Observations of displacements and retractions by sea pens (superfamily Pennatuloidea) in the Gully Marine Protected Area, northwest Atlantic Ocean

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2026

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 3358

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Cat. No. Fs 97-4/3358E-PDF ISBN 978-1-100-01328-2 ISSN 1488-5387

https://doi.org/10.60825/de44-nk38

Correct citation for this publication:

Nozères, C., De Clippele, L.H., Xu, J., Kenchington, E. 2026. Observations of displacements and retractions by sea pens (superfamily Pennatuloidea) in the Gully Marine Protected Area, northwest Atlantic Ocean. Can. Manuscr. Rep. Fish. Aquat. Sci. 3358: v + 42 p. https://doi.org/10.60825/de44-nk38

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ABSTRACT

Nozères, C., De Clippele, L.H., Xu, J., Kenchington, E. 2026. Observations of displacements and retractions by sea pens (superfamily Pennatuloidea) in the Gully Marine Protected Area, northwest Atlantic Ocean. Can. Manuscr. Rep. Fish. Aquat. Sci. 3358: v + 42 p. https://doi.org/10.60825/de44-nk38

Several movement behaviours by sea pens were observed with benthic landers deployed in a canyon of the Northwest Atlantic Ocean from October 2022 to July 2023. Images were taken at 30 min intervals at two sites, one dominated by *Pennatula aculeata* and the second by *Balticina finmarchica*, with a single colony of *Ptilella grandis* at each. Horizontal displacements by sea pens were very rare events, and were also observed for a sea anemone, *Bolocera tuediae*, and a cup coral, *Flabellum alabastrum.* Polyp contractions by *P. grandis* were for longer periods in autumn than in winter-spring, while patterns were less evident with *B. finmarchica*. Physical contact by a predatory sea star, *Hippasteria phrygiana*, led to polyp contraction by a *B. finmarchica*, the exit of a *P. grandis*, and colony retraction into the sediment by *P. aculeata*. Disturbance by crabs (*Cancer borealis, Lithodes maja*) and fishes (*Urophycis tenuis, Hippoglossus hippoglossus*) led *P. aculeata* to move or retract. No reaction was seen with a shrimp (*Atlantopandalus propinqvus*) on a *B. finmarchica*.

RÉSUMÉ

Nozères, C., De Clippele, L.H., Xu, J., Kenchington, E. 2026. Observations of displacements and retractions by sea pens (superfamily Pennatuloidea) in the Gully Marine Protected Area, northwest Atlantic Ocean. Can. Manuscr. Rep. Fish. Aquat. Sci. 3358: v + 42 p. https://doi.org/10.60825/de44-nk38

Plusieurs comportements des plumes de mer ont été observés à l'aide des plateformes benthiques déployés dans un canyon de l'océan Atlantique Nord-Ouest, d'octobre 2022 à juillet 2023. Des images ont été prises toutes les 30 minutes sur deux sites : l'un dominé par *Pennatula aculeata* et l'autre par *Balticina finmarchica*, avec une colonie de *Ptilella grandis* présente à chacune. Les déplacements des plumes de mer étaient très rares et ont également été observés chez une anémone de mer, *Bolocera tuediae*, et un corail-coupe, *Flabellum alabastrum*. La contraction des polypes de *P. grandis* était plus longue en automne qu'en hiver-printemps, tandis que les variations étaient moins marquées chez *B. finmarchica*. Des interactions incluent le contact physique avec une étoile de mer prédatrice, *Hippasteria phrygiana*, ce qui a entraîné la contraction des polypes de *B. finmarchica*, la sortie de *P. grandis* et la rétraction des colonies de *P. aculeata* dans le sédiment. La perturbation des crabes (*Cancer borealis*, *Lithodes maja*) et des poissons (*Urophycis tenuis, Hippoglossus hippoglossus*) a conduit *P. aculeata* à se déplacer ou à se rétracter. Aucune réaction n'a été observée avec une crevette (*Atlantopandalus propinqvus*) sur un *B. finmarchica*.

