development of strategies for fisheries management.

Yield-per-recruit analysis has been applied to shrimp fisheries (Arreguín-Sánchez and Chávez, 1985) and the Spanish and king mackerel (Schultz *et al.*, 2000). Shark fisheries assessments are still in early stages, possibly due to lack of data. Yield-per-recruit analyses have been applied to the shark fishery by Cid *et al.* (2000).

Biomass dynamics models, fitted assuming equilibrium, have been applied to several fisheries, including grouper (Arreguín-Sánchez, 1985) and octopus (Arreguín-Sánchez *et al.*, 1999). These are also used to evaluate recovery time of some stocks after high levels of exploitation, as in the case of abalone and red grouper (Arreguín-Sánchez, 1992). Non-equilibrium conditions have been assumed in more recent applications for the mullet and snapper fisheries (Gómez and Monroy, 2000; Monroy *et al.*, 2000b).

Dynamic bio-economic analyses have been applied to several fisheries: shrimp (Arreguín-Sánchez and Chávez, 1985), octopus, lobster and grouper (Seijo, 1986; Seijo *et al.*, 1987; Seijo *et al.*, 1991; Díaz de León and Seijo, 1992; Hernández, 1995; Seijo *et al.*, 2001; Monroy, 1998). The inclusion of estimation of dynamic costs and revenues helps in decision making and to understand the effect on fishers' short-term and long-term dynamics.

Due to the economic importance of crustacean fisheries, including shrimp which produces half of the export revenues from fisheries and currently receives subsidies and tax returns, financial analyses have been required (Goudet and Goudet, 1987; FAO/World Bank, 1988; FIRA, 2003). However, these studies concentrate primarily on the industrial shrimp fishery.

Although some analyses, including uncertainty and risk analysis, in the assessment of some fishery resources have been undertaken by the National Fisheries Institute, the results have not yet been published. Few case studies have been reported. Solís-Ramirez *et al.* (1998) evaluated the octopus fishery integrating uncertainty on the estimation of some parameters on the predictions made based on an age-structured model.

Some ecosystem trophic models based on the Ecopath-Ecosim software have been applied to different ecosystems on both coasts of the country: Campeche Bank, the coasts of Veracruz and Yucatán, the northern and central Gulf of California, La Paz Bay, Huizache-Caimanero system of lagoons, and the coasts of Jalisco and Michoacan, among others (Arreguín-Sánchez, 2002; Arreguín-Sánchez and Calderón-Aguilera, 2002; Arreguín-Sánchez *et al.*, 2004; Zetina-Rejón *et al.*, 2004; Arreguín-Sánchez and Martínez-Aguilar, 2004; Lercari, 2006; Cruz-Escalona, 2005; Zetina-Rejón, 2004; Galván-Piña, 2005; Díaz-Uribe *et al.*, 2007).

4.1 Status of the fisheries

A summary of the status of the main small-scale fisheries of both the Gulf of Mexico-Caribbean and the Pacific regions is presented in Tables 3 and 4.

TABLE 3
Status of the main Mexican small-scale fisheries of the Caribbean and Gulf of Mexico region

Small-scale fishery	Status	Catch 2003 (tonnes)
Shrimp **Brown** (*Farfantepenaeus aztecus*) **Seven Bearded** (*Xiphopenaeus kroyeri*) **White** (*Litopenaeus setiferus*) **Pink** (*Farfantepenaeus duorarum*) **Red** (*Farfantepenaeus brasiliensis*)		26 798
Finfish **Red grouper** (*Epinephelus morio*)		9 081
Octopus *Octopus maya* *Octopus vulgaris*		15 713
Spiny lobster *Panulirus argus* *Panulirus guttatus*		828
Shark (27 species)		5 651
Conch/snails **Queen conch** (*Strombus gigas*) **White conch** (*Strombus costatus*)		50

Development potential Fully exploited Overexploited Exhausted

Source: Adapted from Seijo and Martínez, 2006.

The status of the main fishing stocks in the Gulf of Mexico, except those of *Octopus vulgaris*, is critical since most of them are fully exploited or exhausted. Effort expansion in the octopus fishery of the Yucatán Shelf is directed toward *O. vulgaris*. The National Institute of Fisheries (NIF) assumed that this increase would not impact the fully exploited *O. maya* stock since *O. vulgaris* occurs at greater depths (>10 fathoms [>18 m]) than *O. maya*. The highest concentrations of *O. maya* occur around 3 to 7 fathoms in near shore limestone crevices. However, there is no control over the operation areas of the fleet.

Most fisheries require precautionary measures to avoid their depletion. In fact, four of the main stocks in the Gulf of Mexico/Caribbean region are fully exploited, two overexploited and two show signs of exhaustion. In contrast with the Pacific region, most of the fisheries are artisanal.

Most artisanal fisheries in Mexico present a high degree of overlap. It is not uncommon to find fishing cooperatives in the same locality that have permits to catch shrimp, shark and finfish throughout the year. This condition complicates the assessment of the stocks involved in different fisheries; usually assessment has been based on single-species analysis. In some regions fishers shift seasonally from one species to another according to patterns of seasonal abundance, as already noted. A list of the main target species (English common name, Spanish local name and scientific name) involved in the above-mentioned fisheries is provided in Appendix I.

TABLE 4
Status of the main Mexican small-scale fisheries of the Pacific region

Small-scale fishery	Status of the stock	Catch 2003 (tonnes)
Shrimp		
Blue shrimp (*Litopenaeus stylirostris*)		97 107
Pacific white shrimp (*L. vannamei*)		
White shrimp (*L. occidentalis*)		
Brown shrimp (*Farfantepenaeus californiensis*)		
Cristal shrimp (*F. brevirostris*)		
Seabob (*Xiphopenaeus riveti*)		
Lobster		
Red (*Panulirus interruptus*)		2 140
Central Baja California Peninsula		
Northern and southern Baja California populations		
Clams		
Baja California Sur and Sinaloa		11 290
Baja California and Sonora		
Octopus		1 044
Sharks (30 species)		
Oceanic		20 960
Alopis pelagicus		
A. vulpinus		
Coastal		
Carcharinus falciformis		
Snappers		4 314
Lujanidae spp.		

Development potential Fully exploited Overexploited Exhausted

Source: Modified from Seijo and Martínez (2006); Seijo *et al.* (2006).

None of the major fisheries along the shores of the Pacific Ocean have possibilities of effort expansion. Six of them are categorized as fully exploited and three as exhausted. For instance, Sala *et al*. (2004) report that, although some catches are stagnant or still increasing for some species groups, catch-per-unit effort shows a declining trend after 1980 in the Gulf of California. The authors state that coastal food webs in the area have been 'fished down' during the last 30 years. A shift in the target species from high to low trophic levels has resulted in a dramatic increase in fishing effort in the region. Fishing not only impacted targeted species, but also caused community-wide changes. In fact, large predatory fishes such as sharks, gulf groupers, gulf coneys, goliath groupers and broomtail groupers were among the most important catches in the 1970s, but became rare by 2000. The results also show that species that were not targeted in the 1970s, such as parrotfish, whitefish, spotted snapper, tilefish and creolefish, have now become common catches. The authors argue that their results exhibit a clear trend that Gulf of California fisheries have fished down the food web, leading to effects on the entire coastal ecosystem well beyond the direct impacts on targeted species. These fisheries are unsustainable in their current state and management needs to be re-evaluated with sound regulatory measures to prevent further degradation.

5. FISHERY MANAGEMENT AND PLANNING

5.1 Historical trends

Since 2000, most small-scale fisheries shifted from an open access regime to a licence limitation management strategy. Effort regulations have historically been enforced by government and, in a limited and successful number of cases, through community management and co-management schemes such as in the case of the spiny lobster fisheries of Punta Allen (Seijo, 1993; Sosa-Cordero *et al*., 2008) and Baja California.

