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Using BRUVS to describe the fish assemblage and its seasonality in two shallow marine inlets within protected areas of Patagonia, Argentina

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Abstract. Baited Remote Underwater Video Stations (BRUVS) complemented with fishing methods were used to describe the fish assemblage and its seasonal pattern in two marine inlets from Patagonia. The combined results for BRUVS and fishing sessions identified 13 fish species. Our results agree with the biogeographic schemes proposed for the southern Southwest Atlantic. The fish species belonging to the Argentine Biogeographic Province presented a seasonal pattern with a peak of maximum abundance (*Notorynchus cepedianus* and *Galeorhinus galeus*) or were recorded during warm months only (*Mustelus schmitti*, *Myliobatis goodei*, and *M. ridens*), coinciding with the general latitudinal pattern expected for fish species richness. The use of BRUVS in this study allowed for the assessment of different fish species and wide range of sizes, from large sharks (*N. cepedianus*) to small cryptic species (*Patagonotothem* sp.). However, three of 13 species were only recorded by fishing methods, like it was the case for *M. ridens*. The record of *M. ridens* is the first in Patagonian waters, extending its distribution for c. 180 km south of the previously known southern limit. This study contributes to filling large data gaps along the Southwest Atlantic regarding the description and understanding of the temporal dynamics of fish assemblages in particular environments within protected areas.

[Keywords: fish monitoring, marine protected areas, Southwest Atlantic, video imagery]

Resumen. Uso de BRUVS para describir el ensamble de peces y su estacionalidad en dos caletas marinas poco profundas dentro de áreas protegidas de la Patagonia, Argentina. A fin de describir el ensamble de peces y su patrón estacional en dos caletas marinas de la Patagonia se utilizaron estaciones de video submarinas remotas con cebo (BRUVS) complementadas con métodos de pesca. Los resultados combinados para BRUVS y sesiones de pesca permitieron identificar 13 especies de peces. Nuestros resultados concuerdan con los esquemas biogeográficos propuestos para el sur del Atlántico Sudoccidental. Las especies de peces pertenecientes a la Provincia Biogeográfica Argentina presentaron un patrón estacional con un pico de abundancia máxima (*Notorynchus cepedianus* y *Galeorhinus galeus*) o se registraron sólo durante los meses cálidos (*Mustelus schmitti*, *Myliobatis goodei* y *M. ridens*), lo cual coincide con los patrones latitudinales esperados para la riqueza general de especies de peces. El uso de BRUVS en este estudio permitió la evaluación de todo el rango de tallas del conjunto de peces evaluado, desde grandes tiburones (*N. cepedianus*) hasta pequeñas especies crípticas (*Patagonotothem* sp.). Sin embargo, tres de las 13 especies sólo se registraron por métodos de pesca, como fue el caso de M. ridens. El registro de M. ridens es el primero en aguas patagónicas, extendiendo su distribución c. 180 km al sur del límite sur previamente conocido. Este estudio contribuye a llenar grandes vacíos de información a lo largo del Atlántico Sudoccidental con respecto a la descripción y la comprensión de la dinámica temporal de los ensambles de peces en ambientes particulares dentro de áreas protegidas.

[Palabras claves: monitoreo de peces, áreas marinas protegidas, Atlántico Sudoccidental, imágenes de video]

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Introduction

The main patterns of distribution and ecology of marine fishes in the Southwest Atlantic Ocean (SWA) are related with two zoogeographic provinces: the Magellanic and the Argentine Province (Balech 1964; Menni 1983; Balech and Ehrlich 2008). The Magellanic Province includes the Patagonian shelf from Cabo de Hornos (55° S) to Península de Valdés (43° S) and it follows a northward path along the edge of the continental shelf (Balech and Ehrlich 2008). The Argentine Province extends over the continental shelf between a fluctuating northern limit at 30-32° S (Rio Grande do Sul, Brazil) and a southern limit in northern Patagonia at 42-44° S (San Matías gulf, Argentina). The biogeographic differences between the two provinces are mainly associated with lower water temperatures in the Magellanic Province (sub-Antarctic origin) and with higher water temperatures in the Argentine Province (subtropical origin) (Menni and Stehmann 2000). Based on ichthyofaunal composition, Menni and Gosztonyi (1982) determined four groups of fish species in southern SWA: a) Bonaerensean Fauna (fauna characteristic of the Bonaerensean District of the Argentine Province), b) Magellanic Fauna (fauna characteristic of the Patagonian District of the Magellanic Province), c) Inner Shelf Mixed Fauna, and d) Widely Distributed Species. Menni et al. (2010) also confirmed the two biogeographic provinces based on distribution patterns of chondrichthyans (sharks, rays, and chimaeras). More recently, two studies by Cousseau et al. (2019) and Sabadin et al. (2020) analyzed updated distribution patterns, richness and endemism of fish and chondrichthyans in the Magellanic Province respectively, corroborating the originally proposed biogeographic units. Note that one study (Briggs and Bowen 2012) has proposed a different biogeographic pattern for the region, but it is currently disregarded because it did not consider previous literature and it was not based on fish distribution data.