INTRODUCTION

Sea pens are octocorals belonging to the superfamily Pennatuloidea, most of which occur anchored in soft sediment, though a few species can also affix to rocks (Williams 2011, Williams and Alderslade 2011). Normally sedentary, sea pens are capable of movement, although the frequency and extent of these movements remain largely unknown. Several species have been remarked to retract their colonies into the sediment, disappearing below the surface (Mori 1960, Birkeland 1974, Langton et al. 1990, Ambroso et al. 2013, Ambroso et al. 2021, Chimienti et al. 2018, Miatta and Snelgrove 2022, López-González and Ólafsdóttir 2025, Nozères et al. 2025).

Horizontal movements have also been recorded for several species, with colonies uprooting and re-anchoring in different locations (Birkeland 1974, Malecha and Stone 2009, Giusti et al. 2024, Kushida et al. 2020). Such movements are likely for short distances, but may be assisted by water currents, as seen in a *Pteroeides spinosum* that was observed to inflate and travel with the current for distances of several metres (Giusti et al. 2024).

Historically, the stimuli for movements by sea pens have been attributed to various factors, including photoperiod, feeding, or avoidance (predation), as observed in laboratory studies and at-sea for shallower water species (*e.g.,* Mori 1960, Buisson 1971, Birkeland 1974, Imafaku 1980). However, movement behaviour remains poorly understood, especially for deep-sea species that are less frequently observed *in situ* and may be also affected by the presence of sampling equipment, with colonies retracting when near or contacted (Miatta and Snelgrove 2021). Furthermore, sea pen movements may be brief events while most deep-sea observations have limited temporal scope, for example in an observation over 24 hrs of several *Pennatula aculeata* sea pens in the Gulf of Maine (Langton et al. 1990).

Recently, an opportunity to monitor sea pen behaviour arose with the deployment of benthic lander platforms in the northwest Atlantic (De Clippele et al. 2023). Two of the platforms were set in sea pen fields on the slopes of an underwater canyon, the Gully Marine Protected Area (MPA), a conservation area designated by the government of Canada to protect special ecosystem features including sea pens https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/gully/index-eng.html). Each platform had a digital camera taking images remotely over the course of several months. The main objective of the deployments was to characterize the biological sounds at each site (Kenchington et al. 2021), with images taken to confirm the identifications of species such as fishes, which was also done with similar landers deployed in the sponge grounds of Sambro Bank, to the west of the canyon (De Clippele et al. 2025). During the annotation of images for the presences of motile species (Nozères et al. 2024), colonies of *P. aculeata* sea pens were noticed to periodically retract into the sediment (Nozères et al. 2025). Subsequent analysis revealed a cyclic group behaviour in these colony retractions (Nozères et al. 2026).

During the analysis of retractions by *P. aculeata*, other behaviours were observed for this species as well as the sea pens *Balticina finmarchica* and *Ptilella grandis,* and by a sea anemone and a cup coral. The use of cameras on the stationary platforms allowed for these observations to be largely unaffected by disturbance from the sampling gear and so are expected to be representative of natural movement dynamics. Here, we present the novel information on movement behaviours incidentally observed over a period of several months.

MATERIALS AND METHODS

Study Sites and Sampling Equipment

Two benthic landers (TL2: Latitude: 43.960317, Longitude-58.947767, Depth: 336 m; TL3: Latitude: 43.961350, Longitude: -58.95535, Depth: 327 m), separated by 620 m, were deployed in the Gully MPA off Nova Scotia in the northwest Atlantic Ocean (Figure 1).

