Chapter 33

The Northern Argentine Sea

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33.1 THE DEFINED REGION

The Northern Argentine Sea is part of the Southwestern Atlantic Ocean, extending from ~35°S to 42°S (Fig. 33.1). The continental shelf is with a very low relief and a general slope of less than 0.01 degree (Cavallotto, Violante, & Hernández-Molina, 2011). Argentina's continental margin is longer than 3500 km, with an average width of ~400 km (Preu, Hernández-Molina, Violante, Piola, et al., 2013). It originated during the Late Jurassic-Early Cretaceous (c.140 My ago), when the opening of the South Atlantic took place (Marcovecchio, De Marco, & Melo, 2017). The width of the shelf within this area varies from ~140 km in the northern area of Río de La Plata outfall, to ~540 km at San Matías Gulf (SMG), with maximum depth of 70–80 m, reaching ~200 m at the shelf edge, to ~160 m within the SMG (Mouzo, 2014).

The main oceanographic features are the encounter of the Brazil and Malvinas/Falkland currents (MCs), producing the Brasil-Malvinas/Falkland Confluence Zone (BMCZ), a complex of mixed waters located between 35°S and 40°S. This region is marked by a strong front formed by the warm, high saline, and low productivity waters of the Brazil Current (BC), and the cold, less saline, and highly productive waters of the MC, and is characterized by intense horizontal and vertical mixing and a seasonal pattern of current intensification and latitudinal instability (Piola, Campos, Möller Jr., Charo, & Martinez, 2000). In the confluence zone, the subantarctic and subtropical waters mix, forming vortices, meanders, and strong vertical and horizontal temperature and salinity gradients, as well as restricted areas of enhanced chlorophyll build-up, isolated upwelling cells, tongues, and patches of cold or warm waters partly or completely isolated from their water mass of origin, and so on. South of 37°S, three water masses are identified: shelf break (outer shelf) water of relatively high salinity (33.7–34), middle shelf water with relatively low values (33.4–33.6), and coastal (inner shelf) waters with values relatively higher (>34).

33.2 NATURAL ENVIRONMENTAL VARIABLES, SEASONALITY

33.2.1 Average Climatic Trends

Wind stress is modulated by the displacement of the South Atlantic subtropical anticyclone (Palma, Matano, Piola, & Sitz, 2004), a high-pressure system centered over the subtropical southern Atlantic Ocean. The seasonal cycle of the high-pressure system is mainly controlled by convective heat sources over South America and southern Africa, and plays a major role in austral winter climatology (Miyasaka & Nakamura, 2010). During winter, the offshore area is marked by very strong westerly stress exerted by the wind on the sea surface, with anticyclonic wind stress curl in an offshore band parallel to the coastline. During summer, the magnitude of the wind stress is reduced, and the region of strong westerly stress in the offshore area is lessened south of 35°S (Marshall & Speer, 2012). The variability of regional weather is also related to large-scale climate modes such as the El Niño-Southern Oscillation (ENSO) and the Southern Annular Mode (SAM). ENSO drives part of the interannual variability of rainfall and sea surface temperature (SST) in the SWAO (Colberg, Reason, & Rodgers, 2004). SST anomalies generally start weakly positive in the warm phase over the SWAO and cools by

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FIG. 33.1 Map of the North Argentine region.

the mature phase, while the anomalies are roughly the reverse during the cold phase. The SAM mode is the main driver of climate variability at mid to high latitudes in the Southern Hemisphere (Marshall, 2003). ENSO and SAM indirectly shapes biotic communities through their effect on local climate; for instance, El Niño years promote a decrease in phytoplankton biomass through their effect on nutrient concentration and river runoff in the Río de la Plata Estuary (Sathicq, Bauer, & Gómez, 2015). The shift of westerly winds driven by positive anomalies of SAM, promotes a deepening of the mixing layer and light attenuation that in turn, reduces chlorophyll concentration in the subantartic zone (Lovenduski & Gruber, 2005).

Circulation patterns and tidal dynamics within the Argentinean Shelf favor the development of highly productive frontal systems (Acha, Mianzan, Guerrero, Favero, & Bava, 2004). Water column stability is strongest in summer and may vanish in winter. The coastal shelf area is characterized by strong tidal mixing, which may homogenize the whole water column in shallower areas (Olguín & Alder, 2011). Consequently, during the summer, numerous shelf sea fronts occur (Matano, Palma, & Piola, 2010).

Shelf waters result from the mixing of coastal, subantarctic, subtropical, and mixed waters. Subantarctic shelf waters are diluted by low salinity discharges from Magellan Strait, and modified seasonally by the outflow of high salinity waters from SMG in the middle shelf (Palma & Matano, 2012), freshwater from the Río Negro and Río Colorado and periodic intrusions of oceanic waters (Piola et al., 2010). Considering salinity variations along the shelf are relatively large, this parameter usefully describes the water masses within the continental shelf (Fig. 33.2). Muelbert, Acha, Mianzan, Guerrero, et al. (2008) suggested that the abundance distribution of Chl-*a*, copepods, and ichthyoplankton was related to the Río de La Plata Plume Waters (PPW), rather than to the presence of the subtropical shelf front (STSF).

The northern region is microtidal, changing to mesotidal on the southeast coast of Buenos Aires Province. SMG is macrotidal (Piccolo, 1998).

33.2.2 Nutrient and Chemical Environment

Continental shelf waters are characterized by three subantarctic water masses: (a) internal shelf; (b) middle or central shelf; and (c) external shelf or slope, and all are nutrient enriched (both N and P), fertilizing annually the Argentine continental shelf (Brandini et al., 2000). Owing to the increase of salinity, temperature or density horizontal gradients within the shelf,

