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Towed Video-Diver: A Useful Low-Cost Tool for Rapid Benthic Mapping and Biodiversity Monitoring

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Abstract: Marine Protected Areas (MPAs) require efficient monitoring tools to assess habitats and biodiversity, particularly in remote or understudied regions. This study demonstrates the utility of the towed video-diver technique combined with high-resolution video for rapidly surveying benthic habitats and associated taxa. Applied in Arredondo, a shallow bay within an MPA in Atlantic Patagonia, the method covered 14,000 m^2 through eight transects, utilizing just 180 min of dive time and ~300 min of video analysis. Substrate types and their associated taxa were classified using the CATAMI framework, yielding a list of 28 taxa and density estimates of mobile organisms. Additionally, the percentage cover of *Gracilaria* sp.—a commercially valuable macroalga historically overexploited in the region—was estimated for the bay. The invasive crab *Carcinus maenas* was found across all substrate types on the bay, underscoring its ecological tolerance and the need for ongoing monitoring. This cost-effective, rapid methodology is highly effective for detecting and describing areas of ecological or conservation interest, providing critical baseline data for targeted, detailed studies. Its simplicity and efficiency make it ideal for initial surveys in remote regions, supporting the conservation and management of MPAs.

Keywords: GIS; MPAs; software BIIGLE; simplified taxonomic categories (CATAMI); Patagonia; SDG14

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1. Introduction

Sampling the seafloor is essential for marine conservation, management efforts, and ecological research. Benthic evaluations, combining physical and biological data, serve to allow us to better understand biodiversity [1], habitat quality [2,3], bioresources [4] and the dynamics of marine ecosystems [5], among other things. These evaluations provide tools for management and protection of marine habitats, many of which are threatened by human activities and environmental changes [6,7]. By exploring and documenting the seafloor, scientists can identify vulnerable species and habitats, track changes over time, and develop strategies to mitigate impacts and preserve biodiversity. Such efforts contribute valuable data that supports the objectives of the United Nations Decade of Ocean Science for Sustainable Development (2021–2030) and Sustainable Development Goal 14 (SDG 14), "Life Below Water", which aim to advance scientific knowledge, drive technological innovation, and promote international collaboration to address the significant challenges facing our oceans [8–10].

A wide range of techniques have been designed to map and study the seafloor, with the choice of method primarily depending on the scale of implementation, the level of detail required, the study's objectives, and the available resources, technology and time [2,11]. Among the techniques used for small- to medium-scale surveys, the towed diver technique involves towing a diver with a rope connected to a small boat, allowing the diver to sample large areas without having to propel themselves [12–21]. Initially utilized in the 1960s, it has since been employed and refined in numerous monitoring programs. Notable examples include the Long-Term Monitoring Program (LTMP) of the Australian Institute of Marine Science (AIMS), the Global Coral Reef Monitoring Network (GCRMN), and the Coral Reef Ecosystem Division (CRED) of the Pacific Islands Fisheries Science Center (PIFSC-NOAA) in Hawaii, following the methods of Kenyon [19]. This technique can be performed in two ways: one where the towed diver uses a snorkel and conducts the survey from the surface, normally known as manta tow, e.g., [13], and another where the towed diver uses SCUBA equipment, allowing for surveys at different depths, e.g., [19,21]. Traditionally, this technique has not included a photographic or videographic component, and divers annotated registers underwater [15]. The inclusion of photography or video in towed diver surveys has provided a permanent record, reduced observer bias [22], and more recently, enabled the use of artificial intelligence tools to streamline the analysis process [23–25].

In regions of the world with clear waters and warm temperatures, such as the Caribbean, traditional manta-tow surveys allow easy observation of the seafloor from the surface. However, in Atlantic Patagonia, water visibility may be reduced to a few meters, so it is necessary to include SCUBA equipment in the tow so that the diver can reach depths where the seafloor can be clearly observed (generally no more than 2 m above the bottom). Additionally, the cold waters in Patagonia reduce dive times, requiring techniques that minimize bottom time while maximizing survey distance. Although divers can conduct large transects over rocky reefs swimming under their own power [26–28], the towed diver technique becomes a more suitable option when larger areas with diverse habitats need to be surveyed. This technique was successfully implemented in the Atlantic Patagonian region, particularly for estimating the stock of commercially important bivalve and gastropod species [29,30]. The data derived from these surveys have played a crucial role in fisheries management decisions by the Fisheries Secretariat of Chubut, Argentina; however, they lack spatial distribution information or provide only low-resolution data. Furthermore, these surveys focus solely on target fisheries' resources, without offering broader estimates or records of other taxa, macroalgae, or habitat types. Despite its widespread use, the integration of video cameras, low-cost georeferencing tools, and standardized data processing protocols have not yet been incorporated into this method.

In this study, we employed the novel towed video-diver (TVD) technique for a comprehensive survey of Arredondo Bay within the MPA Interjurisdictional Marine Coastal Patagonian Austral Park (PIMCPA) as a case of study. We integrated video capabilities into the towed diver method to produce a detailed map of the bay's seabed sediment types, quantified mobile invertebrate density, estimated the coverage of macroalgae (*Gracilaria* sp., which is of commercial interest), and compiled a species list for the area. The article includes a detailed protocol illustrating data analysis procedures using open-source tools.

