

Chapter 11

Ecology and Biology of Fish Assemblages



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11.1 Estuaries as Key Habitat for Fish

Estuaries are important habitats for several species of fish, due to the high levels of primary production which supports highly diverse and abundant prey. Estuaries also provide nursery and feeding grounds for many species (Elliott et al. 2007). In these regions environmental gradients are large and generate a unique combination of biotic and abiotic factors (Day et al. 1989). The major biotic and abiotic factors which determine the distribution and abundance of fish in estuaries are shown in Fig. 11.1. These factors are not independent but interact directly and indirectly with the fish species that inhabit estuaries. Hydrographic conditions directly influence mouth condition, estuarine water temperature, salinity, turbidity, and dissolved oxygen concentrations and indirectly affect habitat diversity, productivity, fish recruitment, food availability, and competition (Whitfield 1999). The high productivity of estuaries has often been identified as the main reason why fish are attracted to these areas in such large numbers, which is explained by the large food webs these environments support. Food, especially detritus and benthic invertebrates, is abundant in most estuarine systems. However, the availability of a particular food type is likely to show marked fluctuations over time and space, particularly in response to environmental changes which characterize all types of systems on the subcontinent (Potter et al. 2015). Species that are broadly tolerant of biotic and abiotic variability are at a considerable advantage over those fish species that cannot survive such fluctuations, because the former are able to occupy a food-rich environment from which many potential competitors are excluded (Whitfield 1999).

Bahía Blanca Estuary thrives with fish life. This estuary is a complex ecosystem encompassing several islands, salt marshes, mudflats, and large tidal flats which

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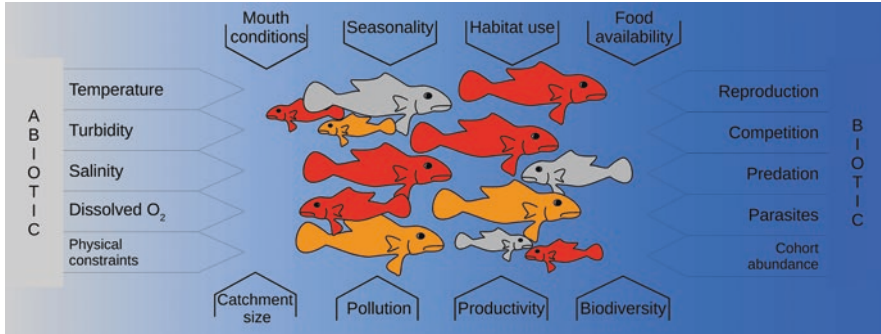


Fig. 11.1 Major abiotic (blue) and biotic (green) factors that influence the distribution and abundance of fish populations in estuaries. (Modified from Day et al. 1989)

generate marked environmental gradients thus promoting a high diversity of biological systems in a relatively small area (see Chaps. 1 and 3 of this book). This diverse ecotone provides several different types of habitats for fish. A world-scale review by Blaber (2002) states that the number of fish species in subtropical and tropical estuaries is much greater than in temperate regions: at least 100 species, with some reaching more than 200. Pasquaud et al. (2015) evaluated the latitude as potential factor determining fish species richness in estuaries, and they also identified a fish species richness distribution in relationship with latitude, with the lowest values of richness at 40° S. Yañez-Arancibia et al. (1980) recorded 121 species in tropical estuaries and lagoons of the Caribbean Sea. Atlantic areas appear relatively richness-poor regarding the worldwide average species richness of tropical estuaries (Simier et al. 2006). In the southwestern Atlantic temperate regions, the estuarine ichthyofauna is composed of ~110 species in dos Patos Lagoon (32° S), South Brazil (Chao et al. 1985); 119 fish species inhabit the Río de la Plata estuary (34° S) (Jaureguizar et al. 2016); and a total of 28 species were registered in Mar Chiquita coastal lagoon (37° S) in Argentina (González Castro et al. 2009). The number of fish species (32; Table 11.1) registered in Bahía Blanca Estuary (39° S) is consistent with the widely held view that latitude plays a critical role influencing richness, with tropical areas being more diverse than temperate ones.

More than 25 different mechanisms have been suggested for generating systematic latitudinal patterns in biodiversity, commonly emphasizing reasons as to why the tropics are highly specious. These include explanations based on chance, historical perturbation, environmental stability, habitat heterogeneity, productivity, and interspecific interactions. In these explanations, mean annual temperature is commonly used as a proxy of the energy of the system (Gaston 2000), i.e., the systems with a higher temperature would have higher energy, although this is not always the case. Among the different hypotheses that have been proposed in order to explain gradients in species richness, the species richness-energy relationship hypothesis received the greatest support, mostly from studies of terrestrial or freshwater organisms. For marine organism, a few studies addressed this framework, and their results are not consensual. In estuaries, the species richness-energy relationship has not

Table 11.1 Fish species presence in the inner, middle, and external zones of Bahía Blanca Estuary in the two periods of sampling: 1979–1983 and 2017–2018

Species	Inner zone		Middle zone		External zone
	1979–1983	2017–2018	1979–1983	2017–2018	1979–1983
<i>Galeorhinus galeus</i>					●
<i>Mustelus schmitti</i>		●	●	●	●
<i>Notorhynchus cepedianus</i>				●	●
<i>Squatina guggenheim</i>					●
<i>Sympterygia acuta</i>			●	●	●
<i>Sympterygia bonapartii</i>		●	●	●	●
<i>Myliobatis goodei</i>	●	●	●	●	●
<i>Conger orbignianus</i>		●	●	●	●
<i>Brevoortia aurea</i>	●	●	●	●	●
<i>Ramnogaster arcuata</i>	●	●	●	●	●
<i>Anchoa marinii</i>		●		●	
<i>Lycengraulis</i> sp.	●		●	●	●
<i>Genidens barbatus</i>		●		●	
<i>Macruronus magellanicus</i>		●		●	
<i>Porichthys porosissimus</i>	●	●	●	●	●
<i>Mugil liza</i>	●		●		●
<i>Odontesthes argentinensis</i>	●	●	●	●	●
<i>Acanthistius patachonicus</i>			●		●
<i>Dules auriga</i>					●
<i>Pomatomus saltatrix</i>	●	●	●	●	●
<i>Parona signata</i>			●	●	●
<i>Cynoscion guatucupa</i>	●	●	●	●	●
<i>Macrodon ancylodon</i>			●		●
<i>Menticirrhus americanus</i>				●	●
<i>Micropogonias furnieri</i>	●	●	●	●	●
<i>Pogonias cromis</i>			●	●	
<i>Umbrina canosai</i>					●
<i>Percophis brasiliensis</i>					●
<i>Stromateus brasiliensis</i>	●	●	●	●	●
<i>Paralichthys patagonicus</i>					●
<i>Paralichthys orbignyanus</i>	●	●	●	●	●
<i>Oncopterus darwinii</i>					●
<i>Symphurus jenynsi</i>			●	●	●
Total species	12	16	21	23	29

been considered in former studies probably due to the complexity and the variability of these systems (Pasquaud et al. 2015).

Bahía Blanca Estuary is a shallow temperate estuarine system that produces hypersaline conditions, where the salt concentrations in the inner portion of the estuary often exceed those of the inner continental shelf (average salinity is 33 ppt even though values as low as 17.3 ppt and as high as 41.9 ppt have been registered;

Freije et al. 2008). The estuary can be divided in three zones, depending on the composition of fish species that make use of the environment: inner (from the head of estuary to Ingeniero White), middle (from Ingeniero White to Puerto Rosales), and external (from Puerto Rosales to the mouth of the estuary) (see references in Fig. 2.1; Chap. 2). The inner zone has abundant intertidal habitats that are harsh and variable, forcing fish to either perform tidal migrations or be exposed to the naturally variable abiotic conditions. This zone also gathers most of the freshwater outputs of the tributary river meaning salinity can vary greatly. The inner and middle zones are where most of the human activity takes place. The last zone is abundant in islands and channels of varying depth. Some of these islands and channels are populated by important salt marshes. This large mudflat contracts in low tide, forcing fish to the deeper channels. The changes in temperature in this area are the widest of the three zones. The external zone is not subjected to changes in environmental parameters as much as the other two and resembles oceanic conditions the most.