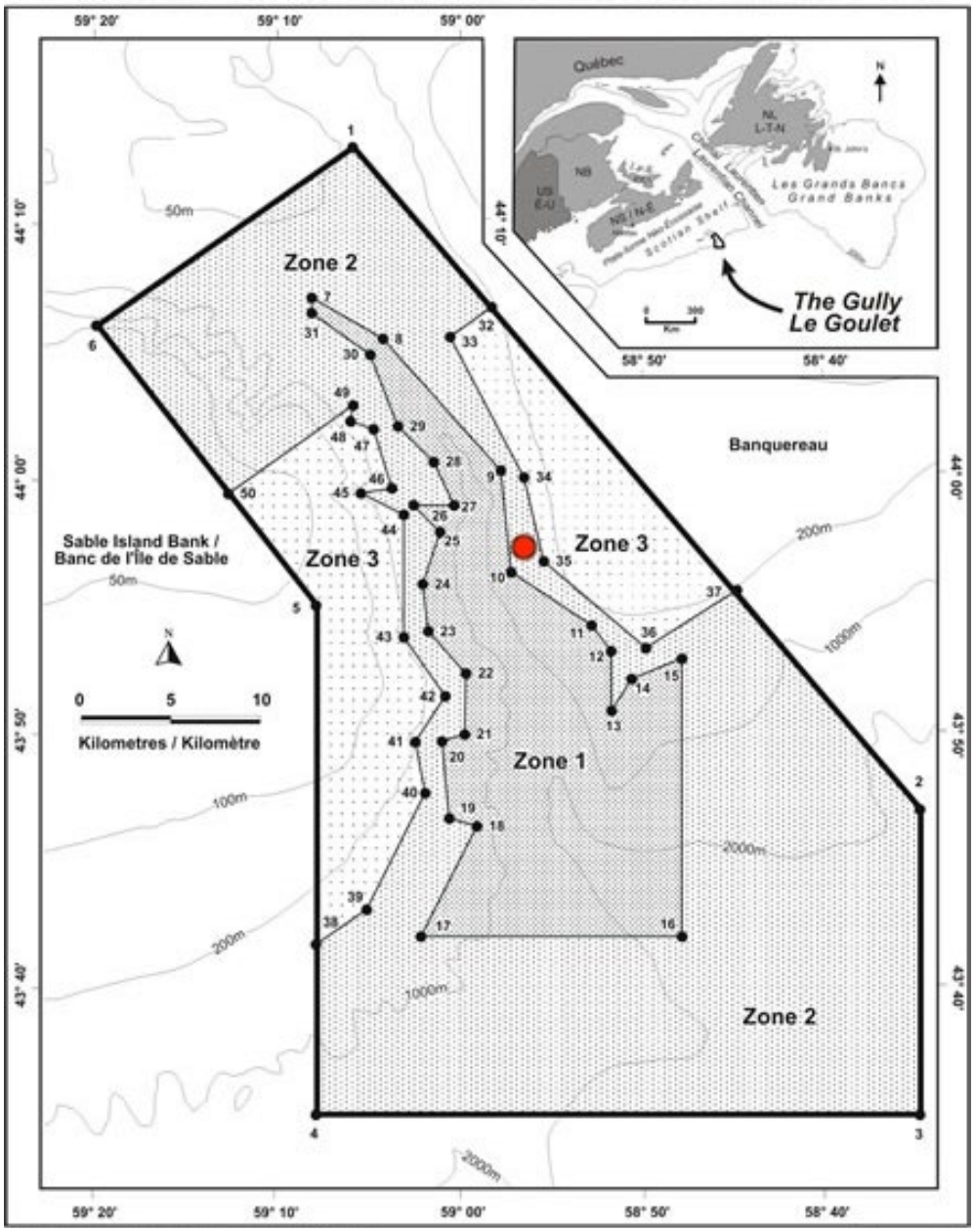


Figure 1. Map with the general location (red circle) of the benthic landers deployed in the Gully MPA, an underwater canyon on the Scotian Shelf of the northwest Atlantic Ocean. Source: https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/gully/coordinates-coordonnees-eng.html.

The site surveyed by lander TL2 was dominated by *P. aculeata* sea pens while the one with lander TL3 was dominated by *B. finmarchica* sea pens. The landers were intended to monitor fish acoustics, with images taken to corroborate the acoustic identifications. Details on the lander deployments were reported in De Clippele et al. (2023, 2024) with the relevant details summarized here. The lander cameras were each fitted with custom designed embedded controllers which put the systems into a very low power sleep state between image captures (De Clippele et al. 2023). The controllers were programmed to take flash images every 30 min, recorded as 48000 x 3200 pixel JPG files, with an oblique view, facing down and outwards from the lander. Date stamps from the image metadata, reported in Coordinated Universal Time (UTC), were used to manage the file data from both sites.