2. Materials and Methods

2.1. Site Sampling

The study was conducted in March 2020 in Arredondo Bay, Atlantic Patagonia (S 45.02°, W 65.8°), situated within the MPA Interjurisdictional Marine Coastal Patagonian Austral Park (PIMCPA), in the northern zone of the San Jorge Gulf, Chubut, Argentina (Figure 1). Arredondo is an enclosed bay, with only a small 450 m opening to the south. It covers an area of 1.3 km^2 with a maximum depth of 8 m. The site was selected due to its suitability for mapping its entire area with the chosen method, its challenging access, which makes it impractical to map using other large-scale methodologies (not suitable for large vessels), and its historical significance as one of the key wave-protected bays in southern Chubut for Gracilaria sp. extraction, along with Bustamante Bay and Caleta Malaspina [31]. Since 1995, Gracilaria sp. populations in these areas have experienced a drastic decline in beachcast quantities, reaching nearly zero by 2000 [32]. Now included within a national park, Arredondo Bay holds considerable conservation value and is a focal point for Gracilaria sp. repopulation initiatives.

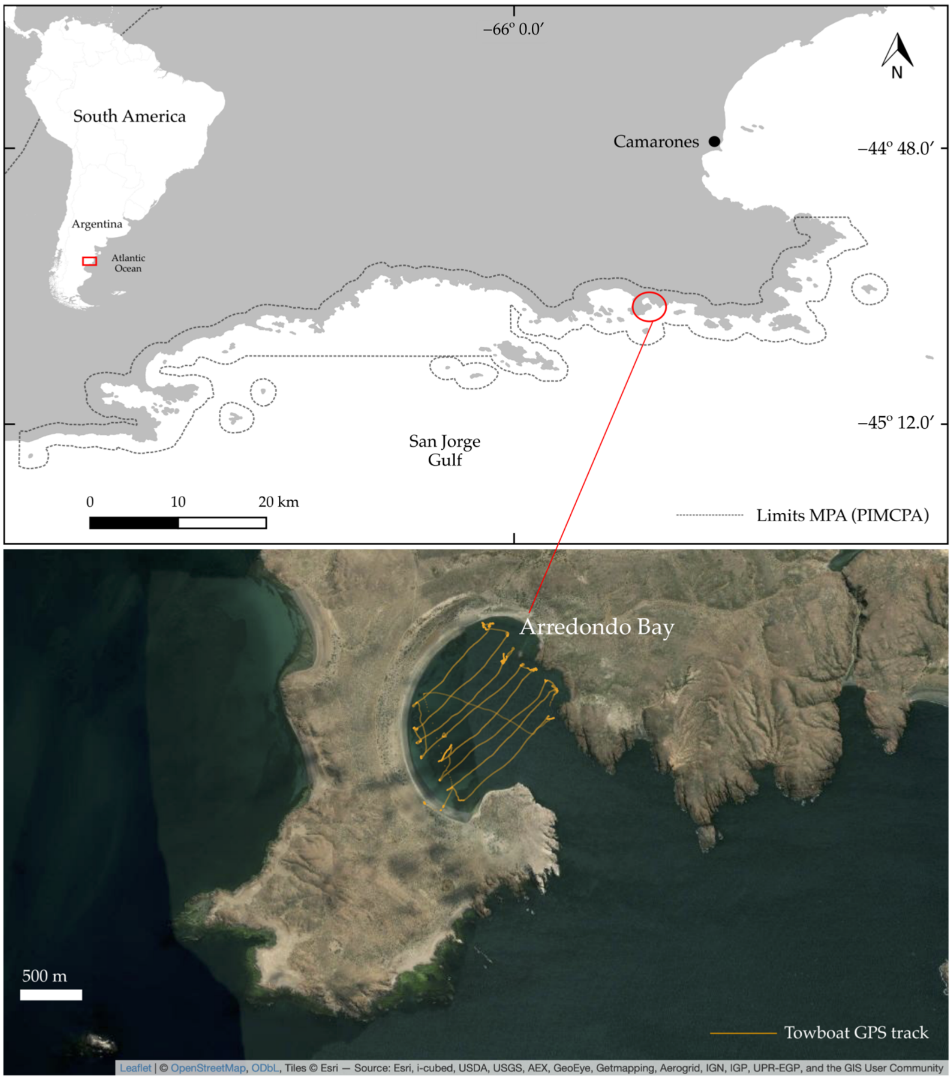

Figure 1. Location of Arredondo Bay in the national park PIMCPA. The park boundaries are shown as dashed lines in the upper panel, and the GPS tow boat track is represented by yellow lines in the lower panel.

2.2. Technic and Equipment Setup

During the study, a total of 8 video transects, each approximately 900 m in length, were conducted, spaced ~100 m apart, as illustrated in Figure 1. Throughout these transects, a diver equipped with a towboard and camera was towed at a speed of 2.8 km/h, maintaining an approximate height of 1 m above the seabed, controlled by the diver using the towboard and a diving computer (Figure 2). The fieldwork was executed by two divers (Gonzalo Bravo and Gaston Trobbiani, four transects each) in two consecutive diving sessions, amounting to a total of 180 min of immersion at an average depth of 6 m.