Fisheries management in Mexico has undergone changes of emphasis and approaches several times in the last decades. In the 1970s, a promotion policy reasserted exploitation of shrimp, lobster, abalone (the most valuable species), oyster, *totoaba*, pismo clam, *cabrilla* and sea turtles to cooperatives.

During the 1970s and 1980s, emphasis was put on production increases. The Ministry of Fisheries was established by 1982. At the end of the 1970s, catches reached nearly 1.4 million tonnes, a fivefold increase in ten years as a result of a fisheries sector development policy that greatly increased fishing effort. However, national catches oscillate around 1.2 million tonnes since the early 1980s.

In the early 1990s, a change in policies occurred that aimed to promote private investment, favour industrial fishers and abrogate the 'reserved species' regime. This policy matured in 1992, when the current Federal Fisheries Law was enacted. Thorpe *et al*. (2000) documented the effect of the introduction of the 'New Economic Model' in fisheries management in several Latin American countries, including Mexico. These authors present the change in emphasis from privileging the social (cooperatives) sector to favouring private investment.

As a result, the fisheries industry was incorporated in 1994 in the newly formed Ministry of Environment, Natural Resources and Fisheries (Secretaría de Medio Ambiente, Recursos Naturales y Pesca [SEMARNAP]) as an underministry, and as part of a global policy aimed at attaining sustainable development. Hernández and Kempton (2003) discussed the effect of attempts to introduce a greater degree of scientific input in the management and public participation processes in Mexico in the mid- to late-1990s. This intended to include fisheries in a broader framework of natural resources management. The new fisheries plan stated sustainability as a goal and the Precautionary Principle as a guideline. Three elements were introduced: (a) an attempt to make the decision-making process more scientific-based; (b) a new legal instrument, the National Fisheries Chart (Álvarez-Torres *et al*., 2002); and (c) a more active participation of stakeholders in decision-making.

Since the end of 2000, at the beginning of the new administration, fisheries were transferred to the Ministry of Agriculture: Agriculture, Livestock, Rural Development, Fisheries and Food (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación: SAGARPA), shifting again to 'incentives' of development (SAGARPA Plan Sectorial, 2001). At present, the agency responsible for fisheries management, monitoring and enforcement is the National Commission of Aquaculture and Fisheries (Comisión Nacional de Acuacultura y Pesca [CONAPESCA]). As a result of its transfer, the underministry of fisheries was downsized, and its state delegations (formerly one in every one of the 32 states) were reduced in number and incorporated into SAGARPA delegations, losing their hierarchical link to CONAPESCA.

5.2 Legal instruments, strategies and management tools

The fisheries included in this analysis are regulated in several ways. The octopus fishery is managed through a closed season (from January to August) that protects individual growth to marketable sizes and an annual catch quota. The shrimp fishery is regulated by closed seasons, mesh size and gear type restrictions and zonal restrictions for different users (prohibitions of trawling for industrial ships below five fathoms, a 15 nautical miles from shore no-fish zone in the Yucatán Peninsula). The lobster fishery has effort restrictions (by limiting the number of concessions), legal size limits, a prohibition of catching ovigerous females and a closed season. The grouper fishery has legal size limits and effort restrictions (number of permits), and a quota awarded to the Cuban vessels operating in the fishery is an allocation instrument. In the mullet fishery, a closed season, legal size limit and mesh size regulations are applied. In the shark fishery, an issuing of new permits moratorium has been in place for some years (Cid *et al.*, 2000), but proposed regulations on closed seasons and protection of breeding areas have still to be applied. Regulations on the finfish fishery have yet to be applied widely.

A relatively new legal instrument, the Official Mexican Standards (Normas Oficiales Mexicanas [NOM]), was developed which included the usual regulations such as permits, gear type restrictions, season and area closures, legal size limits,

quotas and bycatch excluding devices. Until 2000, only 14 fisheries were regulated by NOMs, including shrimp, lobster and octopus.

Fisheries on the Pacific littoral are regulated with different instruments as described below.

Seaweed: Fishing area, gears and landing places are controlled.

Kelp: Exploitation of fishing areas are allocated to groups while areas, fishing gears, seasons and amount of fishing are defined by permits.

Abalone: Closures by area and time. Four administrative areas were established and a quota is defined separately. There is a minimum legal size, fishing gear is regulated and fishing at low tides is prohibited. A stocks-recovery plan has been implemented with measurable success in some areas. The goal is to maintain biomass at 50% of the pristine biomass.

Clam: Pacific calico scallop includes a minimum legal size, catch quota and effort by area in the Baja California Peninsula. A closed season is defined. Pismo clam and the purplelip rock oyster are currently species under special protection and officially they are not commercially exploited. Their use is now regulated by the General Law of Ecological Equilibrium and Environmental Protection (Ley General de Equilibrio Ecológico y la Protección al Ambiente).

Molluscs: Catch quotas by bank are defined for conch; fishing permits allowed for mussel and octopus in the Pacific. Giant squid has a fishing effort control based on an annual catch quota.

Shrimp: Seasonal and spatial closures by region, controls on fishing gears and amount of effort. Fixed gears are used as defined by the fishing law.

Lobster: Minimum legal size by species and area, seasonal and spatial closures. In the central Baja California, fishing cooperatives agreed voluntarily to the use of windows for escapement in traps to reduce pre-recruits (sizes below L_{50}).

Crab: In Sonora, the fishing sector has agreed on a seasonal closure to control fishing effort of several species such as 'stone crabs', where the number of permits is controlled. Fishing areas and minimum legal size are defined by target species. It is prohibited to capture gravid females.

Sea urchin: Characteristics of the gears and landing places are controlled and seasonal and spatial closures, minimum legal size and catch quotas have been introduced.

Sea cucumber: From 2000 to the present, this fishery is regulated under the 'promotion' (*fomento*) scheme because limited information of the resource does not allow access to a high number of users. Promotion permits involve the commitment of the users to generate information for the better understanding of the resource for management purposes.

Marine fishes: All marine fishes are globally managed by controlling access through fishing permits. Some details are added for groupers where areas and fishing gears are defined and for mullets where minimum legal size, mesh size and seasonal closures are established by species and region.

Sharks: Limited number of permits; new participants only by substitution of vessels.

Rays: Just fishing permits.

Sport fishing: Dolphinfish, marlin and swordfish appear as associated species in some commercial fisheries. However, there is no commercial fishing for dolphinfish or swordfish. Marlin is regulated under a commercial fishery, where permits specify fishing gears and areas.

5.3 Management and enforcement

Before the mid-1990s, the Secretariat of Fisheries had an inspection and enforcement body. After being incorporated into SEMARNAP, fisheries inspection and regulation enforcement was incorporated in the PROFEPA (an environmental attorney's office within the Ministry of Environment). When the fisheries regulation was transferred to SAGARPA, most former fisheries inspectors remained in PROFEPA or were transferred to SAGARPA's delegations with no formal links to CONAPESCA, which formally did not have a fisheries inspection role. Since illegal fishing is a serious problem in many parts of the country, the effectiveness of enforcement has been limited at best, even if institutional redesign had not played a role.

The navy, in collaboration with fisheries management institutions, has played an important auxiliary role in enforcement over the years. Several research centres across the country have developed scientific research efforts on fisheries issues. However, although scientists from those institutions have been participating with fisheries (federal and states) authorities and advising enterprises or fishers about management in the last decade, there are no institutional schemes to completely formalize the use of this scientific infrastructure.

5.4 Fishers' participation in fisheries management

Industrial fishers are associated with the National Fishing and Aquaculture Chamber. Artisanal fishers have the National Fishing Cooperatives Confederation. There are 2 976 registered fishing cooperatives in Mexico, along with 2 954 organizations of other types, such as Fishing Production Societies, Fishing Production Unions, Social Solidarity Societies and others. In total, there are 185 756 people associated within these organizations, 118 328 in cooperatives and 67 428 in other kinds of organizations (CONAPESCA, 2001).