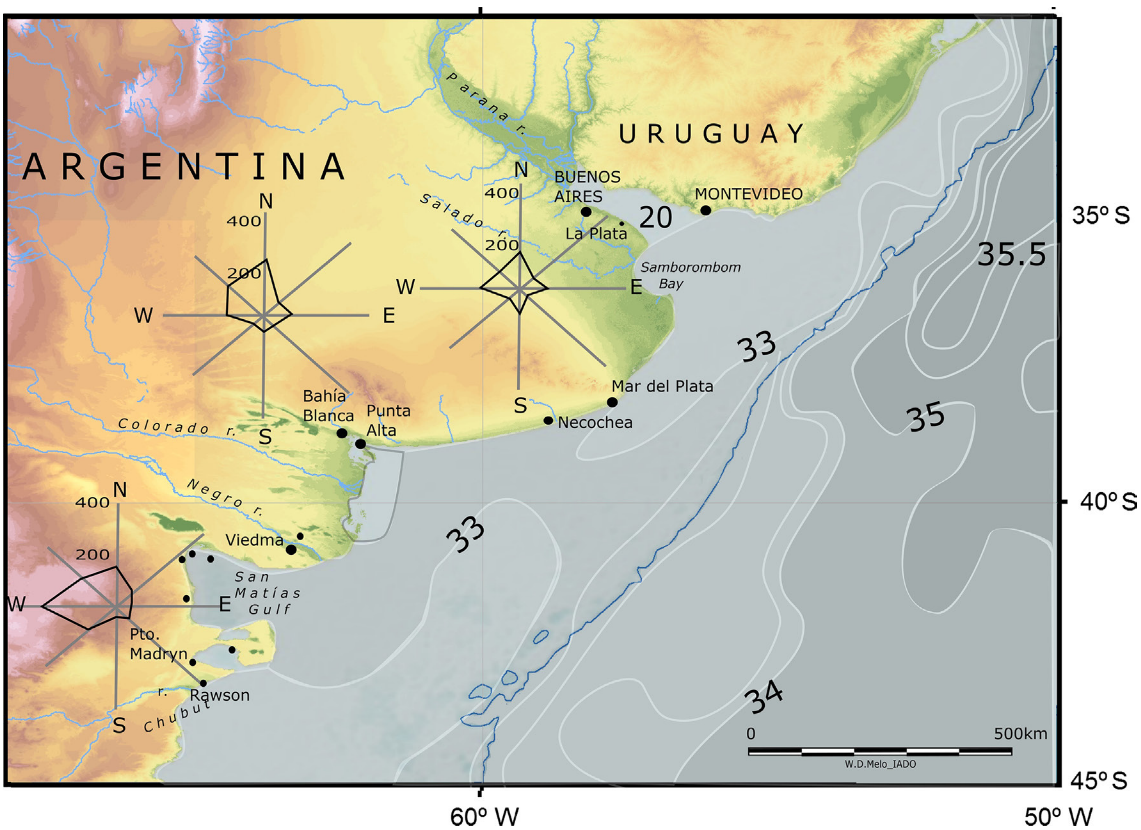

FIG. 33.2 Annual mean distribution of surface salinity for the study area. *(Modified from Perillo, G. M. E., Piccolo, M. C., & Marcovecchio, J. E. (2006). In A. R. Robinson & K. H. Brink (Eds.),* The Sea. The Global Coastal Ocean: Interdisciplinary *regional* studies and syntheses, *Vol. 14–Part A, Ch. 9 (pp. 295–327), Cambridge, Massachusetts: Harvard University Press (ISBN-0-674-01527-4).*

several frontal areas are developed: tidal fronts and slope fronts, acting as retention zones, accumulating not only nutrients but also other dissolved compounds and particulate matter (i.e., detritus, plankton, eggs, and larvae) that generate highly productive areas. In the northern area of the shelf is the subtropical confluence, due to the meeting of the Malvinas-Falkland and BCs, generating many frontal systems between the internal shelf and the slope (Combes & Matano, 2014).

The most productive waters are those within the broad frontal system of the Brazil-Malvinas-Falkland Confluence Zone (BMCZ), enhancing chlorophyll *a* concentrations not only on well-defined fronts but also in the more homogeneous areas between. Thus, the mixing between the nutrient-rich and vertically unstable subantarctic waters and the nutrient-poor warm subtropical waters is responsible for environmental conditions, which allow enhanced phytoplanktonic growth (Marcovecchio, Freije, & Depetris, 2010). Shelf waters show a clear seasonal stratification during spring and summer, but from early autumn and during winter, stratification is broken because of both mechanical mixing and convective processes, homogenizing nutrient distribution along the whole water column (Perillo, Piccolo, & Marcovecchio, 2006).

Coastal waters are usually homogeneous or have minor stratification, showing a strong interaction with inflowing freshwater. Their nutrient loads also have an annual cycle due to inputs from land sources. The highest production levels are in littoral systems of Buenos Aires Province such as Bahía Blanca Estuary, Mar Chiquita coastal lagoon (MCCL) (Fig. 33.3)

FIG. 33.3 Saltmarshes at Buenos Aires Province littoral. (A) Mar Chiquita coastal lagoon. (B) Bahía Blanca estuary.

(Spetter, Buzzi, Fernández, Cuadrado, & Marcovecchio, 2015; De Marco, Beltrame, Freije, & Marcovecchio, 2005), in frontal systems linked to the outlet of large rivers (i.e., Río de la Plata, Río Negro), or in systems with reduced water exchange with the shelf area (i.e., SMG) (Marcovecchio et al., 2010) (Box 33.1).

Considering their oceanographic, geologic and geographic characteristics, as well as the location of the main urban and/or industrial centers, three areas are potential sources of pollutants: (i) Río de la Plata Estuary; (ii) Bahía Blanca Estuary; and (iii) SMG and San Antonio Bay (Fig. 33.4).

BOX 33.1 Mar Chiquita Coastal Lagoon: A Unesco Biosphere Reserve

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Coastal lagoons are considered to be among the most productive estuarine environments (Kennish & Paerl, 2010). Mar Chiquita coastal lagoon (MCCL) is unique within Buenos Aires Province, and has been the subject of numerous scientific studies (De Marco et al., 2005; Marcovecchio et al., 2006).

It is located between 37°33′ and 37°43′S and 57°15′ and 57°30′W, 32 km north-east of Mar del Plata City (Fig. B33.1). MCCL was declared a World Biosphere Reserve in April 1996, and in 1999, the Government of the Province of Buenos Aires included it in the regime of Parks and Natural Reserves (Provincial Law 10,907/99), categorizing it as a Natural Reserve of multiple use (Bertoni, Volpato, López, & González, 2007).

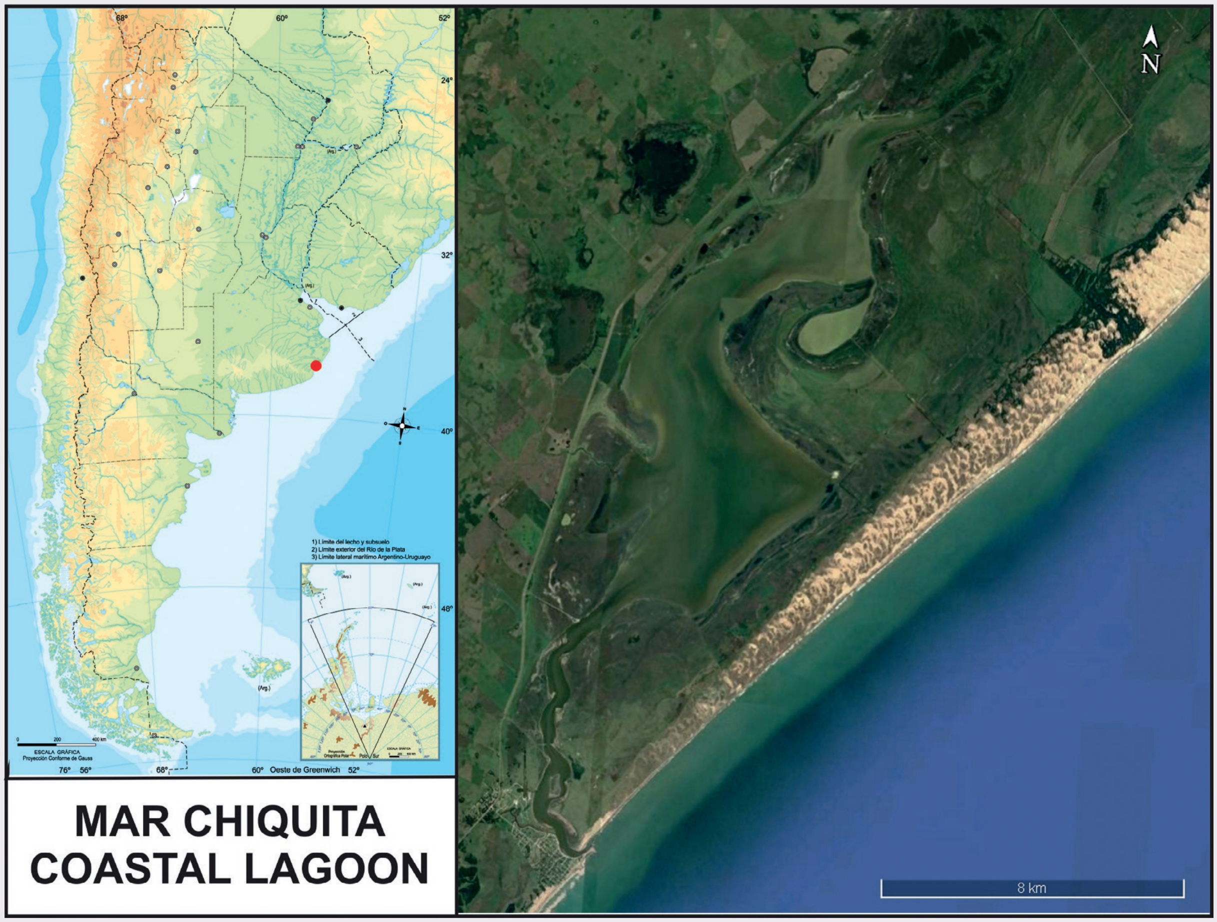

FIG. B33.1 Mar Chiquita Coastal Lagoon, in the Atlantic coast of Buenos Aires province.