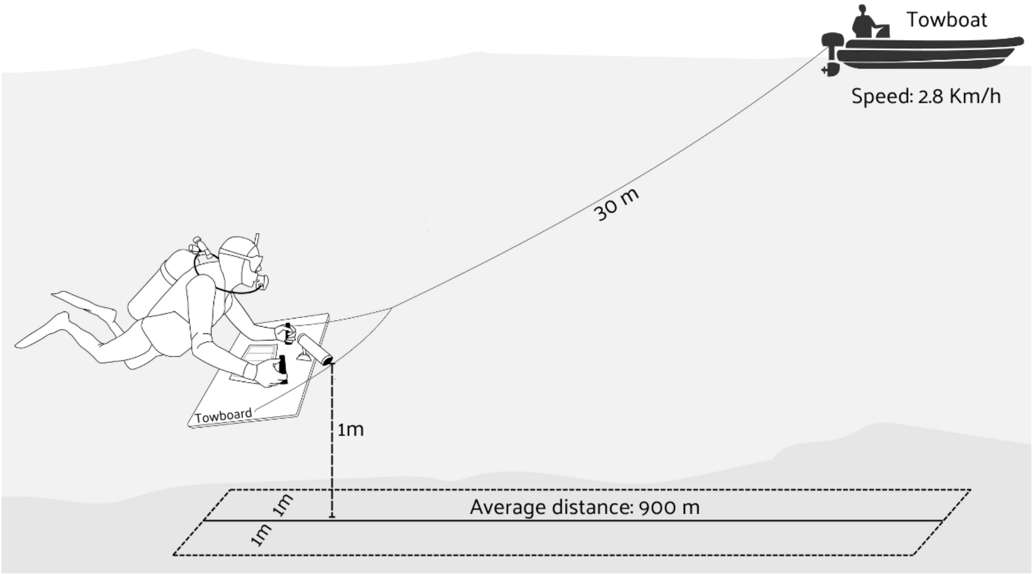

Figure 2. Diagram of the sampling TVD system, where the diver is towed by a small vessel (towboat). Illustration by Candelaria Belén Piemonte.

We used a PARALENZ video camera (Paralenz Group, Copenhagen, Denmark) for video transects. This camera was one of the most compact, complete, and robust options among the action cameras we found on the market, suitable for our budget and applications when carrying out this work (March 2020). It has a LiPo battery that lasts more than 3 h while recording (1080p—60 fps) in water temperatures between 11 and 18 °C, with the possibility of submerging up to 250 m depth (26 atmospheres) without additional seals. However, the most relevant point of this camera is the associated temperature and pressure sensors. The camera continuously records data that can be downloaded as a plain text file or displayed as overlaid information on the video. Since the completion of this work, the manufacture of this camera has been discontinued, but to carry out this work any other action camera could be used. For example, GoPro® HERO models (GoPro, Inc., San Mateo, CA, USA) are widely used in marine research due to their versatility, durability, and high-resolution video capabilities, e.g., [20,33]. If obtaining environmental data such as depth or temperature is of interest, additional sensors could be mounted on the towboard to complement video recording. The camera was mounted on a towboard (rigid rectangular wooden frame of approximately 60 cm × 40 cm,) as shown in Figure 2. This structure provides support for the camera and allows a diver to hold onto it and use it as a guide to maintain direction and depth (towboard diagram available in the Supplementary Materials, Figure S1). A plastic slate was mounted on the same structure, allowing the diver to record important events for post-processing the videos (e.g., start, end of transect, relevant objects on the bottom, etc.) as the transect was performed.

2.3. Georeferencing Video Samples

To georeference all data collected during towing, the GPS (Garmin® Gpsmap 79 S, Garmin Ltd., Olathe, KS, USA) on the towboat was set to continuous tracking mode, recording a trackpoint every 5 s (Enough detail for the proposed trawl speed). The GPS unit used in this study is a handheld device that relies solely on satellite signals for positioning, without the use of differential correction systems. Under standard conditions, this device has a typical horizontal accuracy of approximately ±3.65 m. However, certain environmental factors can influence this accuracy. For instance, in areas with limited satellite visibility, such as narrow channels or regions with tall cliffs, or in locations where atmospheric conditions interfere with signal quality, the positioning error may increase [34,35]. These limitations are inherent to handheld GPS units. Nevertheless, for the scale of the mapping conducted in this study, an error of approximately 4 m is not critical and remains acceptable for generating reliable large-scale maps of substrate types and marine organism distributions.

The GPS time and camera were synchronized by aligning the clocks of the two devices before each dive (if the devices cannot adjust the schedule manually, it is enough to know the difference between them). GPS positioning layback arises from the distance or time delay between the GPS unit on the boat and the diver, typically around 30 s (see the video of the towing maneuver in the dataset section). This layback time difference was estimated during practice tows by timing the passage of a buoy observed from both above and below the surface. The correlation between the events (bottom types, organisms or objects) in the video and the geographical position obtained by the GPS was established using time stamps through an R code built ad hoc for this work.

2.4. Image Analysis

The videos were analyzed by two authors of this work (Gonzalo Bravo and Gaston Trobbiani) using the free software BIIGLE 2.0 [36], accessible online from any device, allowing multiple operators to collaborate on the same project. This platform facilitates the specific labeling of events such as fish, bottom substrate type, invertebrates, and algae within the videos. Species identification and counts were conducted on a 2 m band estimated visually along the video transect on the bottom, following methods similar to those used in Underwater Visual Census (UVC) [37]. The expertise of the observers and divers conducting the UVC methods played a crucial role in the accuracy and reliability of the transect surveys and video analyses [28,38]. We adopted the CATAMI categories [34] for taxa and bottom type classification. The CATAMI classification scheme is a standardized framework developed to annotate categories of benthic substrates and biota in marine imagery. Its versatility allows it to be applied across various image collection methods, annotation platforms, and scoring techniques. CATAMI is well-documented, regularly updated, and maintained to ensure consistency and reliability in benthic classification, promoting data sharing and enabling comparison across diverse research efforts [39–41] and platforms.