The transitional zone in temperate areas between the Argentine and the Magellanic biogeographic provinces has been described as one of the most productive areas in the SWA (~41-48° S) (Acha et al. 2004). The analysis of the bycatch of the different fleets that operate in the area targeting Argentinian hake *Merluccius hubbsi* and red shrimp *Pleoticus muelleri* made possible to identify a total of 101 species of chondrichthyans and bony fishes that characterize both biogeographic provinces (Góngora et al. 2009; Alemany et al. 2013; Bovcon et al. 2013; Ruibal-Núñez et al. 2016). In the case of coastal waters from northern and central Patagonia (~42-45° S), the diversity of fishes of coastal and soft bottom fishes was described through recreational fisheries (Bovcon 2016) and catch analysis of an artisanal coastal net fishery (Elías et al. 1991; Ré and Berón 1999). According to Bovcon (2016), a total of 39 species of fish are caught within coastal recreational fisheries of the region; amongst these, the Patagonian blennie *Eleginops maclovinus* and silversides *Odontesthes* spp. are the most frequent and are caught year-round, but show seasonality in their catches. Chondrichthyans also show seasonality in their catches, being the elephant fish *Callorhinchus callorynchus* one of the most frequent and abundant. In the San José and Nuevo gulfs (~42-43° S), operates an artisanal fishery with coastal nets and landings comprising 23 fish species, among which five silverside representatives of the Atherinopsinae family were reported (Elías et al. 1991; Ré and Berón 1999). These sources of information agree that *O. smitti* dominates the catches both in biomass and number, sustaining the artisanal fishery. On the other hand, Galván et al. (2009) described rocky reef fish assemblages of this area reporting a total of 29 species, including components of the two biogeographic provinces described above.

It is well known that all sampling methods present bias when assessing fish and other animal species compositions (Edgar et al. 2004; Harvey et al. 2004). However, accurate data on the abundance of fish species in space and time, and their biomass is often crucial to making management decisions (Hiddink et al. 2007). For many years, scientists have critically examined the suitability of different fish sampling techniques, both extractive and non-extractive. In many cases, contemporary assessments of fish communities are the basic information for ecological management, conservation and research, making destructive sampling techniques largely infeasible, unethical or counterproductive (Andradi-Brown et al. 2016). Amongst non-destructive sampling techniques, the use of remote video and in particular baited remote underwater video stations (BRUVS) have given promising results and have been widely used for more than 60 years (Mallet and Pelletier 2014). As a result, there has been a widespread call for the use of video methods for monitoring the fish communities (Pelletier et al. 2011; Tessier et al. 2013).

In southern SWA, observational methods based on underwater visual census and video imagery were mostly used to study rocky reef fish assemblages and relative abundance of large sharks (Galván et al. 2009; Trobbiani and Venerus 2015; Irigoyen et al. 2018, 2019). However, across non-rocky bottom types (e.g., soft bottoms), underwater visual census has not been suitable due to the low density of fish species, as well as fish wariness of divers, particularly chondrichthyans (Galván et al. 2009; Irigoyen A., personal observation). Additionally, vast areas of the Patagonian coasts remain unexplored regarding their fish assemblages mainly due to the lack of resources or their inaccessibility. Therefore, more work is needed to study fish assemblages in these areas that remain unassessed to increase our understanding of the various fish communities in Patagonia. The aim of this study is to describe the coastal fish assemblage and its seasonality in two underexplored shallow marine inlets within two different coastal Marine Protected Areas (MPAs) of North and Central Patagonia, Argentina. To achieve this, we used BRUVS on a bimonthly basis complemented with opportunistic fishing sessions. Because one site is located at the southern edge of the Argentine Province and the other on the northern edge of the Magellanic Province, we hypothesize that the fish assemblages of the two sites are composed by species of the two biogeographic provinces, reflecting the functioning of the region as a transitional zone between the two sites. Understanding the temporal dynamics of the fish assemblages is important for effective management of MPAs and is necessary to expand our knowledge on fish distribution and diversity throughout the SWA region.

Materials and Methods

Study site

The study sites are two inlets within MPAs of northern and central Patagonia, namely Caleta Valdés (~42.5° S) and Caleta Malaspina (~45.1° S), which have a complete marine regime (Figure 1a-b). Caleta Valdés (CV) is part of the Península de Valdés (Figure 1a), an area recognized in 1999 by UNESCO as a World Heritage Site because of its concentration of marine mammals and birds. Caleta Malaspina (CM) is located at the northern extreme of San Jorge gulf and it is a part of the Interjurisdictional Marine Coastal Park Patagonia Austral (Figure 1b). This MPA is a protected area of 750 km^2 that extends from the coastline to one nautical mile, and it was created in 2009 to protect its high diversity and biological productivity. Although a priority has been placed to protect birds and marine mammals, it is also a spawning area for fish and crustacean species (Yorio 2009) which have been little studied in relation to other groups of animals.

Both inlets are characterized by a narrow and long water intrusion bounded either by a 35 km-long gravel bank (CV, Figure 1a) or by 10 km-long rocky and gravel shores (CM, Figure 1b). Tidal height in both study sites varies on average ~3 m between high and low tide every ~6 h. As a result of a small mouth and shallow waters (maximum depth of 18 m at high tide), tides produce strong currents of changing direction throughout the day. Despite the differences in width and length, both inlets have similar habitat distribution and dynamics, and two sections can be identified based on environmental features. The inner section of the inlets is characterized by soft bottoms (mud and sand) and a central deep channel (between 8 and 18 m deep depending on the tide) surrounded by shallow bays, large intertidal areas and islets (Figure 1a-b) (Irigoyen A., personal observation). On the other hand, the mouth portion (defined here as the area adjacent to the mouth) of the inlets is characterized by rocky and gravel bottoms, relatively shallow depths (between 3 and 10 m depending on the tide), and patchy kelp forests of *Macrocystis pyrifera* and *Undaria pinnatifida*. Currents are particularly strong in the mouth section due to its narrower and shallower nature (Irigoyen A., personal observation). Water surface temperature fluctuates seasonally between a mean value of 8.6 °C in September and 17.9 °C in March in CM, and between 9.6 °C and 17.9 °C in the same months in CV (average monthly Sea Surface Temperature for the study period 2015-2019, Aqua MODIS; URL: https://tinyurl.com/ybq3axld).