11.2 Distribution and Composition of Fish Assemblage

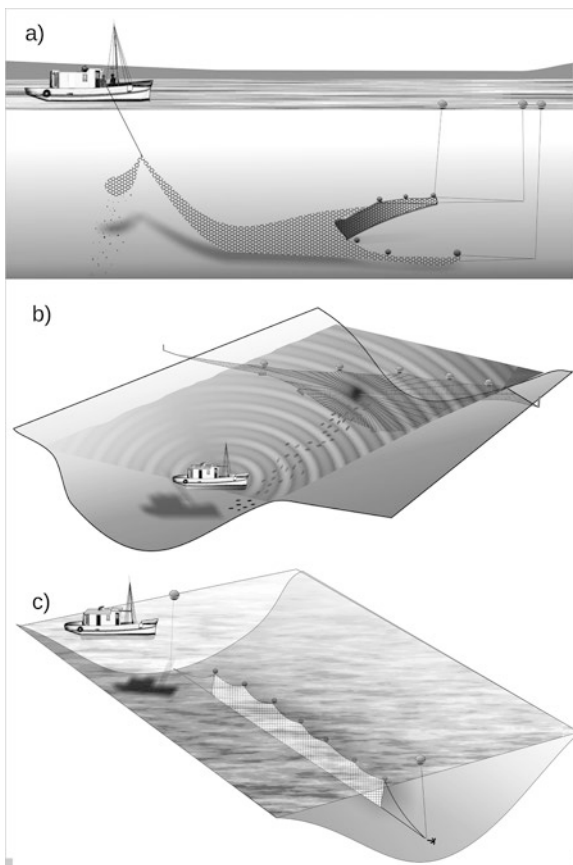
In 1979 Lopez Cazorla started surveying the fish species composition in Bahía Blanca Estuary. In these surveys, which were carried out until 1983, fishing was performed by the local artisanal fishermen, who used gear specific for their fishing needs, whether it is shrimp nets, channel closure nets, or gill nets (Fig. 11.2). These surveys covered the inner, middle, and external zones of Bahía Blanca Estuary. Between 2017 and 2018, our research team started conducting seasonal surveys on the estuary. Fishing was performed using two of the fishing gears used by fishermen (shrimp nets and channel closure nets, Fig. 11.2 a and b, respectively), albeit with lower fishing effort.

In this estuary, fishermen use these types of nets taking advantage of the strong flow of the tidal regime. Shrimp nets are usually set on high tide, and low tide flow forces fish into the net bag. Gill nets are placed in between tides, as fish moving in and out of the inner portions of the estuary are more likely to get entangled in them. Channel closure nets are placed on the inner channels on high tide, and as water level lowers during low tide, fish are pushed against the net, and the fishermen close the net and collect them. Demersal and demersal-benthic fish are most abundantly captured using these methods.

In the former surveys, 45 sampling trips were performed, while in the recent surveys 8 sampling trips were carried out. In both surveys fish were identified, and several measurements were taken (Table 11.1). Of the 32 species of fish found inhabiting the waters of Bahía Blanca Estuary, 7 were chondrichthyans and 25 osteichthyans.

From the initial surveys conducted in Bahía Blanca Estuary, summarized in Table 11.1, it is possible to conclude that there is a progression of species richness, from the inner zone (12 species) to the middle (21 species) and the external zones (29 species). The zoning pattern described at the start of this chapter can explain, up

Fig. 11.2 Net types employed by artisanal fishermen of Bahía Blanca Estuary, also used for the scientific samplings. (a) Shrimp nets, (b) channel closure nets, and (c) gill nets. (Modified from Lopez Cazorla 2004)



to certain extent, these findings. The inner zone is challenging for fish given its wide range of water salinity. Anadromous fish, such as *Myliobatis goodei* and *Mugil liza*, have physiological adaptations that allow them to exploit the resources of this zone. Fish species with tolerance to changes in temperature and salinity can live or move in and out of the middle zone. Most chondrichthyans have less tolerance to abiotic stressors in comparison with bony fish; hence, they occur on the middle and external zones, with only *M. goodei* moving deeper into the inner zone. We have found exclusively marine fish as well, like *Dules auriga* or *Macruronus magellanicus*. The inner and middle zones of the estuary are common fishing grounds for the two study periods; hence, a comparison between both is only possible for those areas. Table 11.1 shows such comparison. In general, the more recent surveys found a greater number of species, especially considering those found in the inner zone, even though the fishing effort in 1979–1983 was considerably larger. In that period a total of 45 sampling trips were made, 14 in the inner zone (31.11%), 26 in the middle zone (57.78%), and 5 in the external zone (11.11%). In comparison, the 2017–2018 period was composed of 8 field samplings, 4 in the inner zone and 4 in

the middle zone. Despite the comparatively low number of samples done in the second period, the increase in the number of species found is significant. Two species, in particular, appeared in the recent surveys that are noteworthy: *Genidens barbatus* and *Macruronus magellanicus*. A notable absence in the recent samplings is the silverside mullet *Mugil liza*. Another fact increasing the number of species in the recent surveys of the inner zone is the occurrence of species that were previously registered only up to the middle zone, like *Conger orbignianus*, *M. schmitti*, and *S. bonapartii*. These species seem to have moved to the inner areas in recent years.

In estuaries, salinity is an important factor influencing fish abundance and distribution. The often abrupt changes in salinity common to estuaries can cause considerable physiological demands on fishes. Although fishes living in estuaries are adapted to salinity fluctuations, individual response to salinity stress varies by species and scale. Low diversity and richness of fishes observed in hypersaline systems have been attributed to the osmoregulatory stress that fishes withstand (Whitfield 2016). As expected, also in Bahía Blanca Estuary, richness values decrease as the amplitude of salinity fluctuation increases. Inner zone species were captured in salinity ranges of 25–36, while external zone species were captured in salinity ranges of 30–36.

11.3 Spatial, Seasonal, and Long-Term Variations in the Fish Assemblage of Bahía Blanca Estuary

Knowledge on the spatial and seasonal dynamics of fish species, especially in temperate coastal areas, is usually incomplete (García-Charton and Pérez-Ruzafa 2001; Topping et al. 2006). This lack of knowledge is an issue for effective and sustainable management of fish populations and their exploitation (McCormick and Choat 1987; Blyth-Skyrme et al. 2006). The seasonal data obtained in Bahía Blanca Estuary from the most recent set of surveys suggest that winter and spring contained the highest species richness, 20 and 17 species, respectively (Table 11.2). Conversely, autumn and summer had the lowest, 12 and 7, respectively. In the previous survey, however, richness was highest in autumn and summer (26 and 23 species, respectively), while it was lower in winter and spring (18 and 20 species, respectively). Some of the migratory species appear all year round in both periods, such as *C. guatucupa*, *M. furnieri*, and *M. schmitti*, although their peaks of abundance may vary according to the species. The occurrence of these species all year round was due to the presence of their juveniles, which remain in the estuary, while the adults migrate elsewhere. Resident species, like *Ramnogaster arcuata*, are present all year round.

For both periods, there is a clear differentiation between summer and autumn samples in the one hand and winter and spring samples on the other. While no clear pattern of species replacement between periods is evident in our results, these two season groups coincide with the periods of warmer and colder temperatures

Table 11.2 Fish species presence in autumn (A), winter (W), spring (Sp), and summer (Su) in Bahía Blanca Estuary in the two periods of sampling: 1979–1983 and 2017–2018

Species	1979–1983				2017–2018			
	A	W	Sp	Su	A	W	Sp	Su
<i>Galeorhinus galeus</i>	●			●	●			
<i>Mustelus schmitti</i>	●	●	●	●	●	●	●	●
<i>Notorhynchus cepedianus</i>		●	●	●		●		
<i>Squatina guggenheim</i>	●	●	●	●				
<i>Sympterygia acuta</i>	●	●		●		●		
<i>Sympterygia bonapartii</i>	●	●	●	●		●		●
<i>Myliobatis goodei</i>	●	●	●	●		●	●	
<i>Conger orbignianus</i>	●	●			●		●	
<i>Brevoortia aurea</i>	●	●	●	●	●	●	●	
<i>Ramnogaster arcuata</i>	●		●	●	●	●	●	●
<i>Anchoa marinii</i>					●	●	●	
<i>Lycengraulis</i> sp.	●		●	●	●		●	
<i>Genidens barbatus</i>						●	●	
<i>Macruronus magellanicus</i>						●		
<i>Porichthys porosissimus</i>	●	●	●	●		●	●	●
<i>Mugil liza</i>	●	●	●	●				
<i>Odontesthes argentinensis</i>	●	●	●	●	●	●	●	
<i>Acanthistius patachonicus</i>	●	●		●				
<i>Dules auriga</i>	●			●				
<i>Pomatomus saltatrix</i>			●	●	●	●	●	
<i>Parona signata</i>	●	●	●	●		●	●	
<i>Cynoscion guatucupa</i>	●	●	●	●	●	●	●	●
<i>Macrodon ancylodon</i>	●	●		●	●			
<i>Menticirrhus americanus</i>		●				●		
<i>Micropogonias furnieri</i>	●	●	●	●	●	●	●	●
<i>Pogonias cromis</i>	●							●
<i>Umbrina canosai</i>		●						
<i>Percophis brasiliensis</i>	●						●	
<i>Stromateus brasiliensis</i>	●	●	●	●		●	●	
<i>Paralichthys patagonicus</i>	●							
<i>Paralichthys orbignyanus</i>	●	●	●	●		●	●	
<i>Oncopterus darwinii</i>	●							
<i>Symphurus jenynsi</i>	●		●	●		●		
Total	26	20	18	23	12	20	17	7

respectively, indicating that water temperature must play an important role in the seasonal species turnover. Being a shallow estuary means that the waters of Bahía Blanca Estuary heat up and cool off quicker than those of the open sea in front of it, as the heat retention within the estuary is poor. This desynchronized heating and cooling of the estuarine waters and the adjacent sea is important for species that employ an optimum temperature strategy to increase fitness, for example (Elisio

et al. 2017). Many chondrichthyan species have been shown to exhibit this behavior, in which the individuals perform small-scale migrations to feed in high-temperature areas, and then return to colder areas to digest (Neer et al. 2007). This journey may involve swimming several kilometers and may take hours to complete. Seasonal dynamics such as this is thought to be responsible for the differences in species composition (Wonton 1992) and might be responsible for the species composition differences observed in Bahía Blanca Estuary.