In a process regulated by the Federal Metrology and Standardization Law (Ley Federal de Metrología y Normalización), committees should be formed to allow stakeholders to participate in decision-making processes, such as issuing Mexican Official Norms or assisting with certain management decisions (i.e. setting closed seasons). Although the fisheries regulatory agency (at present CONAPESCA) is the one that makes the final decision (and bears full responsibility for it), this process is intended to be enhanced by stakeholder participation. At present, this process is far from perfect. Only some committees have been formed so far. The functioning of those already established still has to be improved. Most artisanal fishers' organizations have yet to have consultants who can assist them on technical issues. Full representation of those invited to attend the meetings has yet to be achieved. Hernández and Kempton (2003) discuss difficulties found in implementing this system in the shrimp fishery, in particular the interactions of artisanal and industrial fishers.

Recently an advisory body, the National Fisheries Council (Consejo Nacional de Pesca), was formed that included representatives from industrial and artisanal fishers. However, it is still too early to discuss the results of the implementation of such a body in designing and implementing fisheries policies.

5.5 Community and NGO involvement in fishery management

Beyond state committees, there is little involvement of the local community in fisheries management. However, some communities in the Pacific and in Punta Allen, Quintana Roo, in the Caribbean have experienced successful community-based management programmes applied to the spiny lobster fishery (Seijo, 1993; Bourillon and Ramade, 2004).

Pérez-Sánchez and Muir (2003) quote fishers as saying that distrust over the honesty of cooperative leaders and authorities as an obstacle to an effective community organization. Ostrom (2000) points to these factors as a prerequisite for community management of resources.

The NGOs have had an increasing indirect role in the shape of proposals and studies performed on local fisheries. One example is NGO involvement in processes like ecolabelling (Bourillon and Ramade, 2004). However, this participation is not yet widespread.

Chenaut (1985) reported a traditional, self-imposed, territorial partitioning system for lobster fishers in eastern Yucatán and northern Quintana Roo, where territorial units were assigned to communities, independent of their affiliation to fishing cooperatives. This author comments on the fact that fishing authorities did not recognize the territorial divisions. However, such systems are not widely used in the Gulf of Mexico and the Caribbean. In the Pacific littoral there are several examples of management where communities are participating, such as the cases of abalone, sea urchin and lobsters. Some attempts to involve stakeholders in management have been made in finfish fisheries but without clear results yet.

5.6 Management in accordance to international guidelines

In 1982, Mexico signed the United Nations Convention on the Law of the Sea (UNCLOS) and the Agreement regarding the implementation of Part XI of the Convention. Previously in 1976, the National Constitution was modified to include the 200-nautical-mile EEZ. In 1999, Mexico signed the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas. In 1995, Mexico signed the FAO Code of Conduct for Responsible Fisheries. Mexico has been an active promoter of this Code.

Although in the period 1994–2000 the Precautionary Principle was included explicitly in the Fisheries Sector Plan, it is not mentioned in the new sector Fisheries Plan that defines 'sustainability' as an aim.

The main instrument of allocation of fishing rights is the fishing permit. Although in some cases, issuing of short-term permits has been recommended in fisheries of uncertain status, as in the shark fishery (Cid *et al*., 2000), there is a trend

to issue longer term permits or concessions as a way of "giving legal certainty" to fishing activities and as a "tool for countering deterioration of the resources" (SAGARPA, 2001). At first, concessions had been issued to exploit demersal resources, mostly invertebrates that lend themselves to territorial divisions (such as lobster or abalone).

Quotas have been sparingly used in Mexico's fisheries management. The grouper fishery has a quota awarded to Cuban vessels fishing in the Yucatán. The octopus fishery has a TAC-type (total allowable catch) overall quota that has been used as a substitute for effort regulations. This quota has not been very effective and researchers recommended against it early on (Solís-Ramírez *et al.*, 1998). The closest to an individual quota system is the one applied to abalone cooperatives in Baja California.

6. RESEARCH AND EDUCATION

Statistics are gathered periodically by local fishery offices, subordinated to SAGARPA's delegations. This information is processed by CONAPESCA to produce, among other things, statistical yeardocuments. The National Fisheries Institute (Instituto Nacional de la Pesca [INP]) gathers data from samples on some fisheries included in research projects.

Concerning fisheries research, a number of scientific research projects have been conducted to assess stocks harvested by small-scale fisheries in Mexico, including:

(i) Studies on the octopus fisheries dating back to the early 1960s, which include the description of the main exploited species (*Octopus maya*) (Voss and Solís-Ramírez, 1966), growth and recruitment (Arreguín-Sánchez, 1992), and the development of the fisheries (Arreguín-Sánchez *et al*., 1987; Solís-Ramírez, 1975, 1988, 1991, 1994, 1997; Solís-Ramírez and Chávez, 1986; Solís-Ramírez *et al*., 1998; Arreguín-Sánchez *et al.*, 2000).

(ii) Studies on the shrimp fishery, including some relevant to the management of the artisanal fishery (Castro and Santiago, 1976; Schultz and Chávez, 1976), population dynamics, mortality and growth assessments (Smith, 1984, 1988; Re-Regis, 1989, 1994; Castro and Arreguín-Sánchez, 1991, 1997), and overviews of the fishery (Fernández *et al.*, 2000; Ramírez-Rodríguez *et al*., 2001).

(iii) Several studies on migration, growth, mortality, reproduction and general population dynamics on the Spanish and king mackerels (Mendoza, 1968; Doi and Mendizabal, 1978; Chávez, 1981; Mendizabal, 1987; Vasconcelos, 1988; Aguilar *et al*., 1990; Olvera *et al*., 1991; Sánchez *et al*., 1991; Arreguín-Sánchez *et al*., 1995). Schultz *et al.* (2000) present a general overview of the fishery.

(iv) Studies on mullets, including growth, mortality and general ecological observations from the mid- to late-1970s (Márquez, 1974; Castro, 1978). Gómez and Monroy (2000) summarized results from several unpublished research reports and made a detailed description of the fishery.

(v) The grouper fishery has been studied in depth. Early studies date back to the 1960s (Solís, 1969). Later studies include growth (Rodríguez, 1986), catchability (Arreguín-Sánchez, 1999), the state of the fishery (Doi *et al.*, 1981; Arreguín-Sánchez, 1985; Contreras *et al*., 1995; Burgos and Defeo, 2000; Burgos and Defeo, 2004: Giménez-Hurtado *et al*., 2005), and interaction of fleets (Zetina *et al*., 1996a). Monroy *et al*. (2000a) summarize many important aspects of the fishery. Mexicano-Cintora *et al*. (2007) also integrate a list of references of studies related to grouper and other demersal fishes from the Yucatán shelf.

(vi) The lobster fishery studies include works on feeding (Colinas and Briones, 1990), reproduction (Ramírez, 1996), morphometrics (Zetina *et al*., 1996b), density and distribution (Bello *et al*., 2000), and descriptions of the fishery (Arceo and Seijo, 1991; Briones and Lozano, 1994; Ríos *et al*., 1995, 1997, 2000; Cervera *et al*., 1996; González-Cano *et al*., 2000). An overview of the fishery can be found in González-Cano *et al*. (2000) and Salas *et al*. (2005).

Although earlier work on shark fisheries can be found (e.g. Hernández, 1971), the first systematic studies in the 1980s and 1990s were performed by the INP (e.g. Uribe, 1990; Castillo-Géniz, 1992; Castillo-Géniz *et al*., 1998). Studies performed include species proportion in catches, morphometrics, types of fishing gears used, and times and places of occurrence of juveniles (Bonfil, 1997; Cid *et al*., 2000; Márquez, 2000; Soriano *et al*., 2000).

Many studies of several finfish species from different areas have been presented in different catalogues (e.g. Vega-Cendejas, 1998; Espino *et al*., 2003, 2004). Other aspects such as growth and reproduction studies of some demersal fishes can be found in different theses (e.g. Rodríguez, 1992; Leonce-Valencia, 1995). Mexicano-Cíntora *et al.* (2007) present about 500 references on studies undertaken on fishery resources from the Yucatán shelf.