Sampling design

Sampling trips were conducted on a bimonthly basis between June 2015 and February 2017 in CV, and between January 2018 and January 2019 in CM. In each trip, several BRUVS were deployed in a single day. The site, moon phase and tide variables were fixed for each site to avoid effects on BRUVS-derived relative abundance estimates. Sampling dates were set on full moon days with the high tide occurring at midday (between 11:00 and 14:00 h) for CV and with the low tide occurring at midday (between 11:00 and 14:00 h) for CM. Because of logistic limitations, sampling with BRUVS in CV was restricted to the central section across 3 km to the north and 3 km to the south of Punta Bajo location (42°25′ S - 63°37′ W) (Figure 1a) where it was possible to safely access the site. On the other hand, sampling with BRUVS in CM occurred across different areas of the inlet that were accessed from a particular beach in the central west part of the inlet (Figure 1b). Additional deployments in spring of 2018 and 2019 in CV were conducted to increase the number of samples and to eventually detect the presence of more species.

Baited remote underwater video stations (BRUVS)

Deployments of BRUVS were conducted to detect the presence of fish species and to determine the seasonal variation in the relative abundance of fish species. The BRUVS consisted of iron poles and a trestle shape frame, enclosing a GoPro® camera (models Hero 3+ and Hero 4). A perforated bait canister of 63 mm Ø and 20 cm-long stuffed with 600 g of chopped Atlantic chub mackerel *Scomber colias* was held with detachable 110 cm-long arms (25 mm Ø plastic conduit). The BRUVS were deployed 4-9 m (CV) or 3-12 m (CM) deep only within the 2-hour time window ranging between 1 h before and 1 h after high/low tide to avoid the high currents occurring during the rest of the tide period. Between four and eight BRUVS equally distributed across the south and north of Punta Bajo in CV and 15 BRUVS in CM were deployed per sampling trip. The BRUVS were set at least 400 m apart from each other to ensure independence between samples. The positions of BRUVS deployments were recorded using GPS and were repeated throughout the study in both inlets.

For each video record, the first 60 minutes of video imagery was analyzed, given that the experimental design guaranteed the most stable physical conditions at high/low tide in

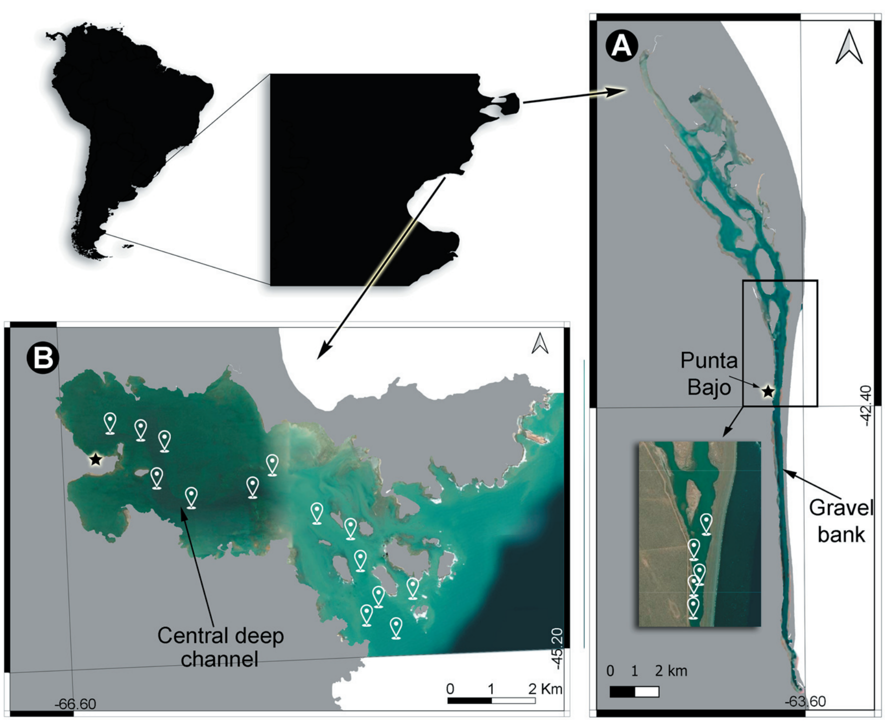

Figure 1. Location and main features of the two study sites of Caleta Valdés (A) and Caleta Malaspina (B) in North and Central Patagonia, Argentina. In A, the inlet is separated from the ocean by a long gravel bank and the sampling location of Punta Bajo (black star) is indicated. In B, the star indicates where the fishing sessions took place and the main deep channel is indicated. Both maps show masked satellite images (Bing satellite images) to highlight bathymetric conditions and the baited remote underwater video station (BRUVS) deployment positions.

Figura 1. Ubicación y características principales de los dos sitios de estudio Caleta Valdés (A) y Caleta Malaspina (B). En A, la caleta se muestra separada del océano por un largo banco de grava, y se indica la ubicación de muestreo de Punta Bajo (estrella negra). En B, la estrella indica el sitio donde se realizaron las sesiones de pesca y se indica el canal principal profundo. Ambos mapas muestran imágenes satelitales enmascaradas (imágenes de satélite Bing) para resaltar las condiciones batimétricas y las posiciones donde se desplegaron las BRUVS.

each session (more details can be found in Irigoyen et al. 2018). The MaxN index of relative abundance was calculated for the species identified in the videos. This index is defined as the maximum number of individuals observed in a single video frame over the entire video session (Harvey et al. 2004). On the other hand, the Nocc index was calculated as the total number of occurrences in the field of view over the entire video record session. In the case of the silverside *O. smitti*, the MaxN index was not appropriate because the species usually forms large schools (i.e., +100 individuals) saturating the field of view (Whitmarsh et al. 2017). To avoid bias in estimates an *ad-hoc* index of relative abundance (N_S) was established to consider the frequency and size of the school formations that are observed. Therefore, the relative abundance of *O. smitti* was classified by the N_S index as:

0: total absence in the video session,

I: sporadic presence of solitary individuals (n<50),

II: continuous presence of solitary individuals or small schools (n>50),

III: low frequency of small and large schools (for 0-10 minutes of video),

IV: high frequency of small and large schools (for 10-30 minutes of video),

V: highest frequency of large schools (for more than 30 minutes).