Further spatial structure in the fish community of Bahía Blanca Estuary was found in the 1979–1983 surveys, using hierarchical classification procedures (Sneath and Sockal 1973) applied to the matrix of similarity indexes between sampling sites. Sampling sites close to shore were grouped together, some of them located on the internal zone and the southwestern quadrant of Bahía Blanca Estuary. A second separated cluster was formed by sites that were close to the main channel. Further subdivisions of these two groups had much smaller mean similarity indexes. The robustness of the discrimination between the two groups is supported by the total (100%) coincidence of the groups using the two similarity indexes. As explained at the first section of this chapter, depth plays an important role in structuring fish communities. Additionally, habitat resources such as food and shelter and environmental stressors vary greatly between close-shore intertidal environments and deeper subtidal zones. The main dredged portion of the inner zone of the navigation channel might represent an artificial deep subtidal environment, promoting species composition differences with the adjacent shallow intertidal shore habitats as described by Carbines and Cole (2009) in a similar estuary in New Zealand.

11.4 Species Spotlight: Biological Description of Some of the Fish Species of Bahía Blanca Estuary

11.4.1 *Mustelus schmitti* (Springer, 1939)

Locally called “gatuzo,” the narrownose smoothhound *Mustelus schmitti* (Fig. 11.3a) is a small shark of the Triakidae family, attaining a maximum total length of 110 cm. This shark is endemic to the Southwest Atlantic Ocean, from the south of Brazil to the Argentinean Patagonia (22° S to 47°45' S), dwelling from coastal waters to up to 120 m of depth (Menni 1985). This shark is known to migrate seasonally in large numbers between wintering grounds in southern Brazil and summer grounds in Argentina (Vooren 1997) and also performs seasonal ingresses to estuaries, protected bays, and gulfs (Lopez Cazorla 2004; Chiaramonte and Pettovello 2000; Colautti et al. 2010). *M. schmitti* is one of the most studied sharks of Argentina: presently its reproduction, food habits, age, and growth and other of its biological processes have been described (Menni 1985; Chiaramonte and Pettovello 2000; Sidders et al. 2005; Segura and Milessi 2009; Colautti et al. 2010; Molina and Lopez

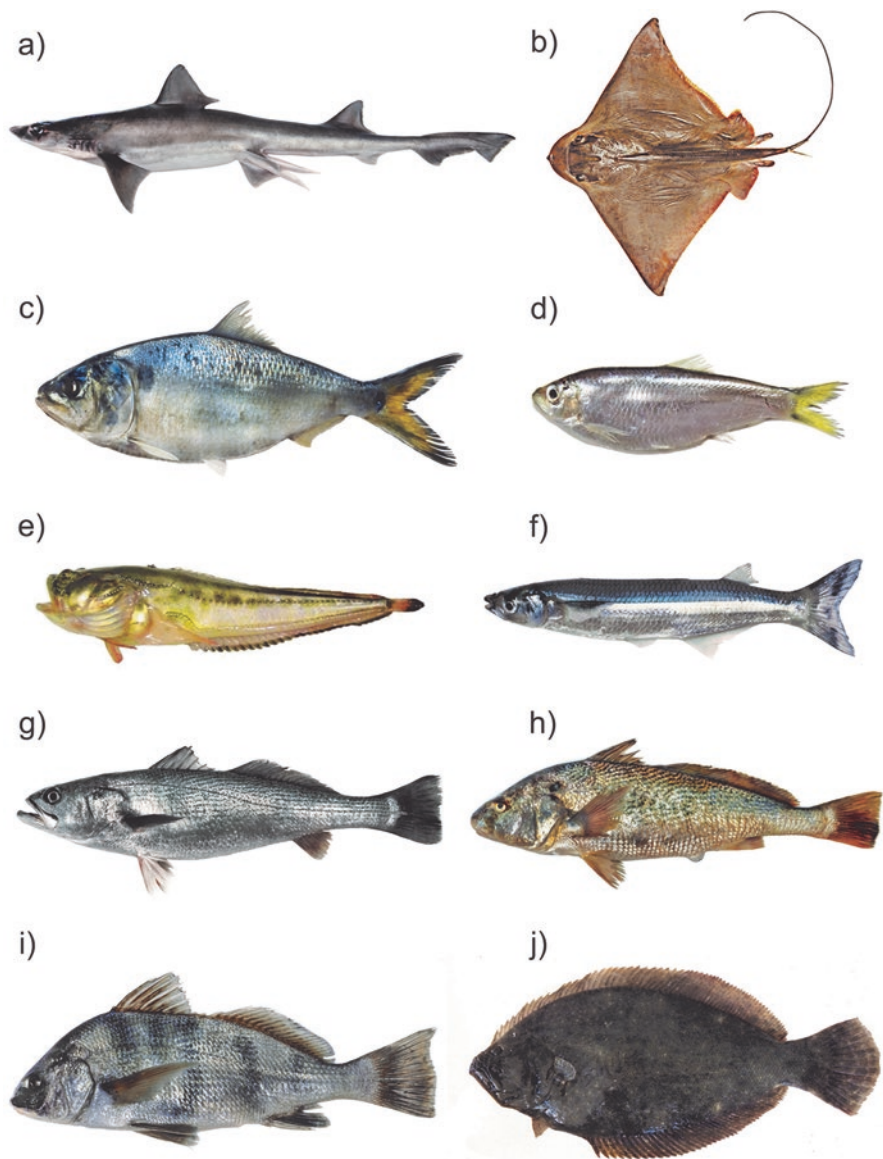


Fig. 11.3 Fish species spotlight of Bahía Blanca Estuary. (a) *Mustelus schmitti*, (b) *Myliobatis goodei*, (c) *Brevoortia aurea*, (d) *Rammogaster arcuata*, (e) *Porichthys porosissimus*, (f) *Odontesthes argentinensis*, (g) *Cynoscion guatucupa*, (h) *Micropogonias furnieri*, (i) *Pogonias cromis*, and (j) *Paralichthys orbignyanus*. (Photos a, b, c, f, g, h, i, and j modified from Cousseau MB and Rosso JJ (2020) in *Peces Argentina*, edited by Vázquez Mazzini Editores, Ciudad de Buenos Aires-Argentina. Photos by Gabriela Blasina d and e)

Cazorla 2011; Molina et al. 2017). This species feeds mainly on crustaceans when close to the coast and on fish as it migrates to deeper waters. Seasonal and ontogenetic differences in diet composition have been described, with polychaetes being more important in the colder months of the year, while decapods become the main prey item in the warmer months (Molina and Lopez Cazorla 2011). Larger narrownose smoothhound sharks feed on larger crabs and fish, while neonates and juveniles prey on a greater variety of crustaceans and polychaetes. The species reaches sexual maturation at approximately 5 years old, with the males maturing faster than the females and also attaining less weight and length (Molina et al. 2017). The species migrates to the nursery areas of Bahía Blanca Estuary to give birth in spring-summer and then mates and leaves as temperature drops by the beginning of autumn. It gives birth to up to six pups, the size and number depending on the size and age of the female. The maximum age determined for this species is 20 years old (Molina et al. 2017).

The narrownose smoothhound is the most exploited elasmobranch species in Argentina, Brazil, and Uruguay, with an important percentage of the capture destined to exportation to England and China (Molina and Lopez Cazorla 2011). This shark is caught by both industrial and artisanal fishing fleets. The exploitation of this species throughout its distribution range led to recent declines in its populations despite maximum permitted catch regulations established by Argentina and Uruguay (Molina and Lopez Cazorla 2011). The narrownose smoothhound is currently considered endangered in these two countries by the IUCN (Massa et al. 2010).

11.4.2 *Myliobatis goodei* (Garman, 1885)

The southern eagle ray, locally called “chucho,” *Myliobatis goodei* (Fig. 11.3b) is a large stingray of the Myliobatidae family, reaching a meter in disc width. This species distributes from south California (35°N) to the south of Argentina (40°S). This chondrichthyan is diadromous, tolerating a wide range of salinity. It enters estuarine waters to give birth (Refi 1975). Two very similar species cohabit with *M. goodei*, *M. ridens* (Ruocco et al. 2012) and *M. freminvillii* (Aguiar et al. 2004).

M. goodei migrates to bays and estuaries during the warm months of spring and summer, to improve neonates and juveniles' access to food and shelter, providing effective protection against predators and optimum conditions for development (Castro 1993; Simpfendorfer and Mildward 1993). This migrating behavior of *M. goodei* was also reported by Molina and Lopez Cazorla (2015), Jaureguizar et al. (2003b), and Lopez Cazorla (1987) in Anegada Bay, Río de la Plata, and Bahía Blanca Estuary, respectively.

Molina and Lopez Cazorla (2015) inferred that the mating and spawning season for *M. goodei* may occur in summer, although the authors lack a complete yearly series of gonadosomatic index values (GSI) to accurately demonstrate this. The presence of mature males and pregnant females with highly developed embryos in the uterus in summer, and recently born pups, would strengthen this hypothesis and

also imply that they became pregnant immediately after parturition (Hamlett 1999). *M. goodei* in the study area behave as generalist feeders, with a uniform diet composed mainly of bivalves. Trophic level of *M. goodei* in Anegada Bay (3.2) characterizes it as a secondary consumer (Molina and Lopez Cazorla 2015).