Taxa densities visible in the video transects (>10 cm) were calculated as individuals per 1000 m^2. Since each recorded organism was associated with a specific substrate type, density estimates were based on the area covered only by that substrate type. Two types of substrate were considered for this analysis: rock and unconsolidated (soft), with the latter including three subcategories: fine sand (no shell fragments), coarse sand (with shell fragments), and gravel (2–10 mm). Regarding macroalgae, the study focused on three key aspects: (1) the presence of CATAMI categories, (2) the density of forest-forming macroalgae, such as *Undaria pinnatifida* and *Macrocystis pyrifera*, and (3) the estimation of the percentage cover of *Gracilaria* sp. For the latter, a systematic approach was used when frames were observed every 10 s, and in each frame, points from 1 to 5 were assigned depending on the percentage cover of *Gracilaria* sp. (Table 1). This method provided a precise categorization of the area covered by this algae, contributing to an estimation of its distribution within the transects.

Table 1. Percentage cover estimates categories, as per Bass [42].

Category	Cover Estimate
0	0
1	>0–10%
2	11–30%
3	31–50%
4	51–75%
5	76–100%

2.5. Mapping Production

To characterize the seafloor, the substrate type observed in the video was identified, followed by labeling all subsequent changes. We categorized the substrate using four CATAMI classes, allowing us to define intervals along the transects with assigned bottom types. Since this information was categorical, it was converted into numerical values to facilitate modeling and map generation of the study area. Each bottom type was assigned a numerical value corresponding to its grain size or hardness. This transformation enabled the interpolation of substrate data using the Inverse Distance Weighting (IDW) method in R software (version 4.3.2) [43]. However, IDW's effectiveness decreases when data points are unevenly distributed. Additionally, the maximum and minimum values of the interpolated surface can only appear at locations coinciding with sample points [44]. This often produces small, concentric zones around sample points, referred to as "artifacts" of the technique (Figure 3A). These interpolation artifacts appear as color gradients between different substrate types (Figure 3A), suggesting that between two contrasting substrates (e.g., rock and mud), an intermediate substrate (e.g., sand) always exists—an inaccurate assumption. To address this, we performed raster reclassification. Pixels with values ≥ 4 (rock) were isolated to generate a rock layer. The rock points were then removed from the dataset, and a second IDW interpolation was performed using only sedimentary bottom points (1, 2, 3). The two layers were merged for visualization, resulting in the high-resolution map of bottom types for the study area (Figure 3B).