6.1 Ecosystem-based management approach

A number of ecosystem models based on trophic webs have been developed with emphasis on fishing activity using an 'Ecopath with Ecosim' platform (i.e. Arreguín-Sánchez, 2002). Several of them have been used for modelling fisheries dynamics in the context of the ecosystem approach management strategies or assessing fisheries impact on the ecosystems.

A number of trophic ecosystem models have been constructed along both littorals, putting emphasis on the role of fish resources. Generally most of these models consider functional groups at the level of families with the exception of target or overfished species which are considered individually. The research has been focused to investigate the role of some stocks within the ecosystem, concentrating on fisheries management and conservation, and to evaluate the impact of fishing of some resources on the ecosystem. In Table 5, existing trophic ecosystem models are listed indicating the type of ecosystem considered for the analysis and the main research purpose.

TABLE 5
Ecosystem trophic models constructed in Mexico indicating the type of ecosystem and the main purpose for their construction

Ecosystem	Trophic web/role	Fisheries conservation management	Impact of fishery	Reference
Coral reefs Caribbean Sea	X	X		Älvarez-Hernández (2003), Arias-González *et al*. (2004).
North Continental Shelf of Yucatán	X	X	X	Arreguín-Sánchez *et al*. (1993a, b), Vega-Cendejas *et al*. (1993a, b), Arreguín-Sánchez (2000). Arreguín-Sánchez & Manikchand-Heileman (1998), Arreguín-Sánchez & Valero (1996).
Campeche Bank	X	X	X	Arreguín-Sánchez *et al*. (2004), Arreguín-Sánchez & Manikchand-Heileman (1998), Vega-Cendejas (1993a, b), Zetina-Rejón (2004), García-Cuellar (2006), Zetina-Rejón & Arreguín-Sánchez (2002), Arreguín-Sánchez (2002), Arreguín-Sánchez *et al*. (1993a), Arreguín-Sánchez *et al* (2008a, b).
Tabasco	X			Cabrera-Neri (2006)
Southwest Gulf of Mexico (Veracruz)	X	X		Arreguín-Sánchez *et al*. (1993b), Arreguín-Sánchez & Chávez (1995), Cruz-Escalona (2005).
Gulf of Mexico synthetic model	X			Vidal & Pauly (2004)
Jalisco and Colima	X	X	X	Galván-Piña (2005), Galván-Piña & Arreguín-Sánchez (2008)
Southern Sinaloa	X			Salcido-Guevara (2006), Salcido & Arreguín-Sánchez (2007), Lozano (2006)
Central Gulf of California	X	X	X	Arreguín-Sánchez *et al*. (2002), Arreguín-Sánchez & Martínez-Aguilar (2004), Arreguín-Sánchez & Calderón-Aguilera (2002).
Northern Gulf of California	X	X	X	Morales-Zárate *et al*. (2004), Lercari (2006), Lercari & Arreguín-Sánchez (2008), Lercari *et al*. (2007).
Gulf of Ulloa	X			Del Monte-Luna (2004), Del Monte *et al*. (2007).
Models from bays and coastal lagoons				
La Paz Bay	X	X	X	Arreguín-Sánchez *et al*. (2004), Díaz-Uribe *et al*. (2007), Arreguín-Sánchez *et al*. (2007).
Concepción Bay	X			Gorostieta-Monjaraz (2001)
Huizache and Caimanero	X	X	X	Zetina-Rejón *et al*. (2001, 2003, 2004)
Celestun Lagoon	X			Chávez *et al*. (1993). Vega-Cendejas (1998), Vega-Cendejas & Arreguín-Sánchez (2001)
Terminos Lagoon	X	X		Manikchand-Heileman and Arreguín-Sánchez (1998), Rivera-Arriaga *et al*. (2003), Zetina-Rejón (2004), Zetina-Rejón *et al*. (2004).
Alvarado Lagoon	X			Cruz-Escalona (2005), Cruz-Escalona *et al*. (2006).
Tampamachoco Lagoon	X			Rosado-Solórzano & Guzmán del Proó (1993)

TABLE 5 (CONTINUED)

Ecosystem	Trophic web/role	Fisheries conservation management	Impact of fishery	Reference
Madinga Lagoon	X			De La Cruz-Aguero (1993)
Tamiahua Lagoon	X			Abarca-Arenas & Valero (1993)
Ascención Bay	X			Vidal & Basurto (2003)
Mangrove system	X			Vega-Cendejas & Arreguín-Sánchez (2001), Vega-Cendejas (2003), Rivera-Arriaga *et al* (2003).
Interdependent ecosystems				
Alvarado Lagoon and adjacent continental shelf	X	X	X	Cruz-Escalona (2005)
Terminos Lagoon and Campeche Bank	X	X	X	Zetina-Rejón (2004)

7. ISSUES AND CHALLENGES

7.1 Fisheries assessment and approaches needed for integration

There is a reasonable scientific effort on stock assessment when it comes to evaluating fisheries in Mexico. Originally there was a single species focus and, more recently, the ecosystem models have been introduced in some evaluations. However, social science studies related to the fishing sector (including social and economic analysis of fisheries) are poorly developed in Mexico (or at least carried out by only a few researchers and ignored by managers). In recent years, the international community (Jentoft and MacCay, 1995; Berkes *et al*., 2001; Euan *et al*., 2004; Salas and Gaertner, 2004; Salas *et al*., 2007) has recommended the need to integrate natural and social sciences to find management strategies that focus on sustainability. Fisheries need to be examined within a broader natural resource research and management framework.

7.2 Lack of long-term vision on fisheries management

Fisheries management in Mexico has undergone changes in emphasis and approach several times in the last decades, but still lacks a long-term plan. Accordingly, related institutions have undergone several modifications. Fisheries plans are updated every six years and usually change in approaches and emphasis. The Federal Fisheries Law and related regulations are general in scope and mainly give broad structure for management. Hernández and Kempton (2003) and Beltran-Turriago (2007) have discussed the problems resulting from the complete redesign of Mexican institutions every six years, most especially the introduction of new administrations; those shifts have prevented the development of a coherent fisheries policy. Some efforts have been made to generate management instruments

that transcend the institutional administrative changes and shifts in approaches, such as the case of the National Fisheries Chart, which includes a diagnosis of the state of the resources, characteristics of the fisheries, and setting legal limits to fishing effort on a per fishery basis (Álvarez-Torres *et al*., 2002). This chart is updated regularly based on scientific information, but could benefit from widening its scope. There is also a need to develop the mechanisms for social participation in the decision-making and possibly the implementation of management and research programmes.

7.3 Flaws in fishery policies and lack of transparency

Hernández and Kempton (2003) stated that conditions such as low stock levels, too many fishers, trends of rent reduction, and no incentives to conserve the resource generate a race to fish and overcapitalization of the resource. In our view, institutional fragility should be added as a cause of these problems. The reduction of institutions devoted to fisheries research and management that have resulted from administrative changes generates deficits in terms of attention to problems in the sector and effectiveness in management (Beltran-Turriago, 2007). Ostrom (2000) points out that effective social organization and institutional structure are the only ways to combat problems related to poorly defined property rights. Allocation of property right has been defined as one of the effective management tools dealing especially with artisanal fisheries. Thorpe *et al.* (2000) also state that greater management resources and expertise are required under such conditions.

Other weaknesses in the management system concern equality among different users of resources and development alternatives during policy changes. It is important not to remain stagnant while searching for solutions to overexploitation and overcapacity. For example, reductions between 50 and 60% of fleet size have been suggested recently for the Mexican Gulf of Mexico shrimp fleet (Goudet y Goudet, 1987; FAO/World Bank, 1988) and financial support from the government has shifted to shrimp culture (36% of credits awarded), compared with 22% of credits devoted to industrial fisheries and 16% to artisanal fisheries. Geographically, there are also differences, with 83% of the credits awarded to five states in the north Pacific Region (CONAPESCA, 2001).