Continued

BOX 33.1 Mar Chiquita Coastal Lagoon: A Unesco Biosphere Reserve—cont'd

The lagoon has an area of ~60 km^2, with a tributary basin of ~10,000 km^2. A chain of dunes developed over a Pleistocene wide barrier separates the lagoon from the ocean. Its shape is irregular, and its bottom topography very smooth, reaching a maximum depth of 1.50 m below the mean spring low-tide level, without vertical stratification (Marcovecchio et al., 2006). Two different subareas have been described: a marine/estuarine subsystem with salinity varying from 22.4 and 28.75 ppt; and an oligohaline part (with salinity varying between 1.1 and 11.35 ppt). The extent of water exchange depends on the tidal amplitude, volume of inflowing freshwater and winds (Marcovecchio et al., 2006).

The lagoon is connected to the sea through an elongated inlet channel of approximately 6 km length and more than 200 m width. Freshwater influence is more significant than that of seawater and its main input is continental drainage. Average rainfall is about 900 mm $year^{-1}$.

During the last five decades, Mar Chiquita's weather has included severe storms with strong winds and hail, as well as the occasional torrential rainfall (González Trilla, De Marco, Marcovecchio, Vicari, & Kandus, 2010). On the other hand, the geomorphology considerably changed with the construction of a bridge in the 1970s at the head of the marine influenced area which induced shoaling within the inlet (Piccolo & Perillo, 1999).

The MCBR includes the coastal lagoon surrounded by low lands with mainly halophyte grasslands (*espartillares* with cordgrass *Spartina densiflora*, and *hunquillares* with *Juncus acutus*), high lands with modified pampean grasslands (*flechillares* represented by a steppe of grasses—Poaceae—of 1–1.5 m in height), coastal dunes, crops, *talares* (small forests of *Celtis tala*) and cultivated hills (Bó, Isaach, Malizia, & Martínez, 2002). Surrounding areas of this Reserve are farmed, causing significant impacts from fertilizers, pesticides, or chemicals used for animal health. In the lagoon, diatoms dominate throughout the year, and blooms of dinoflagellates (i.e., *Gymnodinium* sp.) or cyanophytes (i.e., *Anabaenopsis* sp. or *Merismopedia* sp.) occur in the inner area (De Marco, 2002; De Marco et al., 2005).

MCBR has a very wide biodiversity. Key species include three crabs (*Chasmagnathus granulata, Uca uruguayensis*, and *Cyrtograpsus angulatus*), razor clam (*Tagelus gibbus*), two polychaetes (*Laeonereis pandoensis* and *Mercierella enigmatica* (*Ficopomatus enigmaticus*)) and the snail *Littoridina australis* among others (Olivier, Escofet, Penchaszadeh, & Orensanz, 1972a, 1972b). Two ecosystem engineer species are the burrowing crab *N.* (*Chasmagnathus*) *granulata*, and the reef building polychaete *F. enigmaticus* (Sal Moyano, Luppi, Gavio, Vallina, & McLay, 2012), which have helped to modify the environment. The crabs *N.* (*Chasmagnathus*) *granulata*, *C. angulatus, U. uruguayensis*) are a significant food source for birds and fish in the coastal lagoon (Blasina, Barbini, & Díaz de Astarloa, 2010). Furthermore, Bó et al. (2002) have identified a herpetofauna of 10 amphibians and 17 reptiles species: 3 sea turtles, 5 lizards, and 9 snakes (Vega, 2001). Many species of birds live in or visit the coastal lagoon and related environments, and 182 species have been recorded, with around 80 migrant species and around 100 which live permanently linked to this environment (Ferrero, 2001). Several of the species (i.e., Neotropic Cormorants, American Oystercatchers, gulls, terns, and Black Skimmers between others) use MCCL and related environments as refueling or wintering area, due to the high food availability. The most conspicuous fish species are *P. orbignyanus* and *Oncopterus darwinii*, mullets—*Mugil curema* and *Mugil platanus*—black drum *P. cromis*, whitemouth croaker *M. furnieri*, the silver side *Odontesthes argentinensis*, or the Florida Pompano *Trachinotus carolinus* (Díaz de Astarloa, Figueroa, Cousseau, & Barragán, 2000; Blasina et al., 2010).

Human Impacts

Intense agriculture generates intense environmental pressure on the lagoon. Native grasslands have been replaced by farms (Quirós et al., 2006). The occurrence and distribution of several pollutants in water, sediments, suspended particulate matter, and organisms has been reported, especially organochlorine pesticides (OCs) and polychlorinated biphenyls (PCBs) (Menone et al., 2001), trace metals (Beltrame, De Marco, & Marcovecchio, 2009; Beltrame, De Marco, & Marcovecchio, 2011) (Silva-Barni, González, & Miglioranza, 2014).

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BOX 33.1 Mar Chiquita Coastal Lagoon: A Unesco Biosphere Reserve—cont'd

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(1) Río de la Plata Estuary

This includes the largest urban and industrial centers of Argentina and Uruguay, and residues of metallurgical, textile, petrochemical, and pharmacological industries are dumped there. The main harbors of both countries are located in the same zone (i.e., Buenos Aires, Montevideo). Different levels of hydrocarbons and pesticides (Colombo et al., 2011) as well as heavy metals (Marcovecchio, 2004) have been recorded both in sediments and water as well as in the organisms from the area. It is one of the most severely stressed coastal environments within the region (Lacerda & Marcovecchio, 2014).

(2) Bahía Blanca Estuary

The semi-enclosed estuary has a very limited exchange with the adjacent continental shelf. It is the location of large petrochemical refineries and reservoirs, synthetic compounds, pesticide and fertilizer factories, cold-storage plants, and cereal silos (Marcovecchio & Freije, 2004). Heavy metals, urban and agricultural pesticides, oil and its hydrocarbons, petrochemical residues, and organic materials with high chemical and biochemical oxygen demands occur in this area (Freije et al., 2008; Marcovecchio et al., 2008).

(3) SMG and San Antonio Bay

This large area has abundant fishery resources as well as the potentially most contaminating anthropogenic activities, from iron mining and processing, and the location of a chloralkali plant (currently discontinued). Esteves et al. (1996) have reported heavy metal residues in sediments close to San Antonio harbor, including extremely high Pb concentrations close to the old chloralkali plant. Also, hydrocarbons and persistent organic pollutants (POPs) (Commendatore & Esteves, 2007; Arias, Buzzi, Pereira, & Marcovecchio, 2011) and metals (Idaszkin, Lancelotti, Bouza, & Marcovecchio, 2015; Idaszkin, Lancelotti, Pollicelli, Marcovecchio, & Bouza, 2017) have been reported. But overall, coastal waters from this region (Fig. 33.5) are not severely polluted, even though localized anthropic inputs impact the littoral system.