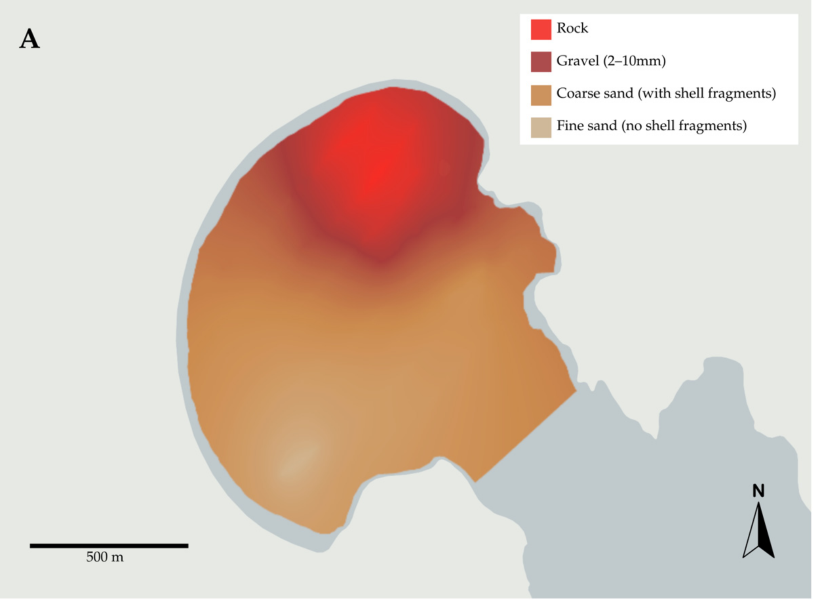

Figure 3. *Cont.*

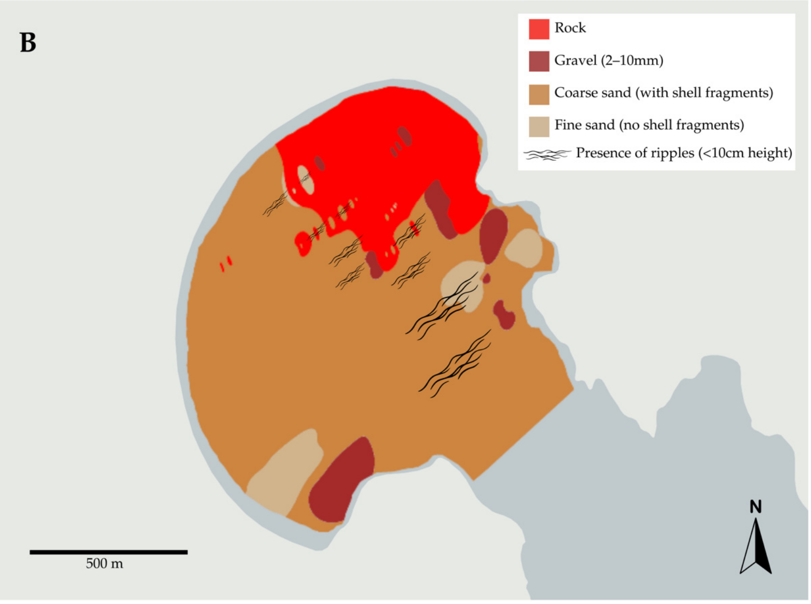

Figure 3. Maps of bottom types. (**A**): Bottom type map generated using linear interpolation with all substrate types combined. (**B**): Bottom type map with separately interpolating soft and hard substrates, which are then overlaid. This map also includes the presence of ripples observed on the soft substrates.

3. Results

The TVD transects covered 7086 m of linear distance with a width of two meters, resulting in a total sampled area of 14,172 square meters. This represents almost 2% of the total area of Arredondo Bay (this covered area was achieved by only two divers and in just 180 min). In total, 3204 annotations were made over the video transects, identifying 27 taxa, 4 substrate types, and 2 bedform descriptions (Table 2). Macroalgae were the most represented by CATAMI categories (8), followed by true crabs with 5 species. Three anthropogenic objects were detected along the transects (one plastic bag, a piece of rope and a concrete block).

The four distinct substrate types are mapped in Figure 3A,B. Coarse sand with shell fragments dominated the coverage in the bay (49.5%), followed by rock (28.3%), fine sand with no shell fragments (11.4%) and gravel (10.8%). The rocky bottom areas were concentrated in the northernmost side of the bay (Figure 3). Near to the mouth of the bay, a higher occurrence of ripples on the sandy bottom was observed, which gradually decreased in frequency with increasing distance from the mouth (Figure 3B). When performing a linear interpolation using all the substrate types, interpolation effects were observed, resulting in intermediate substrate types that do not actually exist (Figure 3A). This contrasts with the interpolation performed separately for soft and hard substrates, which were then overlaid, providing a more accurate representation (Figure 3B).

In Figure 4, the distribution of the most abundant taxa and *Gracilaria* sp. coverage across the transects is displayed, overlaid on the recorded bottom types. This representation highlights spatial patterns of species presence in relation to substrate composition, providing insights into habitat associations and the extent of algal coverage within the surveyed area. Among the crab species recorded, there was a noticeable trend in substrate association. *Leucippa pentagona* was predominantly observed on rocky substrates (Figure 4A, Table 2), while *Leurocyclus tuberculosus*, *Ovalipes trimaculatus*, and *Peltarion spinulosum* were more abundant on sandy substrates (Figure 4C–E, Table 2). The exotic species *Carcinus maenas* was present across all substrate types, showing higher densities on rocky bottoms (Figure 4B, Table 2). Additionally, fish, sea stars, the tunicate *Polyzoa opuntia*, and the anemone *Metridium* sp. were more commonly associated with rocky substrates, whereas the anemone *Antholoba achates* epibiont of *Adelomelon ancilla* and the snail *Odontocymbiola magellanica* showed a stronger association with soft substrates (Figure 4H–K, Table 2).

Table 2. Checklist of CATAMI categories and taxa observed during the sampling in Arredondo Bay. Densities are presented as individuals per 1000 m^2 for organisms that were easily identifiable in the videos. For organisms that are very small or for macroalgae, the term "present" is used to indicate the substrate type on which they were observed. Densities are provided separately for unconsolidated and rock substrate types, as well as an overall density, which represents the density calculated using the total area sampled.

			Density (inv/1000 m^2)		
CATAMI Group	**CATAMI Name**	**TAXA**	**Unconsolidated**	**Rock**	**Overall**
Ascidians	Unstalked: Colonial	*Polyzoa opuntia*	0.5	48.04	8.16
Ascidians	Unstalked: Solitary	Phlebobranchia	0.08	0.43	0.14
Cnidaria	True anemones (associated with gastropods)	*Antholoba achates /Adelomelon ancilla*	0.91	0	0.77
Cnidaria	True anemones	*Metridium* sp.	0.5	7.79	1.67
Crustacea	Crabs	*Carcinus maenas*	1.66	4.76	2.16
Crustacea	Crabs	*Leucippa pentagona*	0.42	13.85	2.58
Crustacea	Crabs	*Leurocyclus tuberculosus*	9.56	0.43	8.09
Crustacea	Crabs	*Ovalipes trimaculatus*	0.08	0	0.07
Crustacea	Crabs	*Peltarion spinulosum*	0.25	0.87	0.35
Echinoderms	Sea cucumbers	Cucumariidae	0.08	0	0.07
Echinoderms	Sea stars	*Allostichaster capensis*	0.08	3.03	0.56
Echinoderms	Sea stars	*Anasterias antarctica*	0.33	8.66	1.67
Echinoderms	Sea stars	*Cosmasterias lurida*	0	0.87	0.14
Fishes	Bony fishes	*Patagonotothen* sp.	Present	Present	
Fishes	Bony fishes	*Sebastes oculatus*	0	1.3	0.21
Macroalgae	Erect coarse branching: green	*Codium* sp.		Present	
Macroalgae	Erect fine branching	*Gracilaria* sp.	Present	Present	
Macroalgae	Filamentous/filiform: red	Rhodophyta		Present	
Macroalgae	Filamentous/filiform: green	Chlorophyta		Present	
Macroalgae	Large canopy-forming	*Macrocystis pyrifera*	0	29.0	4.95
Macroalgae	Large canopy-forming	*Undaria pinnatifida*	1.33	45.01	8.37
Macroalgae	Sheet-like/membraneous: brown	*Dictyota dichotoma*		Present	
Macroalgae	Sheet-like/membraneous: green	*Ulva* sp.		Present	
Molluscs	Bivalves	Mytilida		Present	
Molluscs	Gastropods	*Odontocymbiola magellanica*	0.42	0	0.35
Sponges	Crusts: encrusting	Demospongiae	0.08	2.6	0.49
Sponges	Massive forms: simple	Demospongiae	0	0.43	0.07
Worms	Polychaetes	*Aphrodita* sp.	0	0.87	0.14
	Anthropogenic object		Present	Present	
Bedforms	2D: Ripples (<10 cm height)				
Bedforms	2D: Waves (>10 cm height)				
Substrate 1	Unconsolidated (soft): fine sand (no shell fragments)				
Substrate 2	Unconsolidated (soft): coarse sand (with shell fragments)				
Substrate 3	Unconsolidated (soft): gravel (2–10 mm)				
Substrate 4	Consolidated (hard): rock				