On the other hand, there is a widespread perception of fisheries as a 'production activity' that does not consider the need for environmental protection. This, along with the dire economic situation of many fishers and the ever-growing dependence of the fisheries sector on subsidies, drives upper level officials to design policies that in many occasions are not compatible with other branches of government.

7.4 Need for a definition of use rights

The increasing degree of conflict in Mexico's fisheries stems in part from a free-access regime that persisted for decades. The environment of poorly defined property rights can only lead to a 'tragedy-of-the-commons' and a 'prisoner dilemma' type of outcome (Ostrom, 2000). Hence, cooperation among stakeholders to conserve and obtain maximum benefits from an exploited resource

is an important prerequisite for successful management schemes. There is a broad consensus among social scientists on the pivotal role of institutional arrangements in shaping peoples' interactions with their natural environments and negotiation processes in natural resource management. Incentives for sustainable exploitation of fishing resources come in the shape of long-term assurance of being able to reap benefits from them in a fair and equitable fashion. But this assurance can only occur in a setting of well-defined use or property rights. The co-management of common-pool resources in different parts of the world has been shown. However, territorial concessions are not widespread in Mexico. An exception would be the area concessions awarded to cooperatives exploiting benthic resources such as abalone or lobster in the Baja California peninsula. However, even though allocation of inshore areas to artisanal fisheries has been proposed, it still remains unclear how these reserved areas would be established, especially with pressure from the industrial sector on government agencies and the lack of flexibility of the centralized management system.

7.5 Interactions between industrial and artisanal fleets and with other sectors

Thorpe *et al.* (2000) discuss that conflicts between fishers, particularly between the artisanal and industrial sectors, have generated serious problems in Mexican fisheries. In this sense, it is common to find that industrial fishers and artisanal fishers blame each other for decreases in catches of several resources in different areas. Illegal actions from artisanal fishers are reported by industrial fishers. In contrast, artisanal fishers are concerned with the effects the excessive fishing power from industrial fishers might have on several resources, especially spawners of some species (i.e. grouper or shrimp). Either way, it is a fact that effort and fishing power have increased greatly in Mexican fisheries. For example, the number of artisanal vessels rose more than fivefold since 1970 from 15 000 vessels to 102 000 in 2000. Before 1982, about 1 600 new artisanal vessels were incorporated each year. On the other hand, even though the industrial fleet has decreased approximately 5% from its maximum in 1983, the fishing power has increased due to the adoption of new fishing techniques and gears.

Other productive activities compete for resources use, areas, or can limit the expansion of fishing activities or serve as a complementary source of income for fishers in Mexico. Different regions present different conditions and the interaction of fisheries with other sectors varies among areas. For example, oil exploitation has been an increasingly important activity in the Campeche Bank since the mid-1970s (Melville, 1984). Exclusion of some areas to fishing still remains a problem for some people. Tourism is an important activity in the Yucatán (Méndez, 2004) and Quintana Roo (Cesar and Arnaiz, 1998) coasts and the expansion of this sector increases demand for seafood and labour. On the Pacific coast, there are well developed tourism locations such as Los Cabos, Acapulco, Huatulco, Mazatlan, Manzanillo, Puerto Vallarta, Bahia de Banderas, and a number of smaller tourist centres. Cargo activities in some areas have been expanding, such as Lázaro

Cárdenas, Manzanillo and Salina Cruz. Multiple uses of the coastal areas require efforts to identify possible human and ecological interdependencies. In addition, definition on users' rights of natural resources is required.

7.6 Impact of subsidies on fishing activities

Subsidies to fisheries (in the form of reduction in diesel fuel prices) went from 468 million Mexican pesos in 2001 to 887 million in 2002. Initially, subsidies were directed towards supporting the operations of the industrial fleet (as it only uses diesel). However, they began to be earmarked also to gasoline, used by the artisanal fleet at the end of 2003 (Cámara de Senadores, 2003). Subsidies were seen as an important issue in the Chamber of Deputies consultation's results to 'increase competitiveness' (Comisión de Pesca de la Camara de Diputados, 2001). Although it has been acknowledged that subsidies should not be directed to increasing fishing effort (Cámara de Senadores, 2003), it seems that little attention has been paid to the economic effects, and those over the exploited stocks, of subsidies in maintaining present levels of fishing effort (National Research Council, 1999; World Wildlife Foundation, 2001).

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APPENDIX I

Target species in the Gulf of Mexico and Caribbean region by type of organism, common and scientific names

Groups	Common name	Spanish name	Scientific name
Molluscs Cephalopods	Mayan (red) octopus	Pulpo maya, pulpo rojo	*Octopus maya*
	Common octopus	Pulpo común, pulpo patón	*O. vulgaris*
Crustaceans	Brown shrimp	Camarón café	*Farfantepenaeus. aztecus*
	White shrimp	Camarón blanco	*Litopenaeus setiferus*
	Pink shrimp	Camarón rosado	*F. duorarum*
	Seabob	Camarón siete barbas	*Xiphopenaeus kroyeri*
	Spiny lobster	Langosta espinosa	*Panulirus argus*
	Spotted lobster	Langosta pinta	*P gutatus*
	Green lobster	Langosta verde	*P. laevicauda*
Fish	Lisa	Lisa	*Mugil cephalus*
	White mullet	Lebrancha	*M. curema*
	Grouper	Mero	*Epinephelus morio*
	Spanish mackerel	Sierra	*Scomberomorus maculatus*
	King mackerel	Peto, carito	*S. cavalla*
	Mojarra	Mojarra	*Gerres* sp., *Eugerres* sp., *Eucinostomus* sp.
	Gafftopsail catfish	Bandera	*Bagre* spp.
	Jack	Jurel	*Caranx* spp.
	Snook	Robalo	*Centropomus* spp.
	Weakfish	Trucha	*Cynoscion* spp.
	Snapper	Guachinango, pargo	*Lutjanus* spp.
	Seabass	Corvine	*Cynoscion* spp.
	Rudderfish, amberjack	Esmedregal	*Seriola* spp.
	Yellowtail snapper	Rubia	*Ocyurus* spp.
	Vermilion snapper	Besugo	*Rhomboplites* spp.
	Grunt	Ronco	*Pomadasys, Anisotremus*
	Sea catfish	Bagre	*Arius* spp.
	Croaker	Berrugata	*Menticirrhus* spp.
	Pompano	Pompano	*Trachinotus* spp.
	Cabrilla	Cabrilla	*Paralabrax, Epinephelus*
	Flounder	Lenguado	*Paralichtys, Syacium*

APPENDIX I (CONTINUED)

Groups	Common name	Spanish name	Scientific name
Sharks and rays	Atlantic sharpnose shark	Cazón de ley, caña hueca	*Rhizoprionodon terraenovae*
	Blacktip shark	Tiburón puntas negras, volador	*Carcharhinus limbatus*
	Bonnethead	Cazón cabeza de pala, pech	*Sphyrna tiburo*
	Scalloped hammerhead	cornuda	*S. lewini*
	Bullshark	Tiburón chato	*C. leucas*
	Blacknose shark	Cazón canguay, pico negro	*C. acronotus*
	Smalltail shark	Tiburón poroso,cuero duro	*C. porosus*
	Spinner shark	Tiburón curro, puntas negras, picudo	*C. brevipinna*
	Hammerhead	Cornuda grande, cornuda gigante	*S. mokarran*
	Night shark	Tiburón nocturno, ojo verde	*C. signatus*
	Sandbar shark	Tiburón aleta de cartón, aletón	*C. plumbeus*
	Angel shark	Tiburón ángel, angelote	*Squatina dumerili*
	Dusky shark	Tiburón prieto, negro, tabasqueño	*C. obscurus*
	Spotted eagle ray	Chucho, chucho obispo, chucho pintado	*Aetobatus narinari*
	Skate	Raya	*Raja texana*
	Southern stingray	Raya látigo	*Dasyatis americana*
	Longnose stingray	Raya látigo hocicona	*D. guttata*
	Cownose ray	Raya gavilán	*Rhinoptera bonasus*

APPENDIX II

Target species in the Pacific region by type of organism, common and scientific names