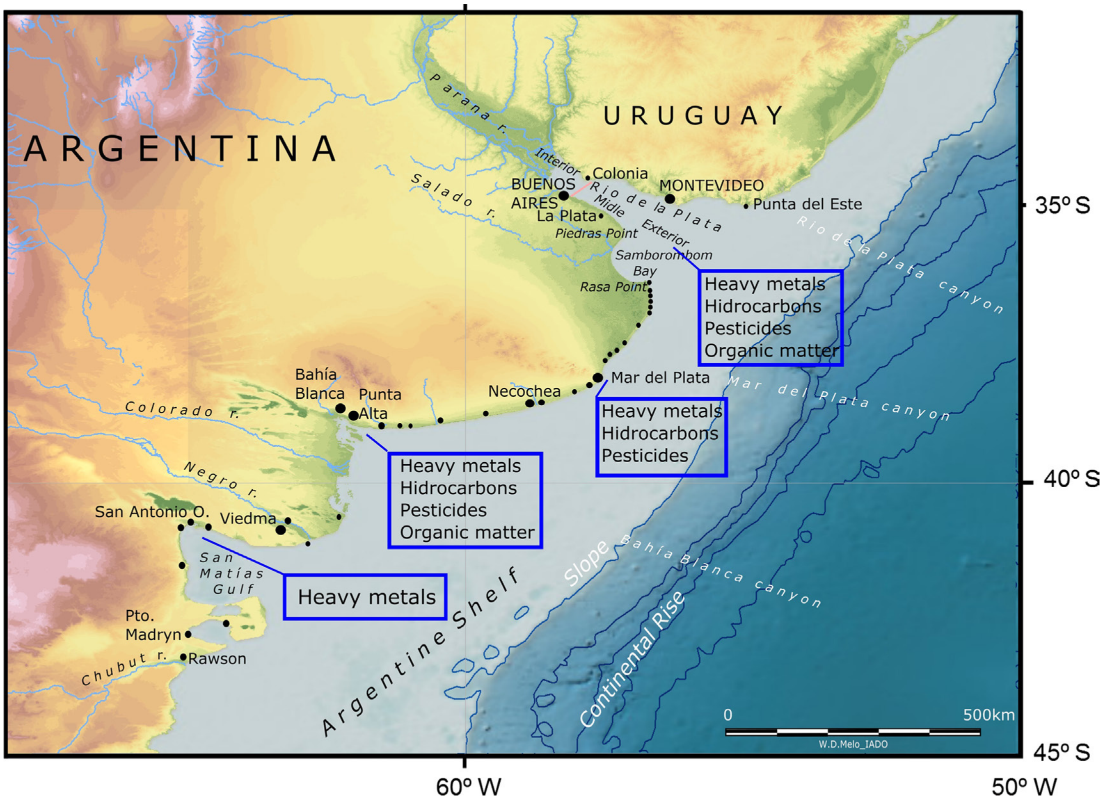

FIG. 33.4 Location of coastal systems with potentially pollutant sources within the Northern Argentina Sea, detailing those for Río de La Plata estuary, Bahía Blanca estuary, and San Matías Gulf.

FIG. 33.5 Cliffs in the San Matías Gulf.

33.3 MAJOR COASTAL AND SHALLOW HABITATS

33.3.1 Coastal Area of Buenos Aires Province

Buenos Aires coastal area from Bahía Samborombón to the mouth of Río Negro is characterized by extended sandy beaches (Fig. 33.6) and numerous isolated hard bottoms of either consolidated sedimentary or quartzite rocks (Genzano, Giberto, & Bremec, 2011) with tide pools of different size and shapes. Small mussel beds of the mytilid *Brachydontes rodriguezii* are dominant on intertidal rocky substrata where benthic macroalgae *Ulva, Chaetomorpha, Polysiphonia*, and *Porphyra* are present during the summer (Becherucci, Lucerito, Benavides, & Vallarino, 2016). These small mussel beds are habitats for numerous amphipods, isopods, crabs, gastropods, polychaetes, and nemerteans (Cao & Darrigran, 2016). Exposed sandy

FIG. 33.6 Coastline at Punta Indio, in the Northern Buenos Aires Province (Close to Río de la Plata outflow).

beaches are characterized by the presence of the yellow clam *Mesodesma macroides*. Mass mortality events of this clam were reported for Brazil and Uruguay in 1993–94 and 1995 in Argentina (Fiori & Cazzaniga, 1999; Bastida, Rodríguez, Secchi, & Da Silva, 2007). Its abundance tends to occur with La Niña and El Niño events (Manta, Barreiro, Ortega, & Defeo, 2017).

In estuarine environments, intertidal saltmarsh vegetation of *Spartina* and *Sarcocornia* are dominant along the coastal zone of the Buenos Aires Province (Isacch et al., 2006). The burrowing crab *Neohelice granulata* is a keystone species in saltmarshes, mudflats, and estuaries, reaching densities >100 individuals m^{-2} (Spivak, 2010). It is an "ecological ecosystem engineer" that can remove 2.5 $kg\,m^{-2}\,day^{-1}$ of sediment (Iribarne, Bortolus, & Botto, 1997), affecting the activity of other crabs, polychaetes, and other benthic invertebrates.

33.3.2 Coastal Areas of SMG

The west coast of the gulf shows extended rocky intertidal shores characterized by tidal pools with the small mussel *B. rodriguezii* and *Pecten purpuratus* as the dominant species, and the presence of various algae, crabs, echinoderms, and gastropods (Narvarte, González, & Fernández, 2006). San Antonio bay, located on the northwest of SMG is 160 km^2 and is a shallow water system with semidiurnal tides between 6 and 9 m in range. The bay has several channels and extensive tidal flats, with sandy-pebbly bottoms, surrounded by salt marshes (Isacch et al., 2006). The crab *N. granulata*, the mussel *B. rodriguezii*, and the sponge *Hymeniacidon perlevis* are the most conspicuous macrofaunal species in the exposed intertidal and form extensive beds.

33.4 OFFSHORE SYSTEMS

In the Río de La Plata estuary (8–15 m depth), the bivalve *Mactra isabellana* and the shrimp *Artemesia longinaris* are the most abundant species in muddy substrates. The adjacent marine zone (17–50 m depth) has different substrates including sand, shells and gravel with mollusks, crustaceans, echinoderms, and polychaetes (Bastida et al., 2007).

33.4.1 The SMG

The SMG is a semienclosed basin (~20,000 km^2) located in northern Patagonia between 40°47′S and 42°13′S. While 55% of the gulf is deeper than 100 m, the central area reaches 180 m depth. Even though there is no direct river discharge into the gulf, its northern part is influenced by the Río Negro, which has a flow rate of about 1000 $m^3\,s^{-1}$ (Guerrero & Piola, 1997). There is a seasonal cycle, typical of subtropical waters where the rate of primary production is relatively stable in autumn-winter and with peaks in late spring. The general circulation pattern in spring-summer is dominated by a cyclonic gyre, located at the northern half of the basin, which in combination with the frontal system determines the relative isolation of the northern water masses (Tonini, 2010).

33.5 CLIMATE CHANGE IMPACTS

All areas are vulnerable to potential floods caused by sea level rises, albeit with different risk rates. The northern part has already been shown to be very fragile in the face of changes in the water levels of the system, and throughout the 20th century and particularly in the 21st, numerous floods have been recorded (Pappenberger, Dutra, Wetterhall, & Cloke, 2012), mainly due to changes in the rainfall and drainage regime of the basin, and linked to the phenomenon of *sudestadas* previously mentioned (Depetris, Probst, Pasquini, & Gaiero, 2003). Haylock et al. (2006) reported an increasing trend in precipitation in the northern part of the Paraná basin, positively correlated with the South Atlantic temperature. Vincent et al. (2005) observed a warming of night temperatures, which allows a more sustained heat exchange between the ocean and the atmosphere. Rignot, Rivera, and Casassa (2003) studied the recorded loss within the 63 largest glaciers from Patagonia during the 1968–2000 period, concluding that the mass of melted ice brought into the Atlantic Ocean was equivalent to a sea level rise of $0.042 \pm 0.002\,\mathrm{mm\,year^{-1}}$, although during 1995–2000 the increase was $0.105 \pm 0.011\,\mathrm{mm\,year^{-1}}$. Finally, Arias, Piccolo, Spetter, Freije, and Marcovecchio (2012) studied a long series of temporal data in the Bahía Blanca estuary, and were able to verify the existence of a tight relationship between the salinity of the system and precipitation, with a very fast response to changes. They recorded the presence of marked anomalies in the temporal distribution of temperature, and, agreeing with Marcovecchio and Freije (2004) attributed those variations to the adjusted correlation between the temperature of the estuarine water and the associated atmospheric temperature. This allows the conclusion that changes in air temperature or precipitation rapidly modify the thermohaline condition within the estuary.