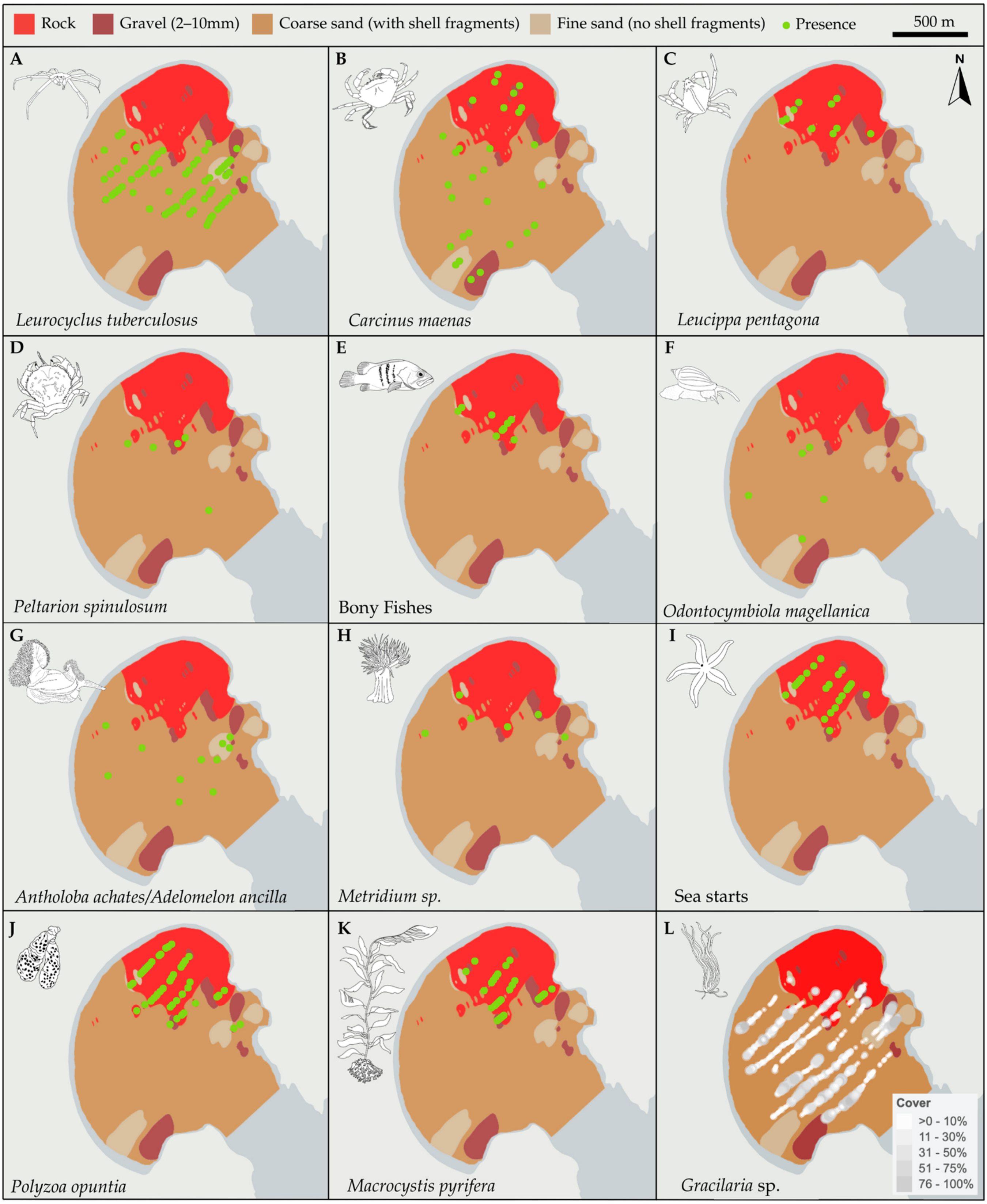

Figure 4. Maps of bottom types overlaid with the presence of various taxa, including crabs (**A**–**D**), fish (**E**), the gastropod *Odontocymbiola magellanica* (**F**), the anemone Antholoba achates epibiont of *Adelomelon ancilla* (**G**), *Metridium* sp. (**H**), sea stars (**I**), the tunicate *Polyzoa opuntia* (**J**), the giant algae *Macrocystis pyrifera* (**K**), and coverage of the macroalgae *Gracilaria* sp. (**L**). Taxa illustrations by Candelaria Belén Piemonte.