Table 1. Mean (±standard deviation) seasonal relative abundance (Nmax) and frequency (Nocc, HD, and LD) of fish species detected at Caleta Valdés study site in North Patagonia, Argentina. The Nmax and Nocc are calculated from sampling with baited remote underwater video stations (BRUVS), and HD and LD from sampling with heavy-duty rod and reel and longlines, and light-duty rod and reel and hand seine fishing equipment, respectively. Classification as dominant (DOM), frequent (FRE), occasional (OCA), and rare (RAR) is shown based on the Olmstead-Tukey diagram (OTD). For the common silverside (*Odontesthes smitti*) that was highly abundant and frequent, its relative abundance is expressed as the most frequently categorical Ns index for the season (see Methods), and its frequency with LD fishing is expressed as <50 (+), 50-100 (++), or >100 (+++). The biogeographic scheme is also indicated: a) Bonaerensean Fauna (BF) - Argentine Province, b) Magellanic Fauna (MF) - Magellanic Province, Internal Platform Fauna (IPF), Widely Distributed Fauna (WDF) and Non-assigned species (NN). The number of BRUVS deployments and the time of video footage analysed is shown.

Tabla 1. Abundancia relativa (Nmax) y frecuencia (Nocc, HD, y LD) estacionales promedio (± desvío estándar) de especies de peces detectadas en el sitio de estudio Caleta Valdés, Patagonia Norte, Argentina. El Nmax y el Nocc fueron calculados con las estaciones de video remoto (BRUVS), y el HD y LD de los muestreos con equipos de pesca pesada y espineles, y la pesca liviana con caña y *reel*, y redes de cerco, respectivamente. La clasificación como dominante (DOM), frecuente (FRE), ocasional (OCA), y rara (RAR) mostrada se basa en el diagrama de Olmstead-Tukey (OTD). Para el pejerrey común (*Odontesthes smitti*) que presenta gran abundancia y frecuencia, su abundancia relativa es expresada como la categoría más frecuente para el índice Ns por estación (ver Métodos), y la frecuencia con pesca LD es expresada como <50 (+), 50-100 (++), or >100 (+++). Para (*Odontesthes argentinensis)* se menciona su frecuencia de ocurrencia en las BRUVS. También se indican las regiones biogeográficas: Fauna Bonaerense (BF) - Provincia Argentina, Fauna Magallánica (MF) - Provincia Magallánica, Fauna de la Plataforma Interna (IPF), Fauna Ampliamente Distribuida (WDF) y especies no asignadas (NN). Se muestra el número de BRUVS desplegados y el tiempo de video analizado.

Species	Summer				Autumn				Winter				Spring				OTD	Biogeogr. scheme
	Nmax	Nocc	HD	LD	Nmax	Nocc	HD	LD	Nmax	Nocc	HD	LD	Nmax	Nocc	HD	LD		
Notorynchus cepedianus	0.33± 0.57	14.66± 25.4	50	0	1	39	34	0	0.33± 0.51	0.66± 1.21	20	0	1.05± 1.05	12.05± 21.68	111	0	DOM	BF
Myliobatis goodei	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	--	BF
Myliobatis ridens	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	--	BF
Mustelus schmitti	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	--	BF
Odontesthes smitti	V		0	++	II / IV		0	++	0 / V		0	++	V		0	+	--	NN
Odontesthes argentinensis	occasionally		0	+	--	--	0	0	--	--	0	0	occasionally		0	+	--	NN
Eleginops maclovinus	0	0	0	0	0	0	0	0	0.16± 0.40	1.16± 2.85	0	0	0.2± 0.41	1± 3.06	0	0	RAR	MF
Bovichthys argentinus	0	0	0	0	0	0	0	0	0	0	0	0	0.25± 0.41	0.25± 0.41	0	0	RAR	MF
Pseudopercis semifasciata	0	0	0	0	0	0	0	0	0	0	0	0	0.05± 0.22	0.15± 0.68	0	0	RAR	IPF
Number of BRUVS	3				2				6				20					
Analysed time	180				120				360				1200					

Fishing sessions

A series of different fishing methods targeting large chondrichthyans and smaller species were conducted opportunistically in between BRUVS deployments to complement the analysis and possibly detect species that may not be spotted on camera. In CV, heavy-duty (HD) fishing sessions lasted 11 h on average and in CM fishing sessions lasted 4.5 h on average using in both inlets between four and six fishing rods equipped with Mustad 10/0 hooks. Only in CV, longlines were deployed from an inflatable boat and then hauled from the coast. Longlines consisted of 140 m lead-core mainline with 0.8 m stainless steel snoods and 20 hooks (Mustad 2330-DT, size 1). The total number of longline settings per day varied depending on soak time, weather and personnel availability. Soak time ranged between 30 and 120 minutes (average 73 minutes). Also, opportunistic fishing sessions were conducted in both inlets with light-duty (LD) rod and reel equipment and small hooks (Sode Nº 8 and Nº10) commonly used for fishing silversides in the region. Atlantic chub mackerel (*S. colias*) was used as bait in all cases. Additionally, 10 m-long hand seines were also deployed in CV as a sampling strategy to detect the potential presence of smaller fish species.

Data analysis

The BRUVS-derived indices (Nmax, Nocc and N_s) were used to determine the relative abundance of fish and its seasonal variation (ANOVA test). We constructed a hierarchical Olmstead-Tukey diagram (Sokal and Rohlf 1981) for each study site to classify species as dominant, frequent, occasional and rare.