Finally, acidification of the oceans must also be considered (Doney, Fabry, Feely, & Kleypas, 2009). In the Argentine coast, there are well-differentiated CO_2 sources and sinks. To the south, the Patagonia platform in the area closest to the coast is a source of CO_2 to the atmosphere, while the middle and outer regions (near the slope) act as a sink (Bianchi, Ruiz-Pino, Isbert Perlender, Osiroff, et al., 2009). The transition between sources and sinks is related to the tidal fronts that develop in spring and autumn between the masses of vertically homogeneous coastal waters and the stratified ones within the middle and outer zone of the platform. Throughout the year, the net balance of CO_2 indicates that the Patagonia Sea acts as an important CO_2 sink (Bianchi et al., 2009), while to the north the southeastern Brazil platform and the slope act as sources of CO_2 throughout the year (Gonçalves Ito, Schneider, & Thomas, 2005) (Box 33.2).

BOX 33.2 Invasive Species in the Argentinian Coast

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In the Argentinean coastline, at least 41 non-native species plus 50 species with a cryptogenic status have been recorded (Orensanz et al., 2002) from a wide range of taxa. Most have been introduced in ballast waters, while a small proportion were introduced for commercial culture. Since ocean shipping is considered the most important vector for transporting and introducing marine species, harbors are commonly hot spots for invasive species introductions (Ruiz, Fegley, Fofonoff, Cheng, & Lemaitre, 2006). Argentina has 13 major marine ports with a few marinas for recreational activities (Boltovskoy, 2008). Schwindt et al. (2014) identified and quantified marine fouling organisms in all Patagonian ports, which represent 77% of all Argentinian ports. They found 247 fouling species, including 17 introduced, one of which is a new record for the region, and another 15 species currently considered cryptogenic of unconfirmed status. According to Boltovskoy, Almada, and Correa (2011), the number of nonindigenous marine species recorded in Argentina may be considered below those reported for other regions because most incoming ship traffic originates from domestic ports or from areas unlikely to supply nonindigenous species. Nevertheless, this situation could be partially because of incomplete knowledge of coastal biodiversity.

Some of the species introduced have had significant ecological impacts, as is the case of *C. gigas* (Thunberg, 1793); *F. enigmaticus* (Fauvel, 1923), and *Undaria pinnatifida* (Harvey) (Suringar, 1873).

The Pacific oyster, *C. gigas*, originally from Japan, was introduced in Argentina in 1982 for a failed oyster-culture operation in San Blas Bay. Only 5 years later it spread more widely (Borges, 2006). Since then, it has spread both northward (38°S) and southward (41°S), and it is probably still expanding (Carrasco & Baron, 2010). The complex habitat formed by the shells of grouped oysters seriously alters the invaded habitats and communities. In addition to its effects on native ecosystems, the species is associated with a potential risk to public health, due to consumption of oysters harvested from areas contaminated by domestic sewage and industrial effluents (Fiori, Pratolongo, Carbone, Zalba, & Bravo, 2016).

BOX 33.2 Invasive Species in the Argentinian Coast—cont'd

The invasive reef-building polychaete, *F. enigmaticus* is distributed worldwide in temperate estuarine environments (ten & Weerdenburg, 1978). In Argentina, there is no evidence of the presence of its conspicuous reefs in Holocene deposits, indicating its exotic origin. In Mar Chiquita coastal lagoon (37°S) a UNESCO Man and the Biosphere Reserve, reefs cover up to 86% of the total area of the lagoon, with individual aggregations reaching up to 2 m in diameter (Schwindt, Iribarne, & Isla, 2004). These interfere with sport fishing and other recreational activities and have an ecological impact that includes controlling phytoplankton extracted by its filtering and increasing in benthic-pelagic coupling. In turn, *F. enigmaticus* reefs produce subsidies for primary macroalgae production (Bazterrica, Botto, & Iribarne, 2012).

The kelp *Undaria pinnatifida* is a successful invasive seaweed native to northeast Asia that has spread along a large area of the Patagonian coast (Casas, Scrosati, & Piriz, 2004). Its presence is associated with a dramatic decrease in species richness and diversity of native seaweeds, affecting populations of the agar-producing red alga *Gracilaria* and settling on shellfish commercial beds (Casas et al., 2004).

Argentina is implementing a policy to prevent their impacts mostly based on the prevention of new introductions. Anticipating the entry into force of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM, IMO), in February 2017, the Ministry of the Environment established the obligation of any international vessel coming from foreign ports to comply with secure ballast management procedures. Also, the National Strategy on Invasive Alien Species presently under construction includes an early detection and rapid response module to be initially implemented in four of the main export harbors of the country. Other actions like completing species surveys and organizing data in a national information system, strengthening expert networks, developing risk assessments, and promoting regional coordination with neighboring countries are also under development in order to minimize the effects of what probably is the most challenging single threat to the remarkable biodiversity of the southern Atlantic.

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BOX 33.2 Invasive Species in the Argentinian Coast—cont'd

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33.6 HUMAN POPULATIONS AFFECTING THE AREA

33.6.1 Impact of Urbanization and Activities

Argentina's population is over 43 million people, with a heterogeneous distribution, including ~21 million (~48.3%) living within the coastal zone or nearby (INDEC, 2010). Most of this population lives within this study area (IGN, 2017). Buenos Aires (Argentina's capital) and its metropolitan area includes ~15 million inhabitants as well as the largest industrial nucleus and harbor, all located on the southern margin of La Plata river or within its basin. Approximately 60 km south of Buenos Aires is La Plata and its metropolitan area (~800,000 inhabitants), also including a large industrial and port center.

Along the Buenos Aires Province, numerous small- to medium-size cities occur, and to the south is Mar del Plata city (~750,000 inhabitants during winter but close to 3.5 million in summer) recognized as being the main touristic center on Argentina's coast (Ministerio de Turismo-Argentina, 2014), and also one of the largest fishing ports in the country. Further south is Necochea (important tourist center) and Quequén (one of the largest ports). From this point toward the mouth of Bahía Blanca estuary, there are several little towns with intense tourist activity during summer (i.e., Claromecó, Pehuén-Có, Monte Hermoso). In the inner area of the latter is Bahía Blanca city (~350,000 inhabitants), and one of the largest harbor complexes within the country, associated with a very big and diverse industrial hub. Finally, in the Province of Río Negro, is the city of San Antonio (~25,000 inhabitants), with another large port complex linked to the export of products.

Marcovecchio (2000) and Marcovecchio et al. (2010) identified Río de La Plata estuary as the main pollution hotspot, considering not only the occurrence of the largest cities, industrial centers, and harbors but also the strong influence of the huge Río de La Plata basin (including the outflow of both the Paraná and the Uruguay river systems), which drains ~3.1 million km^2 (Berbery & Barros, 2002). Large cities, industrial parks, and harbors (i.e., Rosario, Santa Fe, Paraná, Corrientes) are also located along these rivers, and their effluents are dumped into the Río de La Plata (Marcovecchio et al., 2010). Industries include petrochemicals, textiles, metal-mechanical devices, vehicles and supplies, pharmaceutical, manufacture of synthetic products, food and beverages, cosmetics and personal care products, and so on (Quirós, 2004).