This species is captured as bycatch but retained and sold internally as well as exported in significant amounts. *M. goodei* is assigned as Data Deficient by the IUCN, given the possible population threats it faces (Stehmann 2009).

11.4.3 *Brevoortia aurea* (Spix and Agassiz, 1829)

Locally called “saraca,” the Brazilian menhaden *Brevoortia aurea* (Fig. 11.3c) is a planktonic clupeid that reaches up to 40 cm in total length. *B. aurea* is a euryhaline fish, distributed from Salvador de Bahía in Brazil to San Matías Gulf (41°S) in Argentina. This species is abundant in estuarine waters. It has been estimated that it lives up to 12 years and the females reach larger sizes. Adults (larger than 20 cm TL) are captured inside Bahía Blanca Estuary in the spring and summer months, while only juveniles remain during autumn and winter (Lopez Cazorla 1985). While *B. aurea* is not targeted by any specific fishing fleet, it is an important bycatch component in coastal industrial and artisanal fisheries. The IUCN has evaluated the conservation status of this species as Least Concern with a stable population trend (Di Dario et al. 2017).

11.4.4 *Ramnogaster arcuata* (Jenyns, 1842)

Jenyns’ sprat *Ramnogaster arcuata* (Fig. 11.3d), locally called “saraquita,” is a pelagic fish species of the Clupeidae family. It has a wide distribution in coastal areas in the Southwestern Atlantic Ocean, from southern Brazil (estuary of the Patos Lagoon) to Tierra del Fuego in southern Argentina (Lopez Cazorla et al. 2011). It is confined to the external areas of rivers and coastal lagoon mouths, which are characterized by moderate salinity ranges. It is an estuarine-resident species that completes the entirety of its life cycle within estuaries (Garcia and Vieira 2001). The species reaches a total length of 130 mm and present a relatively short life span with a maximum age registered of 3 years. Sexual maturity is reached at 76 mm total length (1 year), and spawning season begins in spring (Lopez Cazorla and Sidorkewicz 2009). According to its trophic habits, it has been classified as a zooplanktivorous feeder, and its diet composition exhibited monthly variability in the main prey items consumed (Lopez Cazorla et al. 2011).

Ramnogaster arcuata is a main functional component of the ecosystem of Bahía Blanca Estuary, where it is not only one of the most abundant species but also one of the most commonly caught fish. It also represents a key food item for *C. guatucupa* and *P. orbignyanus*, two of the most economically important fish species in the

area. The coastal habits and short life span of *R. arcuata* make it an excellent organism to be considered as a bio-indicator of aquatic environmental health (Lopez Cazorla and Sidorkewicz 2009; Ronda et al. 2019). The IUCN has evaluated the conservation status of this species as Least Concern (Di Dario et al. 2017).

11.4.5 *Porichthys porosissimus* (Cuvier, 1829)

Porichthys porosissimus (Fig. 11.3e) is a species of batrachoid known as Atlantic midshipman and locally as “lucerna.” The reported maximum length for this species is 32 cm TL. It is an abundant species, caught as bycatch throughout its distribution range, from Río de Janeiro, Brazil, to Golfo de San Matías (41°S), Argentina. This species inhabits coastal waters from 30 to 200 m deep (Cousseau and Perrotta 2013). Other closely related species exhibit complex mating behaviors, which include nest building, sound- and bioluminescence-mediated courtship, and parental care (Tsujii et al. 1972). Photophores, a special type of skin cells that produce bioluminescence, are present in *P. porosissimus* and would likely play a homologous role in mating and communication between individuals. Mature individuals of this species croak when disturbed, meaning they are capable of producing sound, much like their northern counterparts.

Shrimp trawling and traps capture this species as bycatch, but only one study exists on the biology of this species (Vianna et al. 2000). In Bahía Blanca Estuary, it is captured mainly in the external zone, all year long. The largest adults were present during spring, while the smallest juveniles were found in summer. Size range was from 9 to 31 cm TL, and the most frequent sizes were 17–31 cm TL (Lopez Cazorla 1987). The IUCN has yet to evaluate the conservation status of this species.

11.4.6 *Odontesthes argentinensis* (Valenciennes, 1835)

Locally called “pejerrey,” *Odontesthes argentinensis* (Fig. 11.3f) is a large-sized silverside that is widely distributed along the Atlantic Ocean coast between Sao Paulo, Brazil, and Rawson in Argentina (García 1987; Dyer 2000). It is a planktonic species that feeds on zooplankton, mainly crustaceans. This fish reaches 48 cm in total length, the males being larger than the females (Molina 2013). *O. argentinensis* inhabits shallow coastal waters, and juveniles have been found to be abundant in the surf zones of sand beaches. As for other atherinids, this fish shows a great phenotypic plasticity that allows its adaptation to different environments (Bamber and Henderson 1988) involving a wide range of salinities. This allows this species to inhabit estuaries and inshore waters, where it likely migrates during late spring and summer to reproduce (Cousseau and Perrotta 2013; Beheregaray and Levy 2000; Bemvenuti 2005). According to gonad ripening takes place between September and November with a peak in October, in the nearby location of Anegada Bay. Llompant

et al. (2013) also describe age and growth of this species, which attains a maximum of 7 years, growing quickly in the first 2.

Odontesthes argentinensis in Bahía Blanca Estuary behave similarly, with the main captures being done in the external zone using gill nets and channel closure nets. Bahía Blanca Estuary represents a breeding area for this species, and spawning occurs from late August to November (Lopez Cazorla 2004). The commercial importance of this species is limited to the Argentinean market and is targeted by coastal artisanal fleets (Cousseau and Perrotta 2013). The IUCN has yet to evaluate the conservation status of this species.

11.4.7 *Cynoscion guatucupa* (Cuvier 1829)

The striped weakfish, *Cynoscion guatucupa* (Fig. 11.3g), is locally called “pescadilla de red.” It is a pelagic fish species, which has a wide geographical distribution, extending from Río de Janeiro (22°S) in Brazil to San Matías Gulf (43°S) in Argentina (Cousseau and Perrotta 2013). This fish presents dietary shifts during ontogeny. It feeds from pelagic to benthic crustaceans on its early stages (mysids, sergestids, shrimps) and eventually increases progressively in ichthyophagy (mainly an increase consumption of alevins and young fish) as it develops into adulthood. Its present dietary seasonal differences could be due to changes in abundance and availability of its prey species in the environment (Lopez Cazorla 1996; Sardiña and Lopez Cazorla 2005a). *C. guatucupa* performs seasonal migrations, swimming northwards between autumn and spring, leaving the fishing grounds of Uruguay and Argentina to move to the coast of Brazil, only to return to the south in summer (Villwock de Miranda and Haimovici 2007). Lopez Cazorla (1996) reports the influence of changes in temperature and salinity as triggers for the spawning movements of *C. guatucupa*. Spawning occurs outside of the estuary from spring to mid-autumn (Cassia 1986; Lopez Cazorla 2000), and the fry is pushed into the estuary by tidal movements. Small juveniles recruited from late spring move to deeper waters (25–50 m) in late autumn, when they reach a mean total length of 9.8 cm (age 0+). They remain there for the next 1–2 years before joining the adult stock’s seasonal movements (Haimovici et al. 1996; Lopez Cazorla 2000; Sardiña and Lopez Cazorla 2005a). The total length of adult fish ranges from 34 to 63 cm, and the ages range from 3 to 23 years (Lopez Cazorla 2000; Ruarte and Sáez 2008). The IUCN has yet to evaluate the conservation status of this species.

11.4.8 *Micropogonias furnieri* (Desmarest 1823)

The whitemouth croaker *Micropogonias furnieri* (Fig. 11.3h), locally called “corvina rubia,” is a demersal fish of the family Sciaenidae, inhabiting coastal waters up to 60 m deep. It is a euryhaline fish distributed widely in marine and estuarine

systems of the eastern American coast from the Gulf of Mexico (20°20'N) to “El Rincón” (41°S) in Argentina (Carozza et al. 2004). The maximum recorded size for the species is 74 cm in TL, reaching sexual maturity at 33 cm of TL, which corresponds to 4 or 5 years of age. The reproductive period of *M. furnieri* is very long and extends from spring to summer (Macchi et al. 2003). Spawning occurs in highly saline coastal waters, and subsequently, larval *M. furnieri* enter coastal estuaries during winter months. In Bahía Blanca Estuary, species reproduction occurs in El Rincón area during spring, with the subsequent drift of eggs and larvae into estuary. Juveniles with sizes of 2 and 18 cm total length (Lt) remain inside the estuary from early summer to winter and then leave the region. At late spring, entrance to the estuary of individuals in the adult state with a size range from 30 to 72 cm Lt begins, and they remain in the area until autumn (Lopez Cazorla 2004). Young-of-year (YOY) and adult *M. furnieri* utilize estuarine habitats for feeding and growth (Jaureguizar et al. 2003a; Lopez Cazorla 2004). The species has been identified as a generalist feeder, and its stomach contents largely reflect seasonal changes in prey availability, meaning it has a broad dietary niche width (Mendoza-Carranza and Vieira 2008). Previous studies in estuarine habitats have documented ontogenetic changes in diet. YOY individuals rely heavily on polychaetes in their diets but also consume other food items such as chaetognaths, copepods, and amphipods. Evidence indicates that *M. furnieri* changes its feeding habits as it gets larger, relying more heavily on organisms such as mysids and fish. Adults have been described as opportunistic bottom-feeders that eat decapod crustaceans, such as crabs and shrimps, polychaetes, and, occasionally, small fishes (Sardiña and Lopez Cazorla 2005b; Giberto et al. 2007; Blasina et al. 2016).