Groups	Common name	Spanish name	Scientific name
Molluscs (Gastropods)	Blue abalone	Abulón azul	*Haliotis fulgens*
	Yellow abalone	Abulón amarillo	*H. corrugada*
	Black abalone	Abulón negro	*H. cracherodii*
	Chinese abalone	Abulón chino	*H. sorenseni*
	Red abalone	Abulón rojo	*H. rubescens*
	Crown conch	Caracol burro	*Melongena patula*
	Pink murex	Caracol chino rosa	*Hexaplex erythrostomus*
	Northern radix murex	Caracol chino negro	*Muricanthus nigritus*
	Purpura conch	Caracol de tinta	*Purpura pansa*
	Cortez conch	Caracol burro	*Strombus galeatus*
	Wavy turban	Caracol panocha	*Astrea undosa, A. turbanica*
Bivalves	Pismo clam	Almeja pismo	*Tivela stultorum*
	Squalid callista	Almeja chocolata	*Megapitaria squalida*
	Golden callista	Almeja chocolata roja	*M. aurantica*
	Disk dosinia	Almeja blanca	*Dosinia ponderosa*
	Many-ridged venus	Almeja roñosa de risco	*Peryglipta multicostata*
	Frilled californian venus		*Chione undatela*
	Ornate venus		*C. gnidia*
	Californian venus clam	Almeja roñosa	*C. californiensis*
	Pacific lion´s paw	Almeja mano de león o almeja voladora	*Lyropecten subnodosus*
	Pacific calico scallop	Almeja catarina	*Argopecten circularis*
	Scallop	Almeja voladora	*Pecten vogdesi*
	Ark	Pata de mula	*Anadara tuberculosa*
	Purplelip rock oyster	Almeja burra	*Spondylus calcifer*
	Rugose pen shell	Callo de hacha	*Pinna rugosa*
	Maura pen shell	Callo de hacha china	*Atrina maura*
	Mussels	Mejillón	*Mytilus californianus, M. edulis, Modiolus capax*
Cephalopods	Octopus	Pulpo	*Octopus hubbsorum, O. vulgaris*
	White spotted octopus	Pulpo manchado	*O. macropus*
	Two spotted octopus	Pulpo manchado	*O. bimaculatus*
		Pulpo rojo	*O. rubescens*
	Giant squid	Calamar gigante	*Dosidiscus gigas*
Echinoderms	Red sea urchin	Erizo rojo	*Strogylocentrotus franciscanus*
	Sea urchin	Erizo púrpura	*S. purpuratus*
	Sea cucumber	Pepino de mar	*Isostichopus fuscus, Parastichopus parvimensis*

APPENDIX II (CONTINUED)

Groups	Common name	Spanish name	Scientific name
Crustaceans	Brown shrimp	Camarón café	*Farfantepenaeus californiensis*
	Blue shrimp	Camarón azul	*Litopenaeus stylirostris*
	White shrimp	Camarón blanco	*L. vannamei, L. occidentalis*
	Cristal shrimp		*F. brevirostris*
	Rock-shrimp	Camarón roca, japonés	*Sicyonia dorsalis, S. penicillata*
	Seabob	Camarón siete barbas	*Xiphopenaeus riveti*
		Camarón zebra	*Trachypenaeus faoe*
		Camarón botalón	*T. pacificus*
	Green crab	Jaiba verde	*Callinectes bellicosus*
	Blue crab	Jaiba azul	*C. arcuatus*
	Black crab	Jaiba negra	*C. toxotes*
	Red lobster	Langosta roja	*Panulirus interruptus*
	Green lobster	Langosta verde	*P. gracillis*
	Blue lobster	Langosta azul	*P. inflatus*
	Lobster	Langosta insular	*P. penicillatus*
	Stone crabs	Cangrejo amarillo	*Cancer anthonyi*
		Cangrejo rojo de roca	*C. productus*
		Cangrejo púrpura	*C. gracilis*
		Cangrejo de roca moteado	*C. antennarius*
		Cangrejo	*C. magister*
		Cangrejo mexicano	*C. jhongarti*
Fishes	Jewfish	Cherna o mero	*Epinephelus itajara*
		Verdillo	*Paralabrax nebulifer*
		Sandía	*Paranthias colonus*
		Cabrilla piedrera	*Epinephelus labriformis*
		Baqueta	*Epinephelus acanthistius*
		Cabrilla sardinera	*Myoteroperca rosacea*
	Spotted sandbass	Cabrilla de roca	*Paralabrax maculatofasciatus*
	Spotted cabrilla	Cabrilla pinta	*Epinephelus analogus*
	Flag cabrilla	Cabrilla piedrera	*Epinephelus labriformis*
		Cabrilla cueruda	*Dermatolepis dermatolepis*
		Baya	*Mycteroperca jordani*
		Cabrilla plomada	*Mycteroperca xenarcha*
		Pescada	*Stersolepis gigas*
	Shortfin *corvina*	Corvina azul, corvina de aleta corta	*Cynoscion parvipinnis*
	Orange mouth *corvina*	Corvina boca anaranjada	*C. xanthulus*
	Gulf curvina	Corvina del golfo	*C. othonopterus*
	Stripped *corvina*	Corvina rayada	*C. reticulatus*

APPENDIX II (CONTINUED)

Groups	Common name	Spanish name	Scientific name
Fish (continued)		Corvina chiapaneca	*C. albus*
	White seabass	Corvina blanca	*Atractoscion nobilis*
	Drum	Corvina chata o boquinete	*Larimus argenteus*
		Chano sureño	*Micropogonias altipinnis*
	Gulf croacker	Chano norteño o berrugata	*Micropogon megalops*
		Corvineta armada	*Bairdiella armata*
		Corvineta ronco	*B. icistia*
	King croacker	Berrugata, gurrubato	*Menticirrhus panamensis*
		Berrugata californiana	*M. undutatus*
	Highfin *corvina*	Berrugata real	*M. nasus*
		Berrugata roncadora	*Umbrina xanti*
		Berrugata aleta amarilla	*U. roncador*
	Grunter	Ronco	*Pomadasys macracanthus, P. panamensis*
	Burrito grunt	Burrito	*Anysotremus interruptus*
	Cortez grunt	Mojarrón	*Lythrulof flaviguttatum*
	Bronzestriped grunt	Roncacho	*Orthopristis reddingi*
	Pacific red snapper	Huachinago del Pacifico	*Lutjanus peru*
	Spotted rose snapper	Pargo lunarejo, flamenco	*L. guttatus*
	Yellow snapper	Pargo amarillo, coyotillo, alazan, clavelino	*L. argentiventris*
		Pargo rojo, pargo colmillón	*L. jordani*
	Colorado snapper	Pargo colorado, pargo listoncillo	*L. colorado*
	Dog snapper	Pargo mulato, pargo prieto	*L. novemfasciatus*
		Pargo rabirrubia	*Lutjanus inermis*
	Blue and gold snapper	Pargo azul-dorado,rayado	*Lutjanus viridis*
	Mangrove snapper	Pargo raicero, pargo de manglar	*Lutjanus aratus*
	Mexican barred snapper	Pargo coconaco, tecomate	*Hoplopagrus guentheri*
	Common jack	Jurel	*Canarx hippos*
	Jack	Ojón	*C. marginatus*
		Jurel toro	*Caranx caninus*
		Jurel voraz, ojo de perra	*C. sexfasciatus*
	Green jack	Cocinero, jurel bonito	*C. caballus*
		Chicharro ojoton	*Selar crumenophtalmus*
	Yellow tail	Esmedregal, jurel de castilla	*Seriola dorsalis*
	Amberjack	Esmedregal limón	*Seriola rivoliana*
		Esmedregal cola amarilla	*Seriola lalandi*
		Esmedregal fortuno	*S. peruana*

APPENDIX II (CONTINUED)