The Lander TL2 image series was between October 5, 2022 to July 28, 2023. The Lander TL3 image series began at the same time as that of TL2, but was shorter in duration, ending April 13, 2023. Towards the end of the deployment, the time-lapse controller on Lander TL2 developed issues and images became intermittent from June 11 to July 28, and thus there were observational gaps of hours and days for the final weeks. A total of 12,054 images (11,906 at 30 min intervals up to June 11) were recorded from TL2 while Lander TL3 collected 9,107 images for a total of 21,171 full-sized source images recorded on the sea floor for the two sites. All recorded images were illuminated (no flash failure), though occasionally some views of sea pens were obscured by large fishes passing in front of the camera lens (Nozères et al. 2025).

Image Analyses

The original images were reviewed with cataloguing software (Adobe Lightroom Classic), which enabled the discovery of different behavioral events, such as re-positioning colonies and polyp retractions, across image sets, and their subsequent evaluation using keyword tags, custom colour labels, and collections of selected cropped images (Nozères et al. 2025). Along with the source images, the work catalogue managed sets of cropped images of individual sea pens. New cropped sets were generated as the need arose to investigate behaviours, such as when a colony changed in shape or position between the consecutive images. Having sets of cropped views enabled different annotations to be applied to each colony. To help follow the sea pens over the time series, identification codes were assigned to the individual colonies, then used to name the corresponding cropped images. Generally, colonies occurring in the background were not labelled as the fall-off of light and smaller size of colonies at the greater distance from the lander platform often made them impractical to review for horizontal movement or retractions. Special efforts were made for tracking the smaller colonies of *B. finmarchica* even when they were poorly visible because this size class appeared to be less common and the species behaviour unknown. Originally, the images were very dark in the background. To assist with the examination of colony movements, exposure was increased, and white balance was adjusted using the above-mentioned software.

The sea pens were not measured in the images, but size categories were estimated. The main lander instruments were principally for recording acoustics, and no visual scale marker was placed in view of the camera. A post-hoc analysis of the image frame, based on the lens and lander height, gave an estimated field of view width of 1.79 m in the foreground and 4.27 m in the background, forming a trapezoidal field of view area of about 7.6 m^2. This area of view estimate

helped in assigning the subjective relative sizes of colonies visible above the sea floor. The size categories were also based on experience with samples on research trawl surveys, as shown in this example: https://www.marinespecies.org/aphia.php?p=image&pic=s203560&tid=128515. For *P. aculeata* at site TL2, the colony sizes were characterized as large or medium, small, and very small. Smaller colonies, perhaps less than a cm in size, were barely visible and not assessed. At site TL3, the few *P. aculeata* colonies that were followed were characterized as very small.

For the sea pen *B. finmarchica*, the few colonies at site TL2 were assessed as appearing relatively small to medium-sized, while those at site TL3 where nearly all large (tall). An example of a smaller colony (about 15 cm extending above the peduncle) sampled on a trawl survey is displayed here: https://www.marinespecies.org/aphia.php?p=image&pic=203562&tid=584787, and a larger, medium-sized colony (perhaps 40 cm extending above peduncle) is displayed here: https://www.marinespecies.org/aphia.php?p=image&pic=201311&tid=584787. Two colonies of *Ptilella grandis* (Ehrenberg, 1834) were characterized as medium-large, similar to the specimens as shown here: https://www.marinespecies.org/aphia.php?p=image&pic=41360&tid=128516.

Several types of behaviour by sedentary species are presented in this report, generally in order of when they were noticed during the close-up scrutiny of individual sea pens. Initially, horizontal displacements were noted by some colonies of the three sea pen species (*B. finmarchica, P. aculeata, P. grandis*) at both landers. Next, the frequencies of partial colony retraction and polyp contractions were examined for *B. finmarchica* and *P. grandis*. Retraction patterns by *P. aculeata* are not presented here as they were previously analyzed in Nozères et al. (2026). During the review of sea pens, horizontal movements were also noticed for a sea anemone (*Bolocera tuediae*) and a cup coral (*Flabellum alabastrum*) at lander TL2. Finally, observed interactions are summarized here between sea pens and mobile fauna such as predatory sea stars and incidental contacts with crabs and fishes.