Micropogonias furnieri is one of the most abundant demersal fishes of South American estuaries and an important component of artisanal and coastal industrial fisheries in Brazil, Uruguay, and Argentina (Carozza et al. 2004). *M. furnieri* fishery in the Río de la Plata estuary is mainly artisanal, with fish being caught mostly in winter in Samborombón Bay area of Argentina and during spring and summer in Santa Lucia area of Uruguay (Jaureguizar et al. 2003a, b). In Bahía Blanca Estuary, it was the second most important fish resource, captured in spring and summer. It reached 16% of the commercial landings between 1972 and 1992, although between 1994 and 1996 landings strongly decreased and values as low as 2% were reported (Lopez Cazorla 2004). The IUCN has evaluated the conservation status of *M. furnieri* as Least Concern, although a decreasing population trend is mentioned (Aguilera et al. 2015).

11.4.9 *Pogonias cromis* (Linnaeus, 1766)

The black drum *Pogonias cromis* (Fig. 11.3i), locally called “corvina negra,” is a demersal coastal fish distributed along the western Atlantic Ocean from Massachusetts, USA, to south of Buenos Aires Province in Argentina. It is an estuarine-dependent species and the largest sciaenid found in the estuarine

environments of Argentina. It reaches up to 120 cm in TL and is sexually mature at the end of the second year of life, at 28.5–33 cm of TL (Cousseau and Perrotta 2013). Spawning takes place in regions associated with estuaries, inside or outside of them, and mainly in spring. *P. cromis* juveniles live in estuarine areas as they can tolerate a wide range of salinities and water temperatures, eventually moving to offshore marine waters when they reach the adult stage. Adults are usually common in shallow coastal and estuarine waters and occasionally occur further from the coast (Macchi et al. 2002; Rubio et al. 2018).

Juvenile and adult *P. cromis* exploit a variety of benthic food resources and can use their strong pharyngeal teeth to crush the shells of mollusks and crustaceans (Blasina et al. 2016; Rubio et al. 2018). Gut content analyses have identified significant seasonal differences in the diet composition and trophic niche breadth. Because of this *P. cromis* has been classified as an opportunist predator (Blasina et al. 2010).

Pogonias cromis is the target of an important recreational and commercial fishery in the Gulf of Mexico, and it is commercially harvested in inshore waters of Samborombón Bay, a semi-enclosed region inside the Río de la Plata estuary in Argentina. Fishing effort occurs mainly between late winter and summer, but is especially high during spring, when *P. cromis* forms large schools in shallow waters. This behavior contributes to intensified commercial and recreational activity on this species (Macchi et al. 2002; Rubio et al. 2018). *P. cromis* is classified as Least Concern status by the IUCN, but a decreasing population trend is mentioned (Chao et al. 2015). In Bahía Blanca Estuary, in the period 1979–1983, this species was registered only in three opportunities, all in the same winter month (June) and in Ingeniero White (the middle zone) (Lopez Cazorla 1987). In 2017–2018 this species was captured also in the middle zone, but during summer (Table 11.1 and 11.2).

11.4.10 *Paralichthys orbignyanus* (Jenyns, 1842)

The flounder, locally called “lenguado,” *Paralichthys orbignyanus* (Fig. 11.3j) is a commercially important species generally found in the shallow waters from Río de Janeiro (22° S) southwards in Brazil to San Matías Gulf (41° S) in Argentina (Cousseau and Perrotta 2013). Two other species of the genus *Paralichthys* live in Argentinean waters, *P. isosceles* and *P. patagonicus* (Lopez Cazorla 2005). *P. orbignyanus* is a typical benthonic fish with a wide temporal and spatial distribution in Bahía Blanca Estuary. Two other species of the genus *Paralichthys* live in Argentinean waters *P. isosceles* and *P. patagonicus* (Lopez Cazorla 2005).

The maximum ages recorded for both sexes corresponded to 6 years in males and 7 years in females, respectively, suggesting that *P. orbignyanus* is not a long-living species, and the females are longer and heavier than males (Lopez Cazorla 2005). Similar data have been published for *P. adspersus* by Escobar (1995), who aged this species and found they live a maximum of 6 years and reach up to 74 cm in total length. In addition, Díaz de Astarloa and Munroe (1998) observed that the longest TL for *P. orbignyanus* was 61 cm for males and 103 cm for females, respectively,

although they made no reference to age. Females are longer and heavier than males. Larger size in females could be indicative of a life history strategy supportive of increasing egg production (Masuda et al. 2000). The growth difference between females and males was also observed in *P. adspersus* females which exhibit a length significantly larger than males (Escobar 1995). The length growth registered in *P. orbignyanus* males and females in Bahía Blanca Estuary was significantly higher than that of *P. isosceles* reported by Fabré and Cousseau (1990).

Paralichthys orbignyanus has an active growth period in summer and interrupts its growth in winter. Spawning occurs in the period extending from November to January (spring-summer), and the eggs and larvae of this species are found in January and February (summer) in the area next to the estuary mouth (Lopez Cazorla 2005). This suggests that spawning occurs out of the estuary, as with other species of bony fish, such as *C. guatucupa* (Lopez Cazorla 1996, 2000). A similar behavior has been described for other Pleuronectidae (*Kareius bicoloratus*) which spawn off the coasts, at depths ranging from 20 to 50 m. Once larvae reach 10–15 mm in total length, they approach the coast, migrating to nursery grounds (Malloy et al. 1996). The IUCN has yet to evaluate the conservation status of this species.

11.5 Fish Habitat Uses

The life of fish in estuaries is conditioned by the abundance of food and variations in the abiotic parameters of the water (Elliott et al. 2007). Fish species found in estuaries use these systems in a variety of ways, and this usage can change at different life stages. Ecological characteristics of fish species found in estuaries can be divided into three main functional aspects: (1) the use fish make of the estuary during their life cycle, (2) reproductive characteristics, and (3) feeding preferences and strategies. Elliott et al. (2007) name the three functional groups as “estuarine use functional group,” “reproductive mode functional group,” and “feeding mode functional group” respectively.

11.6 Estuarine Use Functional Group

Many species spawn in marine waters and enter estuaries for variable periods, while others complete their life cycle within the estuary, and yet others employ the estuary as a feeding area (Potter et al. 2015). Thus, fish assemblages include estuarine-resident species, freshwater and marine species that typically use estuaries at a specific life stage, as well as migratory diadromous species (Elliott et al. 2007). Each of these categories is considered to contain two or more functional guilds that represent characteristics associated with the spawning, feeding, and/or refuge locations, which in some cases involve migratory movements between estuaries and other ecosystems (Whitfield 2016).

Guild approach categorization of fishes was proposed by Elliott et al. (2007) and refined by Potter et al. (2015). Two fish guilds are dominant in Bahía Blanca Estuary (Table 11.3): marine estuarine-opportunists and estuarine-residents; they are represented in estuaries by different life stages and are associated with different food chains (see Feeding mode functional group section). Marine-estuarine opportunists are predominantly juvenile fish making use of this ecosystem as a nursery area.

Table 11.3 Species frequency of occurrence in Bahía Blanca Estuary. *R* rare species (up to 33% of occurrence), *C* common species (34–66% of occurrence), *F* frequent species (more than 66% of occurrence)

Species	Resident	Migrant	Straggler
<i>Galeorhinus galeus</i>		R	
<i>Mustelus schmitti</i>		F	
<i>Notorhynchus cepedianus</i>		R	
<i>Squatina guggenheim</i>		R	
<i>Sympterygia acuta</i>	F		
<i>Sympterygia bonapartii</i>	F		
<i>Myliobatis goodei</i>		F	
<i>Conger orbignianus</i>		F	
<i>Brevoortia aurea</i>		F	
<i>Ramnogaster arcuata</i>	F		
<i>Anchoa marinii</i>	F		
<i>Lycengraulis sp.</i>	C		
<i>Genidens barbuis</i>			R
<i>Macruronus magellanicus</i>			R
<i>Porichthys porosissimus</i>	F		
<i>Mugil liza</i>	C		
<i>Odontesthes argentinensis</i>	F		
<i>Acanthistius patachonicus</i>	R		
<i>Dules auriga</i>	R		
<i>Pomatomus saltatrix</i>		C	
<i>Parona signata</i>		C	
<i>Cynoscion guatucupa</i>		F	
<i>Macrodon ancylodon</i>		R	
<i>Menticirrhus americanus</i>		R	
<i>Micropogonias furnieri</i>		F	
<i>Pogonias cromis</i>		R	
<i>Umbrina canosai</i>		R	
<i>Percophis brasiliensis</i>		R	
<i>Stromateus brasiliensis</i>		R	
<i>Paralichthys patagonicus</i>	R		
<i>Paralichthys orbignyanus</i>	F		
<i>Oncopterus darwinii</i>	R		
<i>Symphurus jenynsi</i>	C		
Total species	14	17	2

These fish species regularly enter estuaries in substantial numbers but use, to varying degrees, coastal marine waters as alternative nursery areas. In small-scale studies, some authors have pointed out that estuary mouth width was the most important variable explaining a significant part of the variability in fish species richness (Nicolas et al. 2010; Pasquaud et al. 2015). Estuaries with large mouths can attract numerous brackish water species, as well as marine-estuarine opportunist fish species (Martinho et al. 2009; Vinagre et al. 2009). Estuarine-resident guilds are composed by species with populations in which the individuals complete their life cycle within the estuary. While a number of the marine estuarine-opportunist species have economic importance for the recreational and local artisanal fishermen, none of the small resident species, which are a highly productive component in this estuary, are utilized. In addition, a number of the marine straggler species are frequently registered. These species enter estuaries sporadically and in low numbers and are most common in zones where salinity typically does not decline far below approximately 33 ups. Due to hypersaline conditions in Bahía Blanca Estuary, no freshwater fish species has been registered (Table 11.3).