Groups	Common name	Spanish name	Scientific name
Fish (continued)	California halibut	Lenguado californiano	*Paralichthys califomicus*
		Lenguado huarache	*Paralichthys woolmani*
	Cortez halibut	Lenguado de Cortes	*Paralichthys aestuarius*
		Lenguado cola de abanico	*Xystreurys liolepis*
		Lenguado bocón	*Hippoglossina stomata*
		Lenguado diamante	*Hypsopsetta guttulata*
	Fourspot sole	Lenguado cuatrojos	*Hippoglossina tetrophthalmus*
		Lenguado resbaloso	*Microstomus pacificus*
	Three-eye flounder	Lenguado	*Ancylopsetta dendritica*
	Striped mullet	Lisa rayada, cabezona	*Mugil cephalus*
	White mullet	Lisa blanca, liseta, lebrancha	*Mugil curema*
		Lisa hospe	*Mugil hospes*
		Pierna o blanco	*Caulolatilus princeps*
		Conejo, salmón	*Caulolatilus affinis*
		Robalo plateado o garabato	*Centropomus viridis*
	Black snook	Robalo prieto o piedra	*Centropomus nigrescens*
		Robalo aleta prieta o paleta	*Centropomus medius*
		Robalo espina larga	*Centropomus armatus*
	Black snook	Robalo aleta amarilla, constantino, robalito	*Centropomus robalito*
	Tarpon snook	Constantino	*Centropomus pectinatus*
	Chub mackerel	Macarela	*Scomber japonicus*
	Pacific mackerel	Sierra	*Scomberomorus sierra*
	Spanish mackerel	Sierra	*Scomberomorus concolor*
	Yellowfin mojarra	Mojarra de aletas amarillas	*Diapterus peruvianus*
	Silver mojarra	Mojarra plateada	*Eucinostomus argenteus*
		Mojarra blanca	*Gerres cinereus*
	Pacific flagfin mojarra	Mojarra	*E. gracilis*
	Dolphinfish	Dorado	*Coryphaena hipurus*
Sharks and Rays		Cazón mamón	*Mustelus henlei, M. lunulatus*
	Sharpnose shark	Cazón bironche	*Rhizoprionodon longurio*
	Scalloped hammerhead	Cornuda o martillo	*Sphyrna lewini*
	Pacific angel shark	Angelote	*Squatina californica*
		Tiburón cornudo	*Heterodontus mexicanus*
		Cornuda prieta	*S. zygaena*
	Blacktip shark	Tiburón volador, puntas negras	*Carcharinus limbatus*
		Tiburón aleta de cartón	*Carcharhinus falciformis*
		Tiburón coyotito	*Nasolamia velox*

APPENDIX II (CONTINUED)

Groups	Common name	Spanish name	Scientific name
Sharks and rays (continued)		Tiburón perro	*Alopias superciliosus*
		Tiburón chato	*Carcharhinus leucas*
		Tiburón perro	*Alopias pelagicus*
	Tiger shark	Tintorera	*Galeocerdo cuvier*
		Cornuda gigante	*Sphyrna mokarran*
		Gata	*Ginglymostoma cirratum*
		Tiburón azul	*Prionace glauca*
		Cornuda	*Sphyrna media*
		Mako	*Isurus oxyrinchus*
	Thresher shark	Tiburón zorro	*Alopias vulpinus*
		Tiburón puntas blancas	*Carcharhinus longimanus*
		Tiburón martillo	*Sphyrna corona*
	Small tail shark	Tiburón cuero duro	*Carcharinus porosus*
	Lemon shark	Tiburón limón	*Negaprion brevirostris*
			Mustelus californicus
			Cephaloscyllium ventriosum
			Heterodontus francisci
			Carcharhinus obscurus
			Triakis semifasciata
			Hexanchus griseus
			Notorynchus cepedianus
	Stingray	Raya	*Dasyatis longus*
	Pacific manta	Manta o mantarraya	*Manta hamiltoni*
	Longtail diamond stingray	Raya con espinas	*D. brevis*
	Bat ray	Raya gavilán o tejolote	*Myliobatis californicus*
Seaweeds	Sargazo	Sargazo gigante	*Macrocystis pyrifera*

APPENDIX III
Non-target species and/or bycatch

English name	Spanish name	Scientific name
Finescale triggerfish	Cochi	*Batistes polylepis*
Ocean whitefish	Pierna, blanco	*Caulolatilus princeps*
Bighead tilefish	Conejo, salmón	*Caulolatilus affinis*
Cortez flounder	Lenguado de Cortés	*Paralichthys aestuarius*
Pacific bearded brotula	Lengua	*Brotula ctarki*
California scorpionfish	Lapón californiano	*Scorpaena guttata*
Spotted scorpionfish	Lapón, escorpión, rascado	*Scorpaena plumieri*
Mexican hogfish	Vieja mexicana	*Bodianus diplotaenia*
California sheephead	Vieja californiana	*Semicossyphus pulcher*
Bocaccio	Rocote	*Sebastes paucispinís*
Kelp rockfish	Rocote sargacero	*Sebastes atrovirens*
North Pacific hake	Merluza norteña	*Merluccius productus*
Speckled guitarfish	Guitarra punteada	*Rhinobatos glaucosiigma,*
Whitesnout guitarfish	Guitarra trompa blanca	*Rhinobatos leucorhyncfius*
Shovelnose guitarfish	Guitarra viola	*Rhinobatos productus*
Banded guitarfish	Guitarra rayada	*Zapteryx exasperala*
California butterfly ray	Raya mariposa californiana	*Gymnura marmorata*
Pacific chupare	Raya coluda del Pacífico	*Himantura pacifica*
Whiptail stingray	Raya látigo común	*Dasyatis brevis*
Pacific angelshark	Angelote	*Squatina califomica*
Grey smooth-hound	Cazón, tiburón mamón	*Mustelus califomicus*
Siklefin smooth-hound	Cazón segador	*Mustelus lunulatus*
Brown smooth-hound	Cazón hilacho	*Mustelus henlei*
Pacific sharp-nose shark	Tiburón bironche	*Rhizoprionodon longurio*
Inshore sand perch	Serrano cabicucho	*Diplectrum pacificum*
Spotted sand bass	Cabrilla de roca	*Paralabrax maculatofasciatus*
Flag Serrano	Serrano bandera	*Serranus huascarii*
Flathead mullet	Lisa rayada, lisa cabezona	*Mugil cephalus*
Pacific porgy	Mojarron, pluma marotilla	*Calamus brachysomus*
Paloma pompano	Pampano paloma	*Trachinotus paitensis*
Yellowfin surgeonfish	Cirujano aleta amarilla, barbero	*Acanthurus xanthopterus*
Pacific mutton hamlet	Guaseta del Pacifico	*Alphestes immaculatus*
Scrawled filefish	Lija garrapatera, bota trompa	*Aluterus scriptus*
Burrito grunt	Burro bacoco	*Anisotremus interruptus*

APPENDIX III (CONTINUED)