Table 2. Mean (±standard deviation) seasonal relative abundance (Nmax) and frequency (Nocc, HD, and LD) of fish species detected at Caleta Malaspina study site in Central Patagonia, Argentina. The Nmax and Nocc are calculated from sampling with baited remote underwater video stations (BRUVS), and HD and LD from sampling with heavy-duty rod and reel and longlines, and light-duty rod and reel and hand seine fishing equipment, respectively. Classification as dominant (DOM), frequent (FRE), occasional (OCA), and rare (RAR) is shown based on the Olmstead-Tukey diagram (OTD). For the common silverside (*Odontesthes smitti*) that was highly abundant and frequent, its relative abundance is expressed as the most frequently categorical Ns index for the season (see Methods), and its frequency with LD fishing is expressed as <50 (+), 50-100 (++), or >100 (+++). The biogeographic scheme is also indicated: a) Bonaerensean Fauna (BF) - Argentine Province, b) Magellanic Fauna (MF) - Magellanic Province, Internal Platform Fauna (IPF), Widely Distributed Fauna (WDF) and Non-assigned species (NN). The number of BRUVS deployments and the time of video footage analysed is shown.

Tabla 2. Abundancia relativa (Nmax) y frecuencia (Nocc, HD, y LD) estacionales promedio (± desvío estándar) de especies de peces detectadas en el sitio de estudio Caleta Malaspina,Patagonia central, Argentina. El Nmax y el Nocc fueron calculados con las estaciones de video remoto (BRUVS), y el HD y LD de los muestreos con equipos de pesca pesada y espineles, y la pesca liviana con caña y *reel*, y redes de cerco, respectivamente. La clasificación como dominante (DOM), frecuente (FRE), ocasional (OCA), y rara (RAR) mostrada se basa en el diagrama de Olmstead-Tukey (OTD). Para el pejerrey común (*Odontesthes smitti*) que presenta gran abundancia y frecuencia, su abundancia relativa es expresada como la categoría más frecuente para el índice Ns por estación (ver Métodos), y la frecuencia con pesca LD es expresada como <50 (+), 50-100 (++), or >100 (+++). Las regiones biogeográficas son también indicadas: Fauna Bonaerense (BF) - Provincia Argentina, Fauna Magallánica (MF)-Provincia Magallánica, Fauna de la Plataforma Interna (IPF), Fauna Ampliamente Distribuida (WDF) y especies no asignadas (NN). Se muestra el número de BRUVS desplegados y el tiempo de video analizado.

Species	Summer				Autumn				Winter				Spring				OTD	Biogeogr. scheme
	Nmax	Nocc	HD	LD	Nmax	Nocc	HD	LD	Nmax	Nocc	HD	LD	Nmax	Nocc	HD	LD		
Notorynchus cepedianus	0.62± 0.91	14± 21.30	70	0	0.6± 0.54	5.8± 6.37	12	0	0	0	0	0	0.58± 1.12	12.11± 25.59	6	0	DOM	BF
Galeorhinus galeus	0.5± 0.75	6.25± 9.20	6	0	0.4± 0.54	11.6± 18.71	0	0	0	0	0	0	0	0	0	0	FRE	BF
Odontesthes smitti	0		0	+++	IV		0	++	0		0	0	0		--	+	--	NN
Eleginops maclovinus	0	0	0	+	0.2± 0.44	0.6± 0.89	0	0	0.18± 0.40	1.72± 4.56	0	0	0.11± 0.33	0.23± 0.56	0	0	RAR	MF
Patagonotothem sp.	0.12 ± 0.35	0.75 ± 2.12	0	0	0.2± 0.44	1± 2.23	0	0	0	0	0	0	0.05± 0.24	0.76± 2.48	0	0	RAR	MF
Nemadactylus bergi	6.37± 17.63	12.62± 35.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	OCA	IPF
Sebastes oculatus	0.12± 0.35	0.62± 1.76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	RAR	WDF
Number of BRUVS	8				5				11				17					
Analysed time	480				300				660				1020					

In addition, only the occurrence of species was recorded in opportunistic rod and reel and hand seine fishing sessions. Due to the opportunistic nature of these extra sessions, the relative abundance of species was not possible to be estimated because of the lack of an adequate sampling design. In the case of silversides (*O. smitti*) that were highly frequent and abundant across several sessions, we only determined the seasonal variation in the frequency of the different categories (0, I, II, III, IV and V) of the N_S index (Pearson's Chi-squared test, ^{2}) (Beasley and Schumacker 1995). All analyses were done in R software (R Core Team 2019).

Results

In total, 31 BRUVS deployments were effective to study the fish assemblage in CV and 41 in CM, adding up to a total of 72 hours of video footage analyzed (Tables 1 and 2). These effective deployments represented 48% and 57% of all deployments during each study period, respectively. The rest of the deployments were not considered in the analysis because of sub-optimal conditions caused mainly by strong currents (i.e., poor visibility, algae disturbance, device falling to the side and/or camera displaced from front view). Overall, 13 species of fish (i.e., teleost and chondrichthyans) were identified in the present study, among which 6 were found only in CV (Table 1) and 4 only in CM (Table 2). Of the total species, five corresponded to the a) Bonaerensean fauna, three to Magellanic fauna, two to Internal Platform Fauna, one to Widely Distributed Fauna and other two were non-assigned species (*O. smitti* and *O. argentinensis*). The BRUVS sampling allowed to detect ten of the 13 fish species whereas fishing methods detected only six species. Among the ten species detected on BRUVS, the silverside *O. smitti* was highly frequent and abundant, the sevengill shark (*Notorynchus cepedianus*) dominated the assemblage in both sites, the school shark (*Galeorhinus galeus*) was frequent only in CM, papamoscas *Nemadactylus bergi* was occasional in CM, and the rest of the species were rare in both sites (Tables 1 and 2, Figure 2a-b).