Moreover, most of the land draining into the Río de La Plata basin is heavily used for agriculture and livestock (Coutinho, Noellemeyer, Jobbagy, Jonathan, & Paruelo, 2009). This activity has expanded from ~1 to ~5 million hectares planted in the last decades (Picardi & Giacchero, 2015). Thus, wheat production reached 10.5 million tons in 2014 (Barberis, 2014), while soybean (which began to develop in late 1970s) reached more than 52 million tons in the same year (Strada & Vila, 2014). Furthermore, the sowing and production of other cereals such as corn, sunflower, oats, barley, rye, among others, also expanded. This has had significant consequences to the marine system from all the residues of this agriculture, by direct discharge through streams and rivers or by runoff (Brodie, Kroon, Schaffelke, Wolanski, et al., 2012). The application of fertilizer doses ranging 120–150 $kg\,N\,ha^{-1}$, 30 $kg\ P\,ha^{-1}$, and 15 $kg\,S\,ha^{-1}$ in crops of maize, soybean, and wheat within the Southern Pampas area has been reported (Wyngaard, Echeverría, Sainz Rozas, & Divito, 2012), as has the intensive use of herbicides (Costa, Aparicio, & Cerdà, 2015), or other pesticides (De Gerónimo et al., 2014). The transport of these substances has been reported for different environments within Río de La Plata basin (i.e., Ronco, Peluso, Jurado, Rossini, & Salibián, 2008; Colombo et al., 2011).

33.7 RESOURCES

33.7.1 Artisanal and Industrial Fisheries

33.7.1.1 General Overview of the Fisheries of the Southwestern Atlantic Ocean

The fisheries are that of temperate-cold waters, characterized by a relatively low biological diversity, but with high biomass levels of many commercial species. The northern fishery area between 35°S and 42°S is shared with Uruguay through a legal framework initially signed by both countries as a Cooperation treaty in 1973, with the objectives that both countries are able to carry out their fishing activities (CTMFM, 2017).

The Argentine fishing fleet is currently composed of 548 vessels (Table 33.1) (MINAGRI, 2017), including smaller units of coastal and artisanal fleets, deep-sea fishing and processing vessels (freezers and factory) (Elías, Carozza, Di Giácomo, Isla, et al., 2011).

More than 80% of the landings are used for export (Table 33.2), and the domestic market has also expanded in recent years. Fresh and chilled products, frozen, canned, salted, and flour for indirect consumption (feed) and pet food are directed to the internal market. Products derived from hake, both fresh and frozen, are the mainstay of domestic consumption, followed by squid.

TABLE 33.1 Argentine Marine Fishing Fleet With National Permissions

Vessel Type	Numbers
Small scale (Rada/ría)	113
Coastal (near and offshore)	120
Trawlers (fresh)	141
Trawlers (frozen)	40
Beam trawlers (for shrimp)	83
Jiggers (squid)	81
Long-liners	5
Factory vessels (*surimi*)	3
Crab vessels	2
Total	547

(According to González, R. (2015). FAO, Proyecto UTF/ARG/018/ARG; 67p.)

TABLE 33.2 Summary of Fishery Products Exportations 2005–2013 (MINAGRI, 2017)

Year	Tons	M US$
2005	495,580	810,565
2006	627,469	1,248,804
2007	540,367	1,104,018
2008	561,601	1,299,282
2009	484,816	1,118,742
2010	456,471	1,321,874
2011	471,169	1,490,053
2012	431,668	1,332,558
2013	504,165	1,501,892

33.7.1.2 *Types of fisheries between 35°S and 42°S*

(1) Fisheries in the Río de la Plata

Artisanal, sport, and commercial fisheries (both in the river and marine waters) coexist in this area. Species of higher commercial value are caught in the lower Rio de la Plata: white-mouth croaker *Micropogonias furnieri*, and the stripped weakfish *Cynoscion guatucupa*. Other commercial species are the Patagonian smooth-hound *Mustelus schmitti*, the black croaker *Pogonias cromis*, the flounder *Paralichthys orbignyanus*, and the king weakfish *Macrodon ancylodon* (Casal & Prenski, 2000).

(2) Fisheries in the Common Fishing Zone (ZCP)

The main commercial resource is the Argentine hake *Merluccius hubbsi*, and its associated fauna, including the pink cusk-eel *Genypterus blacodes*, hawk-fish *Cheilodactylus bergi*, and grouper *Acanthistius brasiliensis*. The mean annual Argentine hake catch in the ZCP for the period 2015–16 was 5105.2 tons. Other relevant resources are the anchovy *Engraulis anchoita*, and the Argentine squid, with mean annual catches (2015–16 period) of 6692.4 and 2716.3 tons, respectively.

(3) Fisheries in the Exclusive Economic Zone (EEZ) and Buenos Aires Province

The demersal group (i.e., Argentine hake, squid, shrimp *Pleoticus muelleri*, hake *Macruronus magellanicus*, pink cusk-eel, white-mouth croaker, and red whiting) is the most important within the EEZ, followed by the pelagic group (scomber *Scomber japonicus*, anchovy *E. anchoita*) and benthic (*Zygochlamys patagonica*) (Table 33.3).

TABLE 33.3 Annual Landings (t) of the Main Commercial Species of EEZ Registered in the 2008–2016 Period (MINAGRI, 2017)

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Hake	263,323	280,679	281,757	287,780	257,983	275,705	258,785	266,259	282,856
Squid	255,531	72,604	85,991	76,592	94,932	191,721	168,792	126,671	60,280
Pollock	19,841	21,677	11,636	3518	8375	7975	9016	13,831	13,147
Patagonian grenadier	110,269	110,717	82,855	70,903	59,517	56,196	57,946	50,469	34,925
Shrimp	47,406	53,693	72,938	82,895	79,715	100,671	126,251	142,796	172,827
Pink cusk-eel	17,558	16,694	16,357	16,276	10,086	6692	5735	5238	3300
Anchovy	22,887	27,754	26,450	21,084	15,434	18,077	13,948	14,411	8713
Black hake	2170	2434	3015	2989	3278	3464	4012	3719	3656
White-mouth croaker	22,417	26,620	25,273	24,097	37,798	45,511	38,563	31,359	31,959
Stripped weak fish	15,158	13,239	13,669	13,583	15,081	16,395	14,939	16,898	9,884
Scomber	13,354	12,830	27,437	28,253	20,732	18,161	7639	18,270	11,988
Scallop	8223	11,300	7125	6701	5095	5911	4584	4430	4977
Others	135,212	125,877	110,742	98,393	83,459	76,004	73,094	71,167	61,792
Total	933,349	776,118	765,245	733,063	691,486	822,483	783,304	765,520	700,300