In Bahía Blanca Estuary, the biology and life history of each species condition the use they make out of the resources available. Resident fish species (i.e., estuarine-resident) here, for example, have a remarkable tolerance to environmental variations, while migrant species (i.e., marine estuarine-opportunists) exhibit behaviors that allow them to exploit the high productivity of the intertidal ecotone and leave the area when the conditions become unfavorable. The latter species have a comparatively low tolerance to shifts in abiotic variables.

11.6.1 Resident Species of Bahía Blanca Estuary

In Bahía Blanca Estuary, there are resident chondrichthyans and osteichthyans. Skates of the genus *Sympterygia* lay eggs all year round and are commonplace all along the waters of the estuary. The most ubiquitous species is *Sympterygia bonapartii*, the shortnose south Atlantic skate. This species lays eggs protected with a fibrous black capsule and with four tendrils. The eggs are placed around submerged vegetation or debris so that the tendril holds them in place.

The absence of natural hard substrate and the relative scarcity of submerged macroalgae offer little shelter for resident reef fish; however, species of genera *Dules* and *Acanthistius*, both associated with rocky bottoms and reefs, have been found to occur within the waters of the estuary. Soft sediments, however, are ideal for soles and flounders. In Bahía Blanca Estuary, there are four species of flounders and one of soles. Of these species, only the flounder *Paralichthys orbignyanus* occurs frequently and with considerable abundances, in so as to become a targeted species of the local artisanal fishermen.

The high turbidity of the estuary means that ambush predators like the southern Atlantic midshipman (*Porichthys porosissimus*) have no problem procuring food. Indeed this species is very abundant in the estuary, where it performs seasonal

migrations. It enters from the external area of the estuary in spring and summer to mate and care for their young. This species is caught abundantly in shrimp nets from October to February during ebb tide, suggesting it uses the currents to move in and out of the inner part of the estuary on a daily basis. By autumn/winter it is already unlikely to fish any in the inner zone of the estuary. A possible explanation is the drop in water temperature which in the inner, and shallower, section of the estuary is much more intense and sharp. Changes in water salinity also offer another possible explanation, while it fluctuated sharply in the inner zone, values in the external and middle areas remained relatively constant (Lopez Cazorla 2004), so perhaps the distribution of this fish is due to a behavioral escape from the fluctuating conditions, of temperature and salinity, of the inner zone. Prey availability may also be a factor contributing to this species' distribution. Its main prey, the prawn *Peisos petrunkevitchi*, spawns by the end of winter, prompting an abundance peak during spring and summer. In the late summer months, spawners concentrate in the outer part of the estuary (Mallo and Cervellini 1988), representing a valuable protein and energy source for *P. porosissimus*, who might follow their seasonal movement patterns. Little else is known about this species, as there are no specific studies on it yet.

11.6.2 Migrant Species of Bahía Blanca Estuary

In Bahía Blanca Estuary, the increases in water temperature and salinity during the warmer months of spring are thought to trigger migratory movements of certain species of fish. However, little is known about the drivers of migration movements in the migrant species of Argentina. It is theorized that some species utilize the estuary as feeding ground, others as a nursery for their young, as mating area, or spawning waters. Regardless of the driver, several fish species shoal into the estuary in different times of the year and then leave.

The high productivity, the availability of refuge, and favorable conditions in spring and early summer in Bahía Blanca Estuary seem to be a reasonable explanation as to what draws migrating fish species to these waters. Sciaenids like *Cynoscion guatucupa* and *Micropogonias furnieri* migrate to the estuary and spawn before entering estuarine waters for feeding. Adults of *C. guatucupa* presented two abundance peaks in the estuary: one in early autumn and a more important peak in early spring. On the other hand, the higher abundance of *M. furnieri* adults into the estuary has been registered during spring and summer (Lopez Cazorla 2004). Given that nutrient load increases around winter, with a consequent increase in phytoplankton biomass, it is not surprising that these sciaenids have a bimodal spawning behavior. This behavior might favor the larvae produced in the early spawning event with more food availability, at the expense of lower growing temperatures. Larger juveniles of these species, preying on copepods and brachyuran larvae, are captured at the end of spring and throughout the summer, autumn, and winter, exploiting the zooplankton biomass explosion that follows the peaks of phytoplankton.

The abundant invertebrate assemblages also represent an outstanding food source for benthic predators like *M. furnieri*. This species uses the intertidal during high tide to prey on polychaetes and crabs among the “cangrejales.” Local fishermen report they can see the nuzzling marks of *M. furnieri* in the mud of the “cangrejal” during low tide. Although this species has several specializations in its mouth to feed on hard-shelled prey, like crabs, it will opt for other benthonic prey if they are abundant, exhibiting an opportunistic feeding behavior.

Chondrichthyans also migrate into the estuary to give birth and lay eggs. Adults of the triakid *Mustelus schmitti* can be found in the waters of the estuary from the end of winter up to the beginning of summer. The juveniles can be found from summer to early winter. When this species enters the estuary, it shifts the diet to consume almost exclusively crabs. Females migrate into the inner parts of the estuary to give birth to 2–8 pups and then mate with the males. Stingrays of the genus *Myliobatis* also move into the estuary in spring to give birth and mate, utilizing the abundant populations of polychaetes and crabs to load up on energy reserves. They can be found up until April (autumn). Two species are known to occur here, *M. goodiei* and *M. ridens*, which were thought to be one species until recently (Ruocco et al. 2012).

Large sharks like the seven-gill shark (*Notorynchus cepedianus*), copper shark (*Carcharhinus brachyurus*), and sand tiger shark (*Carcharias taurus*) also utilize estuarine waters as a nursery area during the warm months of spring and summer and also as a hunting ground for both fish and pinnipeds. Studies on these species in Bahía Blanca Estuary are lacking; the only available reference is the presence of *N. cepedianus* (Lopez Cazorla 1987).

11.6.3 Straggler Species

This category is represented by fish species that occur “accidentally” in estuaries; they generally occupy it for only very short periods of time and in limited areas. In Bahía Blanca Estuary, two species have been registered that come from other regions and that visit the estuary to use its favorable conditions opportunistically: *Genidens barbatus* and *Macruronus magellanicus*. These findings represent the first record of both species of fish in Bahía Blanca Estuary. *G. barbatus* is an anadromous species inhabiting estuaries and the marine continental shelf from Bahía in Brazil (17° 00' S) to San Blas Bay in Argentina (40° 32' S) (Avigliano and Volpedo 2015). On the other hand, *M. magellanicus* is distributed on intermediate platform of the Argentine Sea and in the gulfs of San Jorge and San Matías. On the platform its distribution is closely related to the Malvinas current, and it has been recorded at temperatures that varied from 3 to 13° C (Cousseau and Perrotta 2013). Possible explanations for these irregular records are diverse; in some cases they could be due to atypical abiotic conditions, such as the extraordinary incursion of marine waters or the occurrence of adverse climatic conditions in the area outside the estuary, or it could even be due to an intrusion when following their preys.

11.7 Reproductive Mode Functional Group

The spawning features and the degree of parental care are required to define reproductive modes in fishes (DeMartini and Sikkel 2006; Elliott et al. 2007). Fish species are first divided into oviparous and viviparous, according to the maternal investment in individual offspring (DeMartini and Sikkel 2006). Viviparous species present internal fertilization and live-bearing of young with a broad range of post-fertilization provisioning, from no (strictly lecithotrophic viviparity) with live-bearing of young provisioned entirely by ovum yolk to extensive provisioning beyond the nutrition provided by ovum yolk (matrotrophic viviparity). On the other extreme are the oviparous species with lecithotrophic maternal provisioning (limited to the yolking of ovarian oocytes prior to fertilization) and external fertilization. Oviparous species are distinguished on the basis of their egg characteristics, mode of release, and the degree of parental care provided to eggs (Franco et al. 2008). These reproductive modes determine offspring survival; according to the optimization theory, parental care implies a greater investment on offspring (therefore, larger individual offspring) at the expense of the number of offspring in which it is performed. Within of viviparous species category, the most extreme example of parental care is matrotrophic viviparity (DeMartini and Sikkel 2006).