On HD fishing sessions, *N. cepedianus* also showed dominance in the catches as it was frequently caught in both sites year-round with the exception of winter in CM (Tables 1 and 2). Additionally, two species of eagle rays (*Myliobatis ridens* and *M. goodei*) and the narrownose

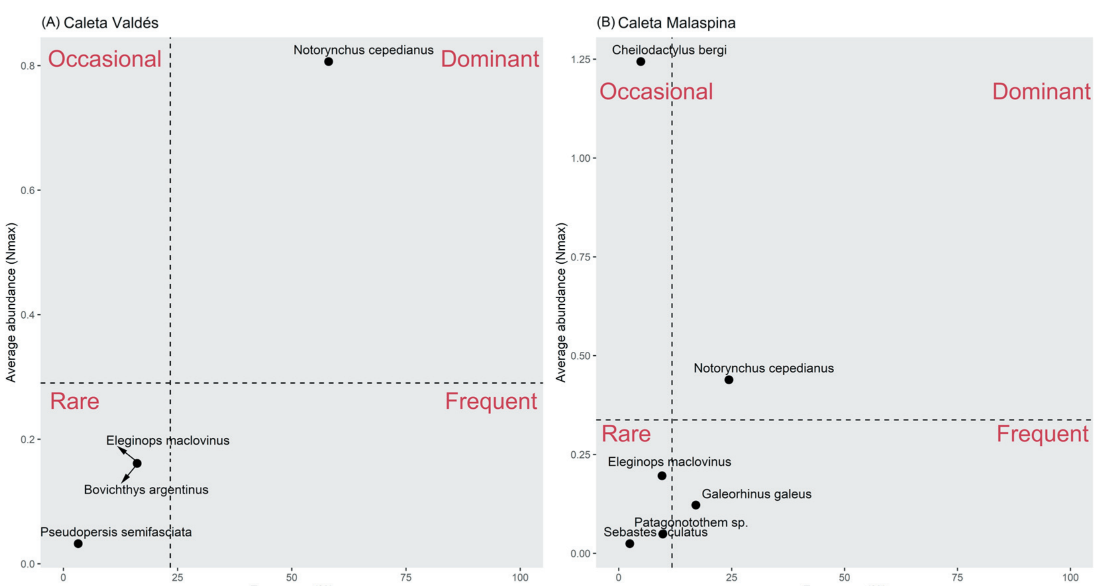

Figure 2. Olmstead-Tukey diagrams showing the relationship between frequency (%) and relative abundance (mean Nmax) of the species detected on baited remote underwater video stations (BRUVS) in the two study sites of Caleta Valdés (A) and Caleta Malaspina (B) in North and Central Patagonia, Argentina. The doted lines correspond to the mean abundance (vertical) and mean occurrence (horizontal), and are used to define dominant, frequent, occasional, and rare species.

Figura 2. Diagrama de Olmstead-Tukey que muestra la relación entre la frecuencia (%) y la abundancia relativa (Nmax medio) de las especies detectadas en las estaciones de video con cebo (BRUVS) en los dos sitios de estudio Caleta Valdés (A) y Caleta Malaspina (B) en Patagonia Central y Norte, Argentina. Las líneas punteadas corresponden a la abundancia media (vertical) y la ocurrencia media (horizontal) utilizadas para definir especies dominantes, frecuentes, ocasionales y raras.

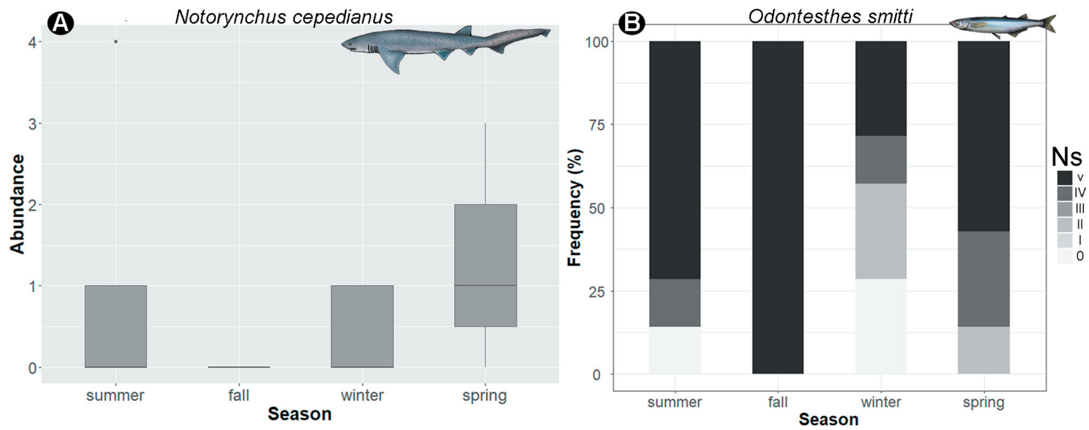

Figure 3. Seasonal variation in relative abundance for the sevengill shark *Notorynchus cepedianus* (A) and the silverside *Odontesthes smitti* (B) in Caleta Valdés between June 2015 and January 2017. Estimates in (A) are based on BRUVS-derived MaxN index. Estimates in (B) are based on the Ns index, that includes six different abundance categories for a species capable of forming large schools (see reference in text).

Figura 3. Variación estacional en la abundancia relativa de *Notorynchus cepedianus* (A) y *Odontesthes smitti* (B) en Caleta Valdés entre junio de 2015 y enero de 2017. Las estimaciones en (A) se basan en el índice MaxN derivado de las BRUVS. Las estimaciones en (B) se basan en el índice Ns, que incluye seis categorías de abundancia diferentes para una especie capaz de formar grandes cardúmenes (ver referencia en el texto).

smooth-hound shark (*Mustelus schmitti*) in CV and *G. galeus* in CM were caught only during warm months (spring-summer). The record of the short-nose eagle ray (*M. ridens*) in CV represents the southernmost record of the species to date. Moreover, LD fishing sessions were largely dominated by *O. smitti* followed by uncommon appearances of *O. argentinensis* and *E. maclovinus.*

Seasonality

Seasonality was analyzed only for dominant and frequent species, which included *O. smitti*, *N. cepedianus* and *G. galeus*. In CV, *N. cepedianus* showed no significant differences in relative abundance between seasons (ANOVA, F=0.89, P=0.464) (Figure 3a). The silverside *O. smitti* was recorded year-round in CV and showed maximum relative abundance in spring and autumn (X^2=174.6, P<0.001) (Figure 3b). Moreover, large schools of silversides during long video intervals (i.e., N_s category V) were frequent in all seasons and the minimum abundances were observed in winter.

