S2. Video-based benthic cover estimation

S2.1. Video acquisition

Underwater video was recorded during one of the two scuba diving transects conducted on 4 February 2026 (austral summer) in the Beagle Channel (Onashaga), Argentina (54°56′32″S, 66°54′43″W). Video was recorded using a Nikon D850 camera in an underwater housing, at a resolution of 1920 × 1080 pixels (Full HD). The transect was conducted at approximately 7 m depth, with horizontal visibility exceeding 6 m. Total video duration: ~181 s (~3 min); estimated transect length: ~30 m (assuming a conservative swimming speed of 10 m min^{-1} for cold-water survey diving with dry suit and camera equipment). The full video (20260204_NIKOND850.MOV) is archived at Zenodo (see below).

S2.2. Frame extraction

Still frames were extracted at 6-second intervals using FFmpeg v4.4.2 (https://ffmpeg.org), yielding n = 25 frames at times 6 s, 12 s, … 150 s. Each frame covers the same 1920 × 1080 px area (2,073,600 total pixels). Estimated transect position per frame was computed assuming 10 m min^{-1} swimming speed (~1 m per 6 s). Original unannotated frames (PNG, full resolution) are archived at Zenodo (see above).

S2.3. Manual annotation in Biigle

Benthic cover was estimated by manually annotating bare substrate in each frame using Biigle Online (https://biigle.io), a web-based platform for large-scale marine image annotation [1]. All visible areas of bare sandy or gravelly sediment — not covered by rhodolith nodules or macroalgae — were delineated using polygon annotations and labelled "Pebble / gravel". Areas covered by rhodolith nodules or epiphytic algae were treated collectively as biotic substrate and left unannotated. The total annotated bare-substrate area per frame (in px^2) was obtained by summing all polygon areas within each frame, as reported in the Biigle area export file (33275_image_annotation_area_report.xlsx, archived at Zenodo).

S2.4. Cover calculation

For each frame i, percentage of bare substrate was calculated as:

$$\text{Bare substrate (\%)} = (\Sigma \text{ annotated area [px}^2\text{]} \ / \ 2{,}073{,}600) \times 100$$

where 2,073,600 = 1920 × 1080 (total pixels per frame)

Biotic cover (rhodoliths + epiphytic algae combined) was calculated as the complement:

$$\text{Biotic cover (\%)} = 100 - \text{Bare substrate (\%)}$$

Note: this estimate cannot distinguish between rhodolith nodules and epiphytic algae or kelp blades, all non-annotated area is classified as biotic. Annotation was performed by a single observer (G.B.).

S2.5. Results

Mean biotic cover across the 25 frames was 91.2% ± 7.8% (range: 58.8–98.5%; median: 92.7%), indicating a near-continuous and dense biogenic substrate. Bare substrate accounted for a mean of 8.8% ± 7.8%. Results confirm a well-developed rhodolith/maërl bed.

Table S2.1. Frame-by-frame benthic cover estimates from Biigle manual annotation (n = 25 frames). Total frame area = 2,073,600 px². Values shown as percentage of total frame area. Colour coding: green = biotic cover > 85%; white = 70–85%; yellow = < 70%.

Frame	Time (s)	Est. dist. (m)	Bare substrate (px²)	Bare substrate (%)	Biotic cover (%)
1	6	~1	48,446	2.3%	**97.7%**
2	12	~2	192,287	9.3%	**90.7%**
3	18	~3	166,840	8.0%	**92.0%**
4	24	~4	42,285	2.0%	**98.0%**
5	30	~5	59,779	2.9%	**97.1%**
6	36	~6	54,934	2.6%	**97.4%**
7	42	~7	152,506	7.4%	**92.6%**
8	48	~8	140,594	6.8%	**93.2%**
9	54	~9	150,556	7.3%	**92.7%**
10	60	~10	176,699	8.5%	**91.5%**
11	66	~11	320,358	15.4%	**84.6%**
12	72	~12	227,686	11.0%	**89.0%**
13	78	~13	338,383	16.3%	**83.7%**
14	84	~14	266,497	12.9%	**87.1%**
15	90	~15	238,266	11.5%	**88.5%**
16	96	~16	855,166	41.2%	**58.8%**
17	102	~17	221,817	10.7%	**89.3%**
18	108	~18	63,319	3.1%	**96.9%**
19	114	~19	133,417	6.4%	**93.6%**
20	120	~20	80,083	3.9%	**96.1%**
21	126	~21	140,959	6.8%	**93.2%**
22	132	~22	230,745	11.1%	**88.9%**