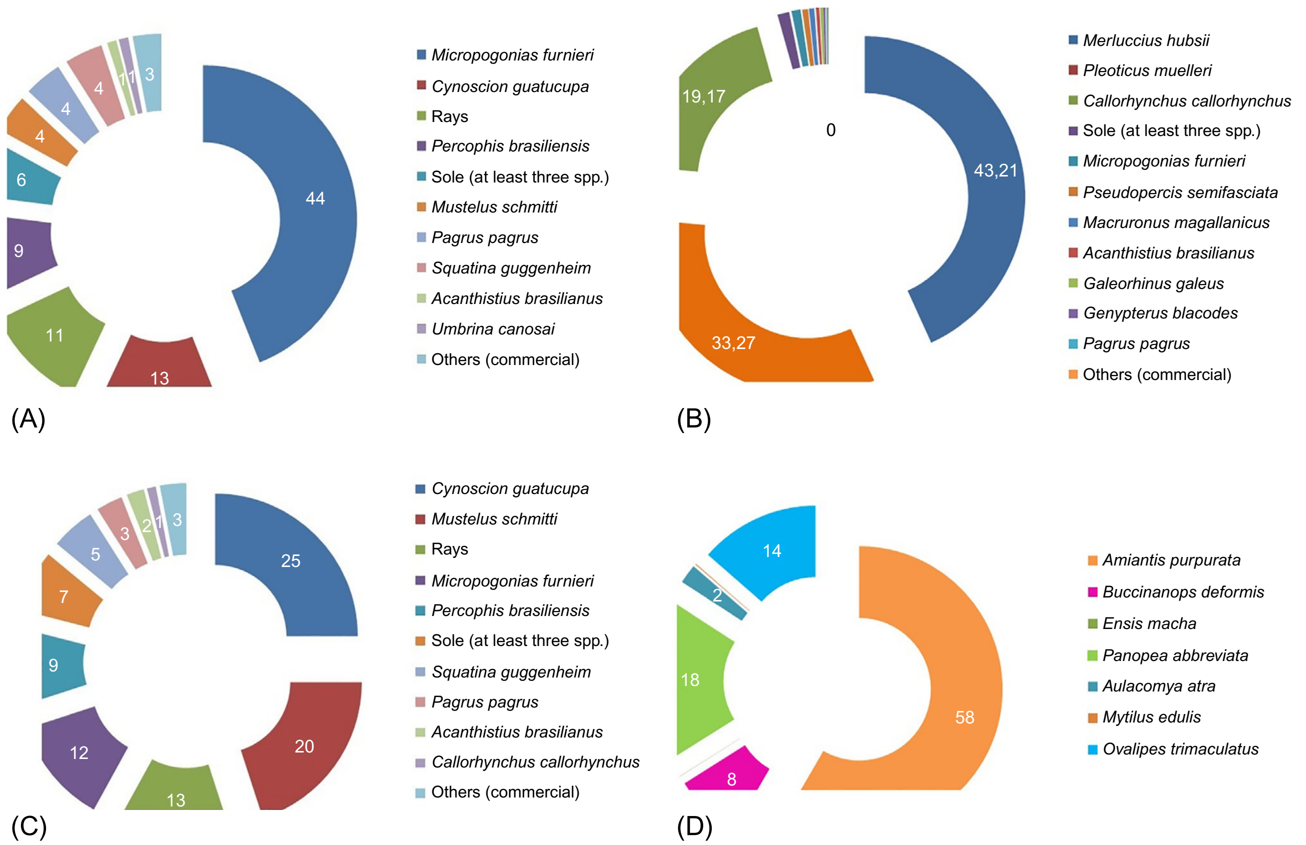

FIG. 33.7 Species composition of the catches for the period 2015–16 (%) in: (A) the demersal fishery of EEZ and Buenos Aires Province; (B) the demersal fishery in the protected zone El Rincón (south Buenos Aires Province); (C) the demersal catches in San Matías Gulf (Río Negro Province); and (D) the shellfisheries of San Matías Gulf.

Argentine hake is the dominant species, corresponding to 40%–50% of the total volume (Fundación Vida Silvestre Argentina, 2008). Since this species was overfished during the 1990s, the fishery focused on several other resources: squid *Illex argentinus*, and the red shrimp *P. muelleri* (MINAGRI, 2017).

From the total annual catch of the coastal fishery (a mean of 73,000 tons in the 2015–16 period), 50% were *M. furnieri* and *C. guatucupa* (Fig. 33.7A).

A special declared zone at the south of Buenos Aires Province, *El Rincón* (39°40′–41°30′ S), where a reduced fishing effort was legally enforced, the mean annual catch in 2015–16 was 4902.5 tons (Fig. 33.7B), more than 50% composed of *C. guatucupa* and *M. schmitti* and at least three species of rays.

The species of the coastal fishery (regionally known as "coastal variant"), inhabit the coastal zones to 50 m depth at the Buenos Aires coast, and are the target of small-scale fisheries. The fish assemblage composition of the coastal shelf showed a clear trend from eurythermic species, associated with the inner coastal assemblage (i.e., *C. guatucupa*, *Myliobatis goodei*, *M. schmitti*, *Squatina guggenheim*), to species mainly associated with relatively colder waters such as *Atlantoraja castelnaui*, *Percophis brasiliensis*, *Discopyge tschudii*, *Pseudopercis semisfasciatus*, *Cheilodactilus bergi* and *Stromateus brasiliensis*, as well as *Trachurus lathami* and *M. hubbsi*, these being typical of the outer coastal shelf (Díaz de Astarloa, Aubone, & Cousseau, 1999).

(4) Fisheries in Río Negro Province

Fisheries of the North-Patagonian gulfs (San Matías, San José, and Nuevo) have traditionally included the Argentine hake, parona leather jack (*Parona signata*), silver warehou (*Seriolella porosa*), haddock, grouper (*Acanthistius brasilianus*), sea salmon *Pseudopercis semifasciatus*), wreckfish (*Polyprion americanus*), southern cod, nototenia, dogfish, Patagonian smoothhound, spiny shark, elephant fish (*Callorhynchus callorhynchus*), and various stripes (Romero et al., 2013).

Since 2013, the Argentine hake *M. hubbsi* and the red shrimp *P. muelleri* have been the most important targeted species, with a mean annual landing of 3001.9 tons for 2015–16 (Fig. 33.7C). The Argentine hake stock from the SMG constitutes a unique independent demographic unit (Di Giácomo, Calvo, Perier, & Morriconi, 1993).

With a relatively lower importance in terms of landings, a varied invertebrate artisanal fishery is carried out in SMG (Narvarte, González, & Filippo, 2007): mussels *Mytilus edulis* and *Aulacomya atra*, and scallop *Aequipecten techuelchus*, clam *Amiantis purpurata*, geoduck *Panopea abbreviata*, and whelk *Buccinanops deformis* (Fig. 33.7D) (Narvarte et al., 2007).

A particular fishery, the most artisanal of the overall study area, is the hand-gathering, intertidal collection of the Patagonian octopus *Octopus tehuelchus* (Narvarte et al., 2006).

33.7.1.3 Processing and Commerce of Fisheries Products

Landings of the traditional high seas fleet are processed on land involving processing and filleting of fresh or chilled fish, frozen fish and shellfish, canning and semipreserving, wet salting, dry salting and preserving, and use of flour and oils. Landings of the smaller fleet mainly supply the domestic market, whether for fresh consumption or providing raw material for canneries and *saladeros*.

Argentinean marine fishery products are basically exported, with the European Union taking the largest volume (FAO, 2010/2015). Although the per capita fish consumption in Argentina is very low, there has been an increase of 80% between 2005 and 2010, from consumption of 2.5–3 kg per person per year to 4.6 kg (Ministry of Agriculture, Livestock and Fisheries-MAGyP, 2014). Almost 80% of the fish is consumed fresh and 40% packaged. About 60% of the fish consumption is located in the city of Buenos Aires and the surrounding area.

33.7.1.4 Factors Contributing to Unsustainability

Government strategy has been aimed at reversing the consequences of strategies implemented in the 1990s, which involved an excessive increase in fishing effort in order to increase exports, which led to critical reductions in fish stocks from the main resources. The Federal Fisheries Council's strategy is to establish annually maximum allowable catches (CMPs) by species, based on the biologically acceptable catches (CBAs) established by INIDEP (National Institute of Fisheries Research from Argentina) each year and to use Individual Transferable Catch Quotas (CITs) for the sector. This criterion has made it possible to adjust species allocations through ITQs and to distribute them according to the seasonality of the resources and their evolution in real time. The new regulatory framework, in turn, promotes the creation of a National Fisheries Fund that is shared with the provinces, and a System of Integral Control of Fishing Activity aimed at strengthening the system of satellite monitoring and surveillance of the closed areas. The Subsecretariat for Fisheries and Aquaculture and the Secretariat for the Environment and Sustainable Development established specific programs with the aim of biodiversity conservation, assessment of incidental fisheries and reducing interactions with birds, reducing catches of chondrichtyes, and avoiding mortality of turtles and marine mammals. At the political level, the MAEyC coordinates international policies and participates in bilateral agreements. The nongovernmental body promotes multidisciplinary research and guides management toward an ecosystem framework, based on the best available reliable scientific information, applying the precautionary approach. It aims to develop a participatory governance scheme that contributes to the generation of consensus among stakeholders and the promotion of responsible fishing practices and diversify the products with added value (González, 2015).