RESULTS

Characterization of Sea Pen Fields

The two lander sites had some differences in their mix of sea pen species and relative sizes, and in which were seen to perform horizontal movements. Lander TL2 had over 50 labelled colonies (details in Nozères et al. 2025) of *P. aculeata* (Table 1), varying in size from very small to medium-large, reaching about 2 to 15 cm in height above the sea floor, with nine colonies that were seen to move (Table 2, Figure 2A). A single colony of *P. grandis* was intermediate in size compared to the other species, estimated at about 15 cm in view, while *B. finmarchica* sea pens comprised one very small (estimated at about 5 cm) and four medium-sized (estimated at about 20 cm) colonies. Lander TL3 had over 30 colonies of *B. finmarchica*, most at their expected full height of about 0.5 m to 1 m tall, with at least 20 colonies visible in the foreground, along with five smaller colonies of *P. aculeata*, and a relatively large colony of *P. grandis* (Figure 2B).

Table 1. Summary of the sea pens followed for horizontal movements (entering, re-positioning, and exiting the view) and polyp contractions (not assessed for *Pennatula aculeata*) at landers TL2 and TL3. Visible refers to the total number of colonies discernible in the field of view.

Sea pen	Site	Visible	Moved	Enter	Reposition	Exit	Polyps
Pennatula aculeata	TL2	60	9	6	5[a]	3	-
	TL3	5	2	0	2	1	-
Balticina finmarchica	TL2	5	4	2	2	0	4
	TL3	34	4	2	4	0	2+group
Ptilella grandis	TL2	1	1	0	0	1	1
	TL3	1	0	0	0	0	1

[a] = minimum; several of the smallest sea pens made minor movements that were not analyzed.