According to reproductive modes described in Jaureguizar et al. (2016), different reproductive strategies occur in estuarine and migrant assemblages of Bahía Blanca Estuary. The 78% of the species are oviparous (62.4% producing pelagic eggs, 6.2% eggs that settle on the substratum and adhesive eggs 9.4% and), followed by 15.6% of viviparous and 6.4% of ovoviviparous species. Of the 13 estuarine-resident species registered, most (61.5%) produce pelagic eggs, spawning within the estuary or in its influence area (e.g., *Ramnogaster arcuata*, *Oncopterus darwinii* and *Porichthys porosissimus*). Species that produce adhesive eggs that are able to attach to substrata and the vegetation are second in importance (23.5%; e.g., *Odontesthes argentinensis*), and finally two species (15%) were ovoviviparous (*Sympterygia acuta* and *S. bonapartii*). The reproductive strategy of marine migrant fish was similar to that of the estuarine-residents, as 58.8% of these species spawn pelagic eggs (e.g., *Micropogonias furnieri*, *Cynoscion guatucupa*, and *Brevoortia aurea*), followed by viviparous species (29.4%; e.g., *Mustelus schmitti* and *Myliobatis goodei*). There was only one ovoviviparous species whose male carry the eggs in their mouth (*Genidens barbatus*).

11.8 Feeding Mode Functional Group

Trophic ecology studies seek to identify the feeding habits of species through the analysis of the major items consumed. Knowledge on the diets of species is one of the basic requirements for a closer examination of the relationships between

organisms in a given ecosystem. A very close relationship exists between the quantity, quality, and availability of food and the distribution and abundance of consumer organisms (Dantas et al. 2013; Campos et al. 2015). The structures of fish assemblages that use the shallow areas of estuaries are strongly influenced by trophic relationships (Blasina et al. 2016). Knowledge on the structure of the trophic web allows the description of the energy flow in an ecosystem and the understanding of the ecological relationships among organisms (Dantas et al. 2013).

Although opportunism is a widely reported feeding strategy used by estuary-associated fish (Gerking 1994; Elliott et al. 2007), intrinsic factors such as morphological and behavioral constraints set the boundaries on what food items can be taken from the environment, thus affecting the individual's ability to obtain certain prey. Extrinsic interactions (of a species or an individual with both the environment and other community members) will also influence the diet of said individual (Elliott et al. 2002; Horn and Ferry-Graham 2006). For example, the foraging range of the fish will affect which prey are encountered and can be potentially included in the diet, while mouth adaptations and morphology will determine which among the potential prey are ultimately consumed. The trophic categories from literature were revised by Franco et al. (2008), and feeding mode functional groups were identified by combining information on predominant diet and feeding location. The trophic groups, indicating the main types of food exploited by fish within estuarine environments and the estuarine compartments (e.g., pelagic, benthic) where these resources are taken, are:

- Microbenthivores: feeds mainly on benthic, epibenthic, and hyperbenthic fauna, with prey size <1 cm.
- Macrobenthivores: feeds mainly on benthic, epibenthic, and hyperbenthic fauna, with prey size >1 cm.
- Planktivores: feeds predominantly on zooplankton and occasionally on phytoplankton in the water column, mainly by filter feeding.
- Hyperbenthivores/zooplanktivores: feeds just over the bottom, predominantly either on smaller mobile invertebrates living over the bottom or zooplankton; diverse prey capture mechanisms (ram, suction, or manipulation).
- Hyperbenthivores/piscivores: feeds just over the bottom, predominantly either on larger mobile invertebrates living over the bottom or fish; diverse prey capture mechanisms (ram, suction, or manipulation).
- Detritivores: feeds on all the small organisms in or on the surface layer of the substratum (e.g., benthic algae such as diatoms, microfauna, and, to a lesser extent, smaller meiofauna) and associated organic matter (usually of plant origin); ingests relatively large volumes of sand or mud (by suction mechanisms); digests the food material and passes out the inorganic particles.
- Herbivores: grazes predominantly on living macroalgal and macrophyte material.
- Omnivores: ingests both plant and animal material by feeding mainly on macrophytes, periphyton, epifauna, and filamentous algae.

11.8.1 Feeding Habits of the Fish of Bahía Blanca Estuary

With the objective to comparatively describe and analyze the trophic spectrum of the most common species and their interrelationship, Lopez Cazorla (1987) studied the stomach content of 1035 specimens belonging to 7 species of fish, between 1980 and 1982. The species studied were *Sympterygia bonapartii*, *Mustelus schmitti*, *Porichthys porosissimus*, *Odontesthes argentinensis*, *Micropogonias furnieri*, *Cynoscion guatucupa*, and *Paralichthys orbignyanus*. Her results indicate that *Neohelice granulata* is the most important food source for almost all the species studied. The remainder of the dietary items presented great differences in the proportions consumed by each of the species. *Sympterygia bonapartii* feeds mainly on benthic decapodic crustaceans, predominately peneids and brachyurans. The diet of *Mustelus schmitti* was found to be composed mainly of benthonic decapod crustaceans, polychaetes, and young fish. *Porichthys porosissimus* fed almost exclusively on *Peisos petrunkevitchi* with a small percentage of misidaceans. *Odontesthes argentinensis* showed a diet consisting principally of *Neohelice granulata*, gastropods, misidaceans, and amphipods. *Micropogonias furnieri* consumed *N. granulata* and *P. petrunkevitchi* as their most common prey. *Cynoscion guatucupa* presented a diet which consisted mainly of *Pleoticus muelleri*, *Artemesia longinaris*, *P. petrunkevitchi*, and young fish of the *Ramnogaster arcuata*, *Brevoortia aurea*, and *O. argentinensis*. *Paralichthys orbignyanus* preys on the following fish species: *O. argentinensis*, *B. aurea*, *R. arcuata*, *Parona signata*, *C. guatucupa*, *Pomatomus saltatrix*, *P. orbignyanus*, and *Lycengraulis olidus* (Fig. 11.4).

Crabs and polychaetes constitute the principal or most important food for benthonic and demersal fish, while Decapoda Natantia such as *A. longinaris*, *P. muelleri*, and *P. petrunkevitchi* were the principal food of demerso-planktonic fish. Although fish select certain types of prey, depending on their size and habitat, consumption of prey depends, above all, on the availability and the community structure of the prey.

In this regard, a brief description of the community structure of prey can help to interpret these findings. In Bahía Blanca Estuary, an adequate supply of food for the diverse life stages of the fish communities depends on a sequential abundance of progressively bigger prey, from autumn to late summer. Nutrient abundance increases by the end of summer, reaching a peak in the autumn months (between April and June) (see Chap. 3). This increase in the nutrient load produces a trophic cascade, triggering blooms in the planktonic fractions. The main phytoplankton bloom occurs between June (winter) and October (spring), followed by the mesozooplankton explosion in November (spring). November is the month when misidaceans and brachyuran larvae, important prey items in the diet of several fish species of the estuary, register their maximum abundance. Teleost larvae of demersal species, like *Cynoscion guatucupa*, feed on small planktonic crustaceans like *Acartia tonsa* and then shift their diets to larger prey like miscidacean *Arthromysis magellanica*. Peneid crustaceans, like *Peisos petrunkevitchi*, *Artemesia longinaris*, and *Pleoticus muelleri*, occur mainly between January (summer) and June and are

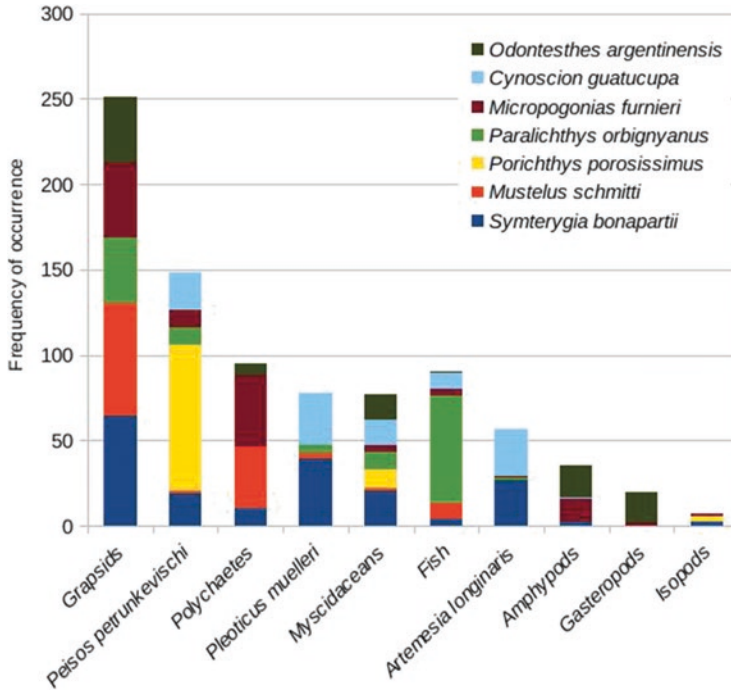


Fig. 11.4 Frequency of occurrence of major prey items in the stomach contents of the studied fish species of Bahía Blanca Estuary

the food of larger juveniles, which eventually prey on other fish. Pups of chondrichthyan are too large to feed on small planktonic prey, exploiting the abundance of larger crustaceans by the end of spring and mid-summer. Resident species like *Ramnogaster arcuata* breed in spring, when abundant food is available for the adults but also for the larvae and juveniles.