English name	Spanish name	Scientific name
Threadfin jack	Jurel de hebra, cocinero, chicuaca	*Carangoides otrynter*
Pacific crevalle jack	Jurel toro	*Caranx caninus*
Bigeye trevally	Jurel voraz	*Caranx sexfasciatus*
Pacific graysby	Enjambre	*Cephalopholis panamensis*
Shortfin weakfish	Corvina azul, corvina aleta corta	*Cynoscion parvipinnis*
Pacific spadefish	Zopilote, peluquero, chavelito, chambo, ojo de perra	*Chaetodipterus zonatus*
Rooster hind	Baqueta	*Epinephelus acanthisbus*
Spotted grouper	Cabrilla pinta	*Epinephelus analogus*
Itajara	Mero guasa, cherna	*Epinephelus itajara*
Starry grouper	Cabrilla piedrera	*Epinephelus labriformis*
Star-studded grouper	Baqueta ploma	*Epinephelus niphobles*
Yellow spotted grunt	Ronco, chano, burro manchas amarillas, jiniguaro	*Haemulon flaviguttatum*
Spottail grunt	Burro rasposo	*Haemulon maculicauda*
Greybar grunt	Burro almejero, guzga	*Haemulon sexfasciatum*
Blue-bronze sea chub	Chopa rayada	*Kyphosus analogus*
Cortez sea chub	Chopa de Cortes, chopa gris	*Kyphosus elegans*
Giant manta	Mantarraya, manta gigante	*Manta birostris*
Wavyline grunt	Ronco rayadillo	*Microlepidotus inornatus*
Gulf grouper	Baya	*Mycteroperca jordani*
Leopard grouper	Cabrilla sardinera, mitan	*Mycteroperca rosacea*
Bronze-striped grunt	Burrito, ronco rayado	*Orthopristis reddingi*
Goldspotted sand bass	Cabrilla extranjera, lucero	*Paralabrax auroguttatus*
Parrot sand bass	Cabrilla cachete amarillo, lucero	*Paralabrax loro*
Pacific cownose ray	Manta gavilán	*Rhinoptera steindachneri*
Pacific spotted scorpionfish	Lapón, escorpión	*Scorpaena mystes*
Almaco jack	Esmedregal limón, esmedregal almaco	*Seriola rivoliana*
Bullseye puffer	Botete diana	*Sphoeroides annulatus*
Orangeside triggerfish	Cochi naranja, bota, pejepuerco	*Suflamen verres*
Gafftopsail pompano	Pampano fino, pampano rayado	*Trachinotus rhodopus*
Polla drum	Berrugata roncadora	*Umbrina xanti*
Longfin salema	Chula, jiguagua, salmonete	*Xenichthys xanti*
Pacific ladyfish	Macabi	*Elops affinis*
Yellowfin mojarra	Mojarra bandera, mojarra rayada	*Gerres cinereus*
Pacific sierra	Sierra del pacifico	*Scomberomorus sierra*
Bluespotted cornetfish	Trompeta, corneta pintada	*Fistularia commersonii*

APPENDIX III (CONTINUED)

English name	Spanish name	Scientific name
Californian needlefish	Agujón californiano	*Strongylura exilis*
Roosterfish	Papagayo	*Nematishus pectoralis*
Threadfin jack	Jurel de hebra, chicuaca	*Carangoides otrynter*
Rainbow runner	Macarela salmón	*Elagatis bipinnulata*
Snouted eagle ray	Raya águila picuda	*Myliobatis longirostris*
Bat eagle ray	Tecolote, raya murciélago	*Myliobatis californica*
Longfin sanddab	Lenguado alón	*Citharichthys xanthostigma*
Spotted eagle ray	Chucho pintado	*Aetobatus narinari*
Threadfin bonefish	Quijo, macabi, chile, banana	*Albula nemoptera*
Anchovy	Anchoveta, anchoa chicotera	*Anchoa sp*
Black snook	Róbalo prieto	*Centropomus nigrescens*
Yellowfin snook	Róbalo aleta amarilla, constantino, robalito	*Centropomus robalito*
Pacific anchoveta	Sardina bocona, boquerón	*Cetengraulis mysticetus*
Milkfish	Sabalote	*Chanos chanos*
Pacific bumper	Jurel de castilla, casabe	*Chloroscombrus orqueta*
Golden mojarra	Mojarra palometa	*Diapterus aureolus*
Peruvian mojarra	Mojarra aletas amarilla, mojarra china, malacapa	*Diapterus peruvianus*
Pacific ladyfish	Machete del pacifico	*Elops affinis*
Pacific flagfin mojarra	Mojarra tricolor	*Eucinostomus curan ischana*
Graceful mojarra	Mojarra charrita	*Eucinostomus gracilis*
Blackfin jack	Chocho, jurel chumbo	*Hemicaranx zelotes*
California kingcroaker	Berrugata	*Menticirrhus undulatus*
Longjaw leatherjack	Piña bocona	*Oligoplites altus*
Squint-eyed croaker	Corvineta bizca	*Ophioscion strabo*
Pacific thread herring	Sardina crinuda	*Opisthonema libentate*
Brassy grunt	Burrito corcovado	*Orthopristis chalceus*
Blue bobo	Barbudo seis barbas	*Polydactylus approximans*
Panama grunt	Ronco mapache	*Pomadasys panamensis*
Bigscale goatfish	Chivo, chivato, salmonete	*Pseudupeneus grandisquamis*
Mexican lookdown	Jorobado escamoso, tostón	*Selene brevoortli*
Barred sand bass	Verdillo, cabrilla de arena	*Paralabrax nebulifer*
Mexican barracuda	Barracuda mexicana	*Sphyraena ensis*
Bigeye croaker	Chano norteño	*Micropogonias megalops*
Gulf weakfish	Corvina golfina	*Cynoscion othonopterus*
Dow's mojarra	Mojarra cantileha o blanca	*Eucinostomus dowii*

APPENDIX IV

List of fish species composing shrimp-trawl bycatch of the southern Gulf of California

Family	Species	Percent (weight)	Cumulative %
Diodontidae	*Diodon holocanthus*	14.08	14.08
Serranidae	*Diplectrum pacificum*	8.64	22.72
Synodontidae	*Synodus scituliceps*	7.72	30.44
Serranidae	*Paralabrax maculatofasciatus*	6.27	36.71
Gerreidae	*Eucinostomus dowii*	6.26	42.97
Hamulidae	*Haemulon steindachneri*	5.64	48.61
Balistidae	*Balistes polylepsis*	4.04	52.65
Haemulidae	*Orthopristis reddingi*	3.50	56.15
Rhinobatidae	*Rhinobatos glaucostigma*	3.09	59.24
Achiridae	*Achirus mazatlanus*	2.70	61.94
Paralichthyidae	*Etropus crossotus*	2.28	64.22
Sparidae	*Calamus brachysomus*	2.25	66.47
Haemulidae	*Haemulidae*	2.14	68.61
Batrachoididae	*Porichthys analis*	2.13	70.74
Triglidae	*Prionotus stephanophrys*	1.87	72.61
Ariidae	*Arius platystomus*	1.60	74.21
Haemulidae	*Haemulopsis elongatus*	1.58	75.79
Sciaenidae	*Micropogonias ectenes*	1.56	77.35
Lutjanidae	*Lutjanus peru*	1.27	78.62
Paralichthyidae	*Hippoglossima tetrophthalma*	1.25	79.86
Urolophidae	*Urobatis halleri*	1.17	81.03
Serranidae	*Diplectrum* spp.	1.06	82.09
Narcinidae	*Diplobatis ommata*	1.05	83.14
Scorpàenidae	*Scorpaena russula*	1.03	84.17
Lutjanidae	*Lutjanus guttatus*	0.79	84.96
Haemulidae	*Haemulon maculacaudi*	0.74	85.71
Tetraodontidae	*Sphoeroides lobatus*	0.74	86.45
Paralichthyidae	*Cyclopsetta panamensis*	0.73	87.18
Mullidae	*Pseudupeneus grandisquamis*	0.63	87.81
Triglidae	*Prionotus ruscarius*	0.60	88.41
Gerreidae	*Diapterus peruvianus*	0.59	89.00
Tetraodontidae	*Sphoeroides* spp.	0.52	89.52
Haemulidae	*Haemulon elongatus*	0.44	89.96
Ophidiidae	*Lepophidium prorates*	0.39	90.35
Paralichthyidae	*Citharichthys* spp.	0.39	90.75
Triglidae	*Prionotus birostratus*	0.39	91.14
Urolophidae	*Urobatis maculatus*	0.38	91.52
Sciaenidae	*Umbrina xanti*	0.36	91.88
Haemulidae	*Pomadasys panamensis*	0.31	92.19
Gerreidae	*Eucinostomus gracilis*	0.29	92.48
Narcinidae	*Narcine entemedor*	0.29	92.76
Rhinobatidae	*Rhinobatos productus*	0.29	93.05
Ariidae	*Arius* spp.	0.28	93.33
Paralichthyidae	*Syacium latifrons*	0.28	93.61
Synodontidae	*Synodus evermanni*	0.26	93.87