23	138	~23	101,964	4.9%	**95.1%**
24	144	~24	31,515	1.5%	**98.5%**
25	150	~25	115,153	5.6%	**94.4%**
Mean ± SD	—	—	—	**8.8 ± 7.8%**	**91.2 ± 7.8%**

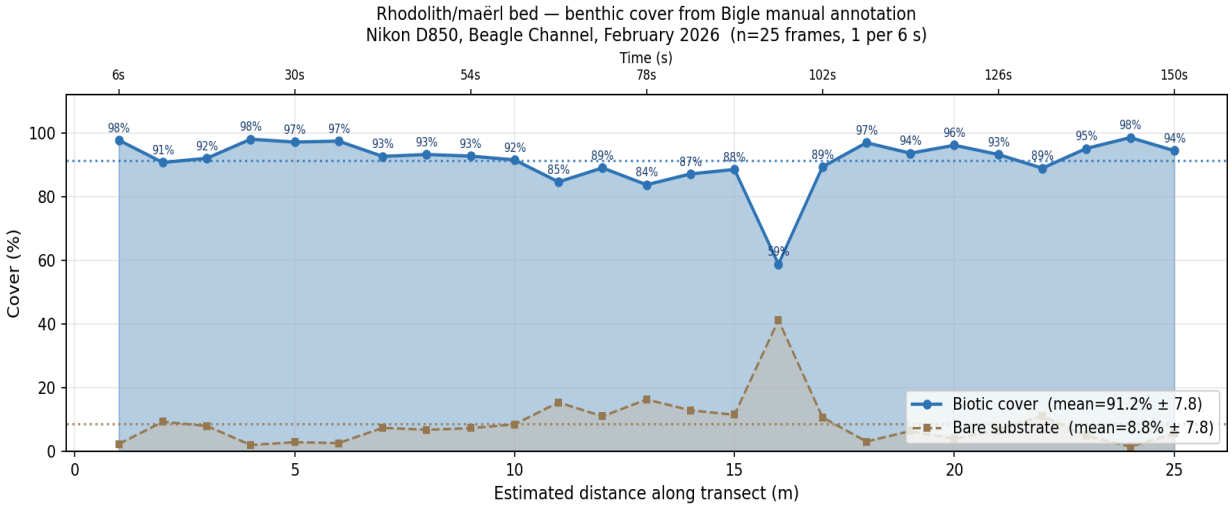


Figure S2.1. Biotic cover (rhodoliths and associated epiphytic algae; blue) and bare substrate (sandy/gravelly sediment; tan) estimated from Biigle manual annotation of 25 video frames extracted at 6-second intervals. Data from Nikon D850 transect, Beagle Channel, February 2026. Horizontal dotted lines indicate mean values. Distance axis estimated at 10 m min^{-1} swimming speed. Individual biotic cover percentages are labelled above each data point.

S2.6. Limitations

1. Perspective distortion: frames are oblique images; distal areas are compressed relative to proximal areas, introducing geometric uncertainty in pixel-to-area conversion.
2. Biotic categories are not separated: rhodolith nodules, epiphytic algae, and kelp blades (*Macrocystis pyrifera*) are all included in the biotic fraction.
3. Temporal snapshot: estimates reflect a single survey in February 2026 and may not capture seasonal variability.
4. Swimming speed assumption: transect distance is estimated using a conservative 10 m min^{-1}; actual speed variability introduces uncertainty in spatial positioning of frames.

References

[1] Langenkämper, D.; Zurowietz, M.; Schoening, T.; Nattkemper, T.W. BIIGLE 2.0 — Browsing and annotating large marine image collections. *Front. Mar. Sci.* 2017, **4**, 83. https://doi.org/10.3389/fmars.2017.00083

Raw data availability: The 25 annotated frames (original, unannotated) and the full-length underwater video (Video S1) are archived at Zenodo: https://zenodo.org/records/19238866. Raw annotation data exported from Biigle are provided as file 33275_image_annotation_area_report.xlsx (archived at the same repository).