The benthic fish species that feed on reptant crustaceans and polychaetes do not experience such a pronounced seasonality as that of the plankton. The intertidal ecotone in Bahía Blanca Estuary is dominated by euryhaline vascular plants, like *Sarcocornia perennis* and *Spartina alterniflora*. These plants dominate the mud flats that cover most of the intertidal environment of the estuary. This habitat is characterized by fast-changing temperatures, oxygen-poor substrate, and lack of refuge. However, the association between the burrowing crab *Neohelice granulata* and the salt marsh plant *S. perennis* creates a unique habitat for other invertebrates, as it promotes sediment oxygenation and nutrient turnover (Parodi 2004). This particular type of habitat is called “cangrejal,” in Spanish meaning “land of crabs.” Polychaetes are particularly benefited, and their abundances in sites with *cangrejal* are significantly higher than in sites without *cangrejal*. This bolstered abundance of crabs and polychaetes might explain why these are the most predominant and important prey

items for the fish species present in Bahía Blanca Estuary. *Cangrejal* sites could be essential for the thriving of the whole trophic network of the estuary (Elías et al. 2004).

Box 11.1 Artisanal Fishery in Bahía Blanca Estuary

It is widely recognized that small-scale fisheries play an important role in providing food and livelihood to people, contributing to poverty reduction and sustainable development in several places around the globe (FAO 2005). In particular, developing countries greatly benefit from this type of fishery, as they constitute the main source of both food and income for people living along the coast (Blaber et al. 2000). Artisanal fishermen communities develop an intricate relationship with the marine environment and the species that constitute their sustenance, which greatly aids the success of conservation and management practices.

The artisanal fishery in Bahía Blanca Estuary has been carried out since the beginning of 1900. Fishermen employ a combination of fishing gear throughout the year, consisting of shrimp nets, channel closures, and gill nets. Each type of net is employed to target a particular species or group of species and is performed in different times of the year to increase yield and reduce bycatch of unwanted species. Traditionally a family business, fishermen formed the *Cooperativa Pesquera Whitense* (White's Fishery Cooperative), a cooperative organization, between 1945 and 1999. The cooperative had a fish processing plant and handled the marketing of the fishermen catch, allowing a better income for the families of the fishermen and a regulatory frame for the activity. However, this organization closed in 1999 due to the collapse of the artisanal fisheries of several species (Lopez Cazorla et al. 2014).

The Collapse of a Fishery

Between 1972 and 1992, catches of *Cynoscion guatucupa* reached 50% of the total annual landings. However, at the end of the 1990s, catches dropped to 15%. In 2004 the Argentinean Government implemented fishing closures in El Rincón area, as a management measure to control the increasing landings and the decrease in biomass of *C. guatucupa* and several other commercial species (Carozza and Fernández Araújo 2009). But the closure came too late to save the artisanal fishermen of Bahía Blanca Estuary; between 2000 and 2004, the artisanal fishery in the south of Buenos Aires Province collapsed.

In Lopez Cazorla et al. (2014), we explore the causes of the collapse of the fishery within the estuary. A cursory look at the reported landings suggested that the greatly increased fishing pressure from industrial vessels operating outside the estuary had depleted the stocks of *C. guatucupa*. The annual

(continued)

Box 11.1 (continued)

commercial landings of the Argentinean fleet reached 5000 t in the early 1970s. After that, landings increased sharply to 20,000–48,000 t in the decade between 1995 and 2004 (Villwock de Miranda and Haimovici 2007). From 1992 to 1998, the number of industrial vessels targeting striped weakfish at the northern continental shelf of Argentina doubled, and the amount of effort measured in fishing hours quadruplicated (Ruarte et al. 2000). For *C. guatucupa*, the first scientific results pinpointing the decrease in the yields of the artisanal fleet fishing this species in Bahía Blanca Estuary were presented by Lopez Cazorla (2004). Carozza et al. (2004) mentioned that since 2000, there was an increase in landings of several coastal species at El Rincón area, especially during the reproductive season of most of them. Additionally, Aubone et al. (2006) mentioned that from 1995 to 2006, biomass of *C. guatucupa* stocks south to the 39° S was severely depleted.

In Fig. 11.5, we plotted landings, effort, and yield (CPUE) for both fleets from 1992 to 2009. Landings in Bahía Blanca Estuary seem to increase steadily since 2004, whereas landings in El Rincón area increased to higher values between 1994 and 2002. Since 2001, landings dropped to lower values in El Rincón area, while they started to increase in Bahía Blanca Estuary.

Effort applied in Bahía Blanca Estuary decreased from 1992 to 2000; from 2001 up to 2004, it remained low and constant, and since 2005 a slight recovery was observed. Effort applied on El Rincón area increased in 1996–2001 period from the lower values of 1992–1995. From 2002, effort dropped considerably, remaining low until 2003, although a slightly positive trend can be observed until 2009. In Bahía Blanca Estuary, there was a steady drop in yield, from 1992 to 1994, and this decrease continues until 1998. On 1999, yield peaked at 265 kg/day and then dropped again until 2003. Starting on 2004, there was a net increase of the yield. Yields in El Rincón area increase since 1993, and up to 2001, around the same average values. Yield between 2002 and 2009 presented an important increase.

Our evidence suggests that the landings of the artisanal fleet operating in Bahía Blanca Estuary were affected by the increased fishing pressure exerted by the industrial fishing fleet of El Rincón area. Effective management of this fishery needs to be implemented to attain sustainability. While the fishing closures in El Rincón area provided certain respite for the weakfish populations, they are not enough to rebuild the stock of this species. *Cynoscion guatucupa* stocks need to be recovered before a sustainable fishery of this species can be implemented (Lopez Cazorla et al. 2014).

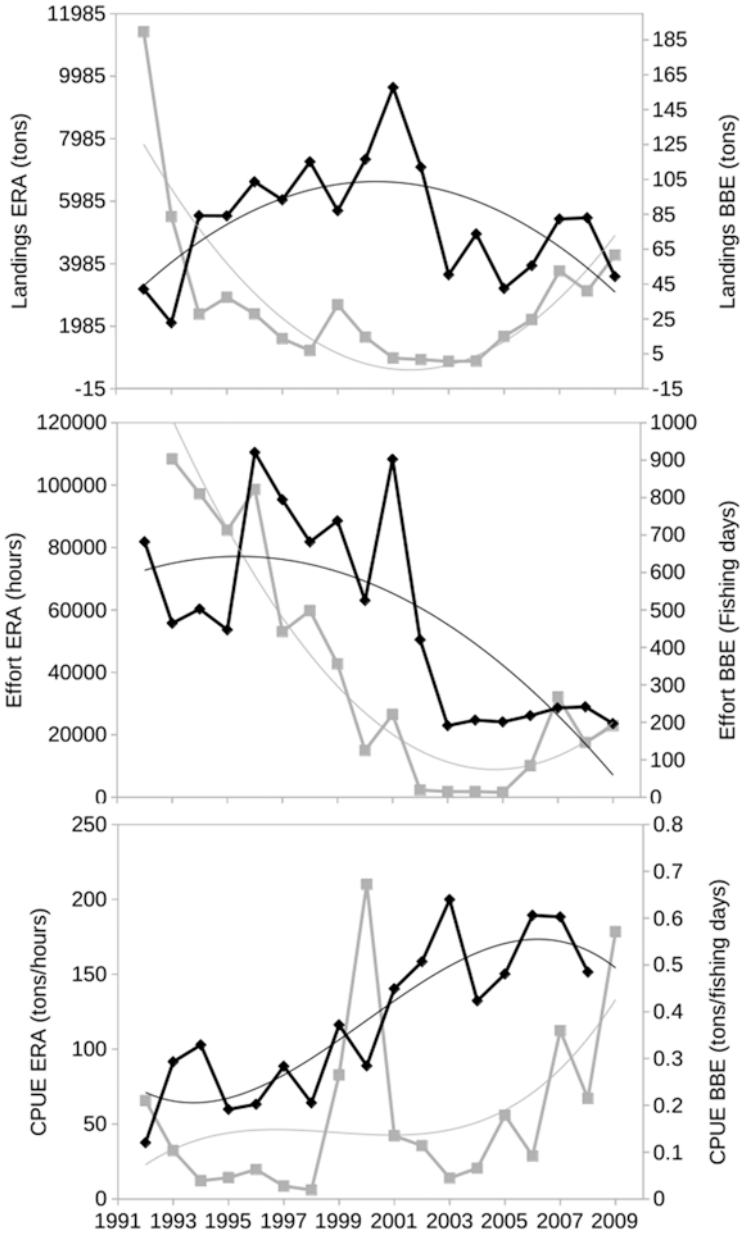


Fig. 11.5 Reported landings (a), effort (b), CPUE (c), and model estimates for Bahía Blanca Estuary (BBE) and El Rincón area (ERA) for *Cynoscion guatucupa* in 1992–2009. Data for Bahía Blanca Estuary is presented with boxes and a gray line for the model estimates. Data for El Rincón area is presented with triangles and a black line for the model estimates. (Modified from Lopez Cazorla et al. 2014)

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