In CM, the relative abundance of *N. cepedianus* and *G. galeus* showed fluctuations over the study period (Figure 4a-b). *Notorynchus cepedianus* showed high relative abundance during warm months (late austral spring-summer), as opposed to the rest of the year when minimum values were observed (ANOVA, F=5.71, P=0.003) (Figure 4a). During winter (June-early September), no sharks were spotted on BRUVS. Maximum relative abundance for *G. galeus* occurred in summer, whereas in the rest of the year it was not detected (ANOVA, F=4.46, P=0.009) (Figure 4b). In addition, the greatest concentration of *O. smitti* was observed during summer, whereas in fall and winter its presence was more sporadic, including solitary individuals and small schools (Figure 4c). No silversides were spotted on BRUVS during spring.

Discussion

The present work represents one of the first studies investigating the fish assemblage and seasonal changes in coastal areas of Patagonia (Argentina) based on baited camera stations. Overall, our results agree with the biogeographic scheme proposed by Menni and Gosztonyi (1982), Menni and López (1984) and Menni et al. (2010), indicating that the study sites fall within a transitional region of convergence of fish species. This convergence corresponds to the fauna associated with the Argentine (from 30-32° S to 42-44° S) and b) Magellanic provinces (across the Patagonian shelf from 55° S to 43° S), including species belonging to the c) Inner Shelf Mixed Fauna, d) Widely Distributed Species and other not classified species (Tables 1 and 2). Therefore, the biogeographic pattern of the study area may be the main explanation for the composition and seasonality of fish assemblage across the study sites.

The fish species belonging to the Argentine Province presented a seasonal pattern (*N.

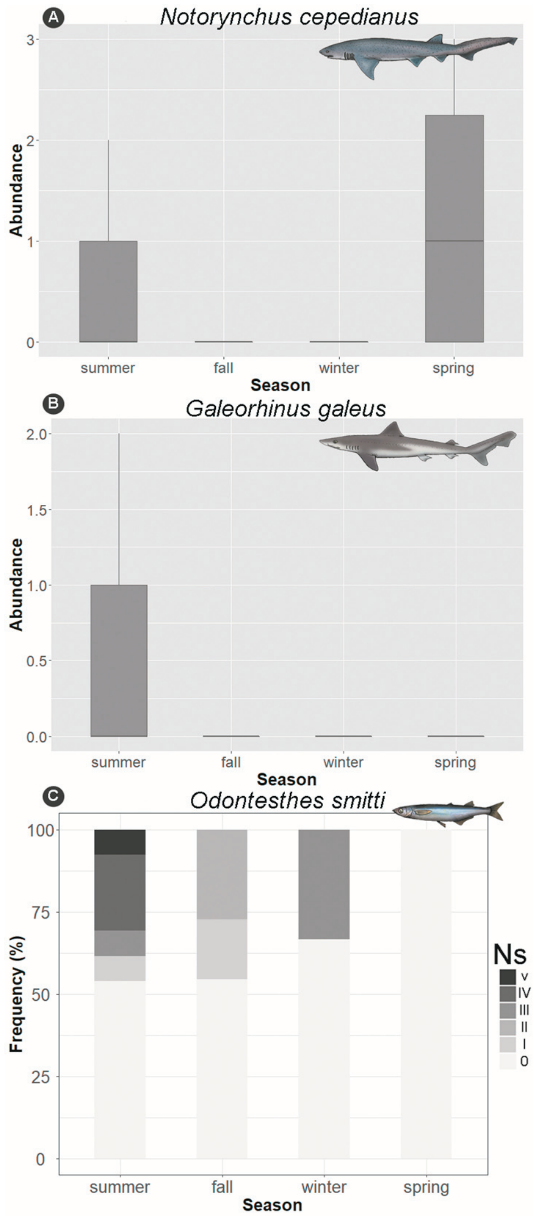

Figure 4. Seasonal variation in relative abundance for the sevengill shark *Notorynchus cepedianus* (A), the school shark *Galeorhinus galeus* (B) and the silverside *Odontesthes smitti* (C) in Caleta Malaspina between January 2018 and January 2019. Estimates in (A) and (B) are based on BRUVS-derived MaxN index. Estimates in (C) are based on the Ns index, that includes six different abundance categories for a species capable of forming large schools (see reference in text).

Figura 4. Variación estacional en la abundancia relativa de *Notorynchus cepedianus* (A), *Galeorhinus galeus* (B) y *Odontesthes smitti* (C), en Caleta Malaspina entre enero de 2018 y enero de 2019. Las estimaciones en (A) y (B) se basan en el índice *MaxN* derivado de BRUVS. Las estimaciones en (C) se basan en el índice Ns, que incluye seis categorías de abundancia diferentes para una especie capaz de formar grandes cardúmenes (ver referencia en el texto).