The macroalga *Gracilaria* sp. exhibited the highest percentage of coverage over the coarse sand substrates sampled, with the exception of the transect near the mouth of the bay, where despite the presence of soft substrates, low densities were recorded (Figure 4L).

4. Discussion

The towed diver technique, widely used in tropical regions [18,19,21,45], also proves to be a robust and effective tool for surveys in areas with lower visibility and colder waters, such as Atlantic Patagonia, where optimizing dive time is crucial to successful sampling. In this study, the TVD method successfully documented the distribution and abundance of benthic taxa, revealing clear patterns associated with substrate types. By integrating substrate and taxa classifications through the CATAMI framework, this method provides a cost-effective and detailed approach to understanding ecosystem and resources dynamics, offering valuable insights into habitat specificity even in remote and understudied areas. One of the key advantages of this technique is its efficiency: with only 180 min of dive time and approximately 300 min of video analysis, it is possible to rapidly generate records of substrate types and associated taxa across a broad area. These fast results-initial data can then be used to plan more detailed studies or target specific taxa.

The substrate map generated here (supported by video evidence) closely aligns with the patterns described before by Boraso de Zaixso [46], confirming that coarse sand with shell fragments predominates in the central and southern regions of Arredondo Bay, while rocky substrates are more common in the northern sectors. This alignment is particularly noteworthy given the methodological differences: previous substrate maps for Arredondo Bay required extensive dive hours and sediment sampling in the lab to delineate substrate types and produce a comprehensive map of the area. In contrast, our approach achieved similar results with higher resolution and in a significantly shorter time frame, demonstrating the efficiency and practicality of the TVD technique for mapping substrate types in shallow waters. Additionally, this method allowed us to infer dynamic processes, such as water circulation, through the observation of ripples on soft substrates. These ripples serve as proxies for areas of higher water movement, and the patterns identified by us coincide with previously determined zones of greater circulation, which were estimated through mass loss of gypsum blocks [46]. This further underscores the potential of this technique not only for mapping substrate distribution but also for integrating physical and biological insights into ecosystem processes.

While towed camera surveys can be conducted without divers, particularly in deeper or more uniform seafloor environments [47–50], the combination of towed techniques with diver involvement and filming equipment offers distinct advantages for shallow, irregular seafloors, such as those in Arredondo Bay. Divers can maintain precise depth control, ensuring closer proximity to the seafloor compared to cameras alone, which is especially critical in areas with significant rocky formations. Additionally, the inclusion of in situ diver observations enhances the accuracy and comprehensiveness of the environmental description, further validating the utility of this approach for complex habitats. Although the TVD technique focuses on epifaunal species visible in video footage, potentially underestimating infaunal diversity, it shows great potential for broader applications, such as predictions based on associations of species with type of substrate and other taxa. For instance, the presence of soft bottoms buried species, such as the snail *Adelomelon ancilla*, could be inferred through its association with the anemone *Antholoba achates*, a typical epibiont of *A. ancilla* [51]. Observing *A. achates* on soft substrates—where it does not typically settle—may indicate the presence of *A. ancilla*, while the presence of *A. ancilla* is associated with bivalve beds and the sympatric sea snail *Odontocymbiola magellanica*, a fact that could be corroborated in Figure 4F,G.

Although there is scarce existing literature for the Patagonian Atlantic region, where the towed diver technique was employed [29,30], in most cases, the diver recorded observations underwater without creating a video record of the transects. Furthermore, those studies did not include detailed substrate type assessments, and density estimates were often based on the total transect length rather than on distances specific to the substrate where each species is associated [30]. This approach likely leads to underestimations in density calculations, as it assumes homogeneity across transects despite the presence of varied substrate types, even though certain species are associated with specific substrates. Building on this, the estimation of organism density based on the substrate type with which they are associated can provide more realistic and useful estimates of their distribution and abundance. For example, in this study, species such as *Leurocyclus tuberculosus*, *Antholoba achates*/*Adelomelon ancilla* and *Odontocymbiola magellanica* were found exclusively or predominantly on soft substrates, while *Leucippa pentagona*, *Anasterias antarctica*, *Allostichaster capensis*, *Cosmasterias lurida*, *Polyzoa opuntia*, *Metridium* sp., *Aphrodita* sp., *Sebastes oculatus* and Demospongiae showed a strong association with rocky substrates. If their densities had been calculated using the total transect length without accounting for substrate type, the estimates would have been misleading, either overestimating or underestimating their actual densities on their preferred habitats (see Table 2). Further highlighting the importance of accurate density estimation, the invasive crab *Carcinus maenas* was one species found across all substrate types, demonstrating its broad ecological tolerance. This, combined with its high voracity [52–54], could potentially lead to biodiversity losses over time [55]. This information underscores the method's potential to inform conservation planning by providing valuable baseline biodiversity data for monitoring programs in MPAs.