However, control and enforcement of fishing quotas are insufficient, promoting an opening of the fishing grounds to foreign fleets; this trend was accentuated through an access agreement between Argentina and the European Union (1993–97). The increase of illegal, unreported, and unregulated (IUU) catches, the lack of transparency of the fisheries management, and the insufficient implementation of conservation strategies to protect fish stocks, have had negative biological and socioeconomic effects. Other management problems (such as periodic interruption of the vessel monitoring system, misinformation by the catch inspection system, and misreporting of catches of hake), have undermined efforts to control quotas and evaluate the status of the fisheries. Despite efforts in the legal framework, both in national and provincial waters, administrative methods still fail to meet the recovery goals for different resources. The failure originates in the unregulated foreign fishing fleets both in the national as well in the provincial areas, the violation of rules in no-take zones, and the nontransparency of fishery activities in general.

Regarding the research on fisheries, centers at the Argentinian National Council for Scientific and Technical Research (CONICET) carry out projects that cover a broad spectrum of marine and fisheries sciences. However, research objectives are not designed to meet the demands of the fishery administration or to carry out assessments on the state of resources which would allow short-term responses to the problems caused by local fisheries. The concept of an ecosystem approach includes only ecological aspects, and social and economic issues are not considered in most fisheries, and also not addressed are the problems associated with by catch of species and juveniles (González, 2015).

In the case of shell fisheries of Río Negro province, a sustainability assessment was carried out (Narvarte et al., 2007). The following, among others, were the main issues preventing fisheries sustainability: (a) the virtually open access to fishing grounds; (b) irregularity in recruitment of target species producing difficulties in long-term planning (complexity and lack of knowledge concerning biological/ecological processes); (c) a general belief held in the community that the fishery could mitigate all unemployment problems when reduction or collapse occurs in other economic activities; (d) repeated violations of norms and regulations (evident in illegal captures of banned species, violation of established catch quotas, use of prohibited methods); (e) lack of organization among fishers and lack of comprehension of harvesting rights for the resources; (f) poverty, especially related to those engaged in collecting octopus; (g) conflicts with other activities (i.e., the growth of tourism affects the natural habitat of the octopus); (h) lack of initiatives for fishers to develop value-added products at the site of production; and (i) lack of adequate management policies; that is, difficulties to rapidly and efficiently respond to requests for information and technical assistance for sustainable fishery management.

33.7.2 Mariculture

The values of current aquaculture production for the country are not yet clear, mainly due to high production costs (i.e., for food in the case of salmonids), the cost of imported inputs, climatic constraints that reduce the chances of breeding in certain areas, water deficits, dominance of agriculture, and livestock as traditional activities (both accentuated in the last decade by the current strong expansion of the agricultural frontier driven by soybean cultivation) (Wicki, 2011).

In the case of marine aquaculture, the greatest limitation lies on the scarce investment in the sector, bearing in mind that the Argentine Sea has poor oceanographic conditions for the development of ranch-based crops. However, despite its limited development due to a lack of investment and climatic/oceanographic limitations for certain species, culture of marine organisms is under technological development, and includes oysters, mussels, scallop, and some fishes (flounders, sea bream, and a native species of seahorse). Oyster farming in Buenos Aires Province, based on the introduced Pacific oyster *Crassostrea gigas*, has been started as a viable economic alternative for local inhabitants; it mostly involves oyster extraction from naturally colonized beds (Álvarez, Ramiro Duffard, & Ferino, 2012). Also, initiatives of bivalve culture, mainly using longlines and suspended structures moored to the seabottom (i.e., strings for mussels and lanterns for scallops) were tried on an experimental or small commercial scale in SMG (Pascual & Zampatti, 1990; Narvarte, 2001, 2003; Narvarte & Pascual, 2001). Under controlled hatchery conditions, advances were made in larval production from different combinations of sperm and oocytes, larval diets for scallops and oysters, selection of settlement substrates for these both species, and grow out until the spat size is ready to outer-hatchery production (Narvarte & Pascual, 2001, 2003).

The oyster farming started in 1999 based on the introduced species *C. gigas* in Bahía Anegada (Orensanz et al., 2002), the main productive zone for this species in Argentina. It may become a complementary alternative socioeconomic activity.

33.8 BIOGEOGRAPHICAL FEATURES AND MANAGEMENT REGIMES

As previously mentioned, this area of the Argentine Sea has high biodiversity, represented by most marine groups of organisms, from microorganism to mammals (Esteves et al., 2000). The coastal Argentinean zone from 35°S to 42°S is biogeographically in the Atlantic Ocean Domain, and inside that, the subregion called Patagonian Shelf (PS), according to the classification proposed by large marine ecosystems (LMEs) (Spalding, Agostini, Rice, & Grant, 2012).

Several biological groups have received special concern. The most abundant vertebrate taxa are bone fish (with more than 400 species), including those of high commercial value. In several cases, the extreme fishing pressure on fish species, such as hake, has been clearly documented (Fundación Vida Silvestre Argentina, 2008), while others such as sharks, are included in International Union for Conservation of Nature (IUCN) Red List (SSPyA, 2009). More than 80 coastal and pelagic bird species reproduce and feed within this marine region, and most of them are very vulnerable and have been shown to have some conservation problems in relation to fisheries caused by incidental capture and competition for the same food resources (Seco Pon, Gandini, & Favero, 2007). The region is also their place of feeding, and is a migratory corridor for three marine sea turtles (green, loggerhead, and hawksbill). The first two are threatened, and the latter is endangered (González Carman, Álvarez, Prosdocimi, Inchaurraga, & Dellacasa, 2011). Also, marine mammals (cetaceans, dolphins, and pinnipeds) occur within this area, and most of them are in the vulnerable category. These move regularly between the coastal and oceanic areas (Cappozzo et al., 2007; Bastida et al., 2007). Although marine mammals are not intentionally caught, other threats affect their conservation status, that is, incidental catch, pollution, ship collisions, habitat alteration, and maybe seismic prospecting (Bastida & Rodríguez, 2003).

Different regulatory regimes operate within the marine area, with different legal dependencies and scope. Regarding planning, administration, and management leading toward an integrated coastal zone management, municipal, provincial, and regional initiatives are being slowly consolidated. The Federal Council of Environment and the Ministry of Environment and Sustainable Development, are developing a federal strategy of Integrated Coastal Management. Within this framework, numerous plans and programs were created, that is, National Action Plan (PAN) for the conservation and management of chondrichthyes. There is a PAN for reducing interaction between birds and fisheries; one for reducing interaction between marine mammals and fisheries; and one for reducing interaction between turtles and Fisheries; among others.

In addition, Argentina lately adopted the International Agreement for the control and management of ballast waters and sediments from ships, which has recently been implemented.

33.9 SUMMARY

The Northern Argentine Sea is a highly diverse species and an environment with rich ecosystems, and it includes areas with significantly high productivity values. Although many factors converge to produce this phenomenon, it is the conjunction of overlying shelf waters with the cold MCs within this area that basically generates this scenario.

The coast presents a geomorphological and climatic diversity which maintains a variety of globally relevant coastal marine species, sheltering, among others, important birds and marine mammal colonies, including cetacean breeding, resting and feeding places, migratory bird areas, reproductive concentrations areas for fish and crustacea, kelp forests, mollusk subtidal banks, and so on.

According to Giaccardi (2014), 61 coastal marine protected areas (AMP in Spanish) have been implemented within the Argentine Sea, and 13 of them are included in the area considered for this chapter, though most are small and were created as isolated and independent units. Some of them have a national regulatory framework for management and administration, while others depend on provincial authorities. This national system of marine-protected areas includes regions of potentially high conservation value, systems in which endangered or highly vulnerable species partially or totally live their life cycles, environments in which notable species usually inhabit, and biologically, geologically, historically, or culturally important environments.

This region includes areas where important oceanographic processes occur, including shelf and slope fronts, the subtropical convergence zone area, and large estuaries.

This large region is important considering its direct interaction with Patagonian waters, which transforms it into a gateway to Antarctica.

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