cepedianus and *G. galeus*) with a maximum abundance during warm months or were only recorded in this period (*M. schmitti*, *M. goodei* and *M. ridens*). It is noteworthy that the seasonal patterns for *N. cepedianus* and *G. galeus* were only statistically significant in the southern study site (CM), since the two species were not recorded in the area during winter. This observation agrees with recent evidence on the migratory pathways for *G. galeus* (Jaureguizar et al. 2018) and *N. cepedianus* (De Wysiecki et al. 2020), characterized by northward displacements during colder months, possibly explaining why they were not found in CM in winter. However, a previous study in CV using fishing technics recorded *N. cepedianus* year-round, but with marked seasonality in catches (Irigoyen et al. 2018). This contrasting result may be explained by a limited capacity of BRUVS-derived indices to estimate the relative abundance of species compared to fishing technics (Harvey et al. 2011). Among the identified species, the record of *M. ridens* is the first in Patagonian waters, extending its distribution for c. 180 km south of the previously known southern limit (Ruocco et al. 2012). The taxa associated with the Magellanic Province were *E. maclovinus* (in both study sites) and *Patagonotothem* sp. in CM. We attribute the findings of *Patagonotothem* sp., as well as other reef fishes of wide distribution or not classified (*Sebastes oculatus*, *Bovichthys argentinus* and *N. bergi*) to the deployments in rocky areas (including kelp forest of *Macrocystis porifera*) that we sampled by chance only in CM [see findings in Galván et al. (2009)].

The number of species identified in CV and CM represents only a fraction (~13%) of the number of species reported in adjacent waters that included a broader geographic range and more habitat types and a greater sampling effort (Góngora et al. 2009; Bovcon et al. 2011, 2013). In comparison with studies using coastal fishing gears, the number of species recorded in the present study represents a larger fraction (~30%) (Bovcon 2016). This relatively low richness may be explained by the narrow range of depths, the dominance of soft bottoms, and the small spatial scale of the study sites. Furthermore, the number of species found is low when compared to other studies in coastal areas of the SWA. For example, between 51 and 82 species have been recorded in coastal waters of northern Argentina (Díaz de Astarloa et al. 1999; Jaureguizar et al. 2006) and 65 species in an estuarine area of southern Brazil (Vilar et al. 2011). Nevertheless, the lower number of species recorded in our study coincides with the hypothesis of a decreasing species richness gradient towards higher latitudes (Macpherson 2002) and with studies from rocky reef assemblages in the SWA (e.g., Floeter et al. 2004; Galván et al. 2009).

Odontesthes smitti was recorded year-round in CV and with maximum concentrations (i.e., Ns index category V) in spring. This coincides with the landings of the artisanal fisheries in San José and Nuevo gulfs, reaching catches in the range of 510-1070 t/year, mainly comprised of juvenile individuals (Elías et al. 1991; Ré and Berón 1999). Elías and colleagues (1991) determined two spawning periods for *O. smitti*, one occurring in fall and other of greater magnitude in spring, which coincides with our results using BRUVS. Moreover, the CV site was historically used by artisanal fishermen during spring to catch *O. smitti* adults, who reported abundant gravid individuals (Ines Elías 1993, personal observation). Therefore, CV may constitute an important spawning ground for *O. smitti*. Additional analysis of the catch of recreational fisheries in coastal areas of Punta Ninfas (43° S - 64.3° W) and Isla Escondida (43.7° S - 65.3° W) indicated a marked seasonality were adults aggregate in coastal areas during these two periods and then disappear from the coast. While the great abundance in September-October seems to be related to a reproductive event in the region, aggregations in April-May of non-sexually active adults may be related to the temporal use of various coastal areas as feeding grounds or as part of a migratory process (Bovcon 2016). In southern areas, like Puerto Deseado (47.7° S), the reproductive season runs from September to March (Cornejo 1998). This temporal latitudinal gradient for the spawning period may explain the seasonal pattern of abundance of *O. smitti* with a peak during summer in CM.

Although *O. smitti* was abundant in this study, the occurrence of other congeners may have been underestimated. The main reason for this is the easily distinguishable yellow coloration in its caudal fin, in addition to a narrower caudal peduncle which makes the species prone to straightforward identification. Notwithstanding, occasionally *O. argentinensis* individuals were identified in BRUVS sessions and this was corroborated by the light-duty fishing catches that detected the species in warm seasons (URL: https: //youtu.be/VGHOh8Xqkcw). In addition, the Patagonian blennie *E. maclovinus* was hardly detected on BRUVS or fished in CM despite it is described as one of the most abundant species in the area (Bovcon 2016). In most sampling trips, schools of individuals (~5 to 50 individuals) were seen from the coast during fieldwork on intertidal areas of mud across CM, including an aggregation of between one and two thousands adult individuals in January 2019 (Irigoyen A., personal observation; URL: https://youtu.be/j_wWQ8MSgfc). Therefore, it is noteworthy that the spatial distribution (see Figure 1) or the timing of BRUVS in this study failed to estimate the accurate abundance patterns of *E. maclovinus*.

The use of BRUVS in this study showed versatility and allowed us to assess the fish assemblage from large sharks (*N. cepedianus*) to small cryptic species (*Patagonotothem* sp.), including shy species that are rarely recorded by divers (e.g., all chondrichthyans described in this work, Irigoyen A., personal observation). Negative interactions between species were observed in the video imagery collected in this study, mainly *Odentesthes* sp. fleeing away when large sharks appeared on the BRUVS' field of view. This visible interaction, as many others not visible (and unknown) interactions may produce bias in our results. In the same way, such interactions may influence fish spatial distribution or assemblage structure. For example, experienced old fishermen from CV reported that eagle rays *Myliobatis* sp. are found only in shallow areas at the bottom of the inlet and that this spatial pattern is caused by the predation pressure by sevengill sharks *N. cepedianus* (Irigoyen A., unpublished data). Three of the 13 species were recorded only by fishing methods, giving us access to the specimens and allowing for proper identification up to the species level (e.g., *M. ridens*), not possible otherwise. As many methodological papers discuss when comparing sampling methods, the combination or the use of complementary sampling tools may be the best option for proper monitoring programs (Cappo et al. 2003). Finally, this study contributes to filling large data gaps along the SWA regarding the description and understanding of the temporal dynamics of fish assemblages in particular environments within protected areas.

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