In this study, we used simplified taxonomic categories (CATAMI) to minimize identification errors, relying only on visible information from the images for classification [56]. Using this approach, we identified eight categories of macroalgae, of which three could be identified at the species level, three at the genus level, and the remaining categorized within groups of multiple species that cannot be distinguished from videos. Within all the macroalgae observed, we decided to focus on density estimates for the giant kelp *Macrocystis pyrifera* and the exotic macroalgae *Undaria pinnatifida*, as well as coverage estimates for *Gracilaria* sp. due to ecological or commercial interest. In the case of *M. pyrifera* and *U. pinnatifida*, these species were easily distinguishable in the videos, particularly when occurring at low densities, which allowed for accurate counts without difficulty. The estimation of *M. pyrifera* density in Arredondo Bay is particularly valuable because many individuals in this area do not reach the surface, making them undetectable via satellite imagery [57]. This is especially relevant as *M. pyrifera* kelp forests are a conservation target within the MPA. In the PIMCPA region, density estimates of *M. pyrifera* (ind/m^2) were previously reported by Barrales and Lobban [58] using transects conducted via diving, with densities of 1.41 ind/m^2 in Camarones and 1.53 ind/m^2 in Caleta Carolina. These values are notably higher than the 0.03 ind/m^2 found in this study, likely due to the sparse nature of the kelp forest within Arredondo Bay. This low density enabled the use of the TVD method for *M. pyrifera*, as dense forests that reach the surface would make it impossible to tow a diver with a boat through the area. Recording locations where *M. pyrifera* occurs at low densities is equally important, as it provides a baseline for monitoring the evolution of kelp forests in this bay over time. This could be particularly useful for evaluating changes in forest extent, density, and recovery in response to conservation efforts within the MPA. For *Undaria pinnatifida*, an exotic alga present in the park since the 2000s [59,60], a density of 0.05 ind/m^2 was recorded during this study. These low densities are primarily explained by the timing of the sampling, which coincided with the end of the alga's reproductive cycle, a period when most adult sporophytes detach from the substrate [60,61]. Additionally, in this area, *U. pinnatifida* has not yet reached the high densities observed in northern regions, such as Golfo Nuevo, where densities can reach 30 to 200 ind/m^2 on average [60]. It is important to note that when *U. pinnatifida* reaches such high densities, it becomes impractical to count individuals, as they can no longer be easily distinguished. In such cases, transitioning to coverage estimation, as was carried out for *Gracilaria* sp. using the TVD technique, would be more appropriate. The estimation of *Gracilaria* sp. coverage is of critical interest due to its commercial value and its historical exploitation in the region [62–65]. Currently, there are projects aimed at restoring *Gracilaria sp.* populations in the bay, emphasizing the importance of having updated data on its distribution. However, the analyzed videos have limitations in distinguishing whether *Gracilaria* sp. is attached to the substrate or floating near the bottom, which could introduce significant errors in coverage estimates. Therefore, we recommend using this technique as an initial tool to map areas of high algal coverage, followed by complementary methods to obtain more precise estimates of *Gracilaria sp.* coverage, density or biomass in selected areas.

The TVD technique demonstrates potential for integration into monitoring plans for MPAs. Its straightforward implementation means that it could be carried out by park rangers with diving skills, fostering stronger connections between scientific institutions and MPA managers, e.g., [66]. This collaboration would enable complementary efforts to rapidly gather data on benthic environments, supporting the early detection of abrupt changes and facilitating timely management responses. Moreover, incorporating artificial intelligence for the rapid detection and identification of taxa in video footage could further accelerate the processing workflow, improving both efficiency and cost-effectiveness for monitoring across more relevant spatial and temporal scales [67–69]. For instance, González-Rivero et al. [25] demonstrated that automated processing of image-based data from coral reefs using machine learning technologies led to a 99% reduction in costs and increased processing speed by 200 times compared to traditional methods.

5. Conclusions

In the context of SDG 14, where increasing scientific knowledge is paramount, refining techniques like the towed video-diver technique (TVD) offers significant potential for enhancing the monitoring of larger coastal areas. This method increases the capacity to detect critical changes such as species loss, range shifts or the spread of invasive species. While ensuring that monitoring methods produce high-quality data is essential, it is equally important that data collection remains accessible and does not depend on large-scale infrastructure. The TVD method, relying on basic equipment commonly available in MPAs (small boats, diving gear, and video cameras), provides a practical and scalable solution for long-term monitoring. The TVD method could provide local managers and researchers with the means to monitor ecological changes effectively, enabling informed decision-making and prompt conservation actions to safeguard marine ecosystems. While the method is limited to shallow areas and locations where navigation with small boats is feasible, the TVD is highly versatile and can be applied across a wide range of coastal zones.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/ecologies6010010/s1: Figure S1 (Diagram of a towboard).

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G.B. (Gonzalo Bravo) and G.A.T.; writing—original draft preparation, G.B. (Gonzalo Bravo) and G.A.T.; writing—review and editing, G.B. (Gonzalo Bravo), G.A.T., G.B. (Gregorio Bigatti) and A.J.I.; visualization, G.B. (Gonzalo Bravo); supervision, G.B. (Gregorio Bigatti) and A.J.I.; project administration, G.A.T.; funding acquisition, G.A.T., A.J.I. and G.B. (Gregorio Bigatti). All authors have read and agreed to the published version of the manuscript.

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