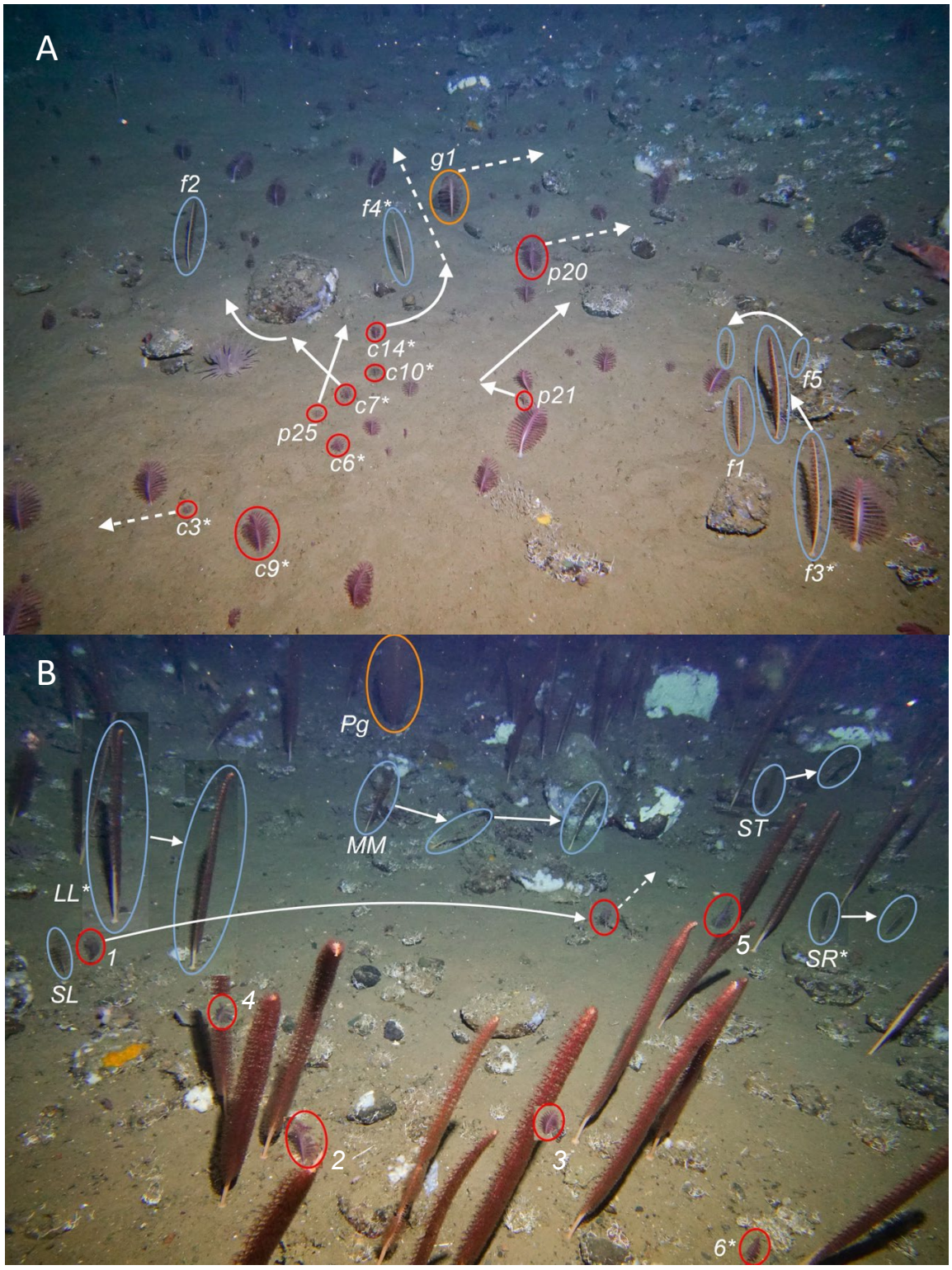


Figure 2. Photo illustrations of analyzed sea pens at A) lander TL2 and B) lander TL3, with ovals in red for *Pennatula aculeata,* orange for *Ptilella grandis,* and blue for *Balticina finmarchica.* New arrivals are indicated by *; solid arrows show major movements while dashed arrows represent possible paths of exits. Colony labelling details are provided in Nozères et al. (2025).

Table 2. Individual sea pens displaying changes in position at landers TL2 and TL3, with date for tracked colonies that entered, repositioned, or exited the field of view. Size classes are estimated (see text above). Movements were self-initiated or from contact with other fauna (details in later sections).

Species	Site	Size	ID	Enter	Reposition	Exit
Pennatula aculeata	TL2	very small	*c3*	2022-12-16		2023-02-09
		very small	*c6*	2022-10-06		
		very small	*c7*	2022-10-30	2023-01-04**	
		small	*c9*	2023-05-27		
		very small	*c10*	2023-03-08	2023-04-03*	
		very small	*c14*	2022-12-07	2022-12-27	2022-12-27*
		very small	*p21*		2022-12-08**	
		very small	*p25*		2023-03-15	
		small	*p20*			2023-02-16
	TL3	very small	*1*		2022-10-26	2022-11-05
		very small	*3*		2023-04-12	
Balticina finmarchica	TL2	medium	*f3*	2023-04-12	2023-07-17	
		medium	*f4*	2022-10-19		
		small	*f5*		2023-04-07	
	TL3	large	*LL*	2022-10-30	2022-11-17	
		small	*SR*	2023-02-14	2023-02-25*	
		small	*ST*		2022-12-21*	
		medium	*MM*		2023-04-04**	
Ptilella grandis	TL2	medium	*g1*			2023-04-18

*= moved after contact with fauna; ** = moved more than once

Horizontal Displacements of Sea Pens

Sea pens at landers TL2 and TL3 were noted to enter in or out of the image frame, or to move to another location within the frame (Table 1). Displacements were recorded for smaller colonies of both *P. aculeata* and *B. finmarchica*, along with a single large colony of *B. finmarchica*, as summarized below (Table 2, Figure 2). At site TL2, a total of nine small or very small *P. aculeata* sea pens were seen to reposition within the image, or to enter or exit the field of view over time (Table 2, Figure 2A). Five colonies moved in December 2022, January 2023, and March 2023, with two colonies, *c7* and *p21* seen to move twice. The very small colony *c10* moved a small distance in April 2023 because of disruption by a crab (see section below on interactions). Six colonies of *P. aculeata* were arrivals, entering from the bottom of the image frame, with examples shown in Figure 3. The very small *c6* and *c7* appeared in October 2022, the very small *c3* and *c14* in December 2022, the very small *c10* in March 2023, and the small *c9* at the end of May 2023. Three *P. aculeata* sea pens also exited the image frame, with *c14* in December 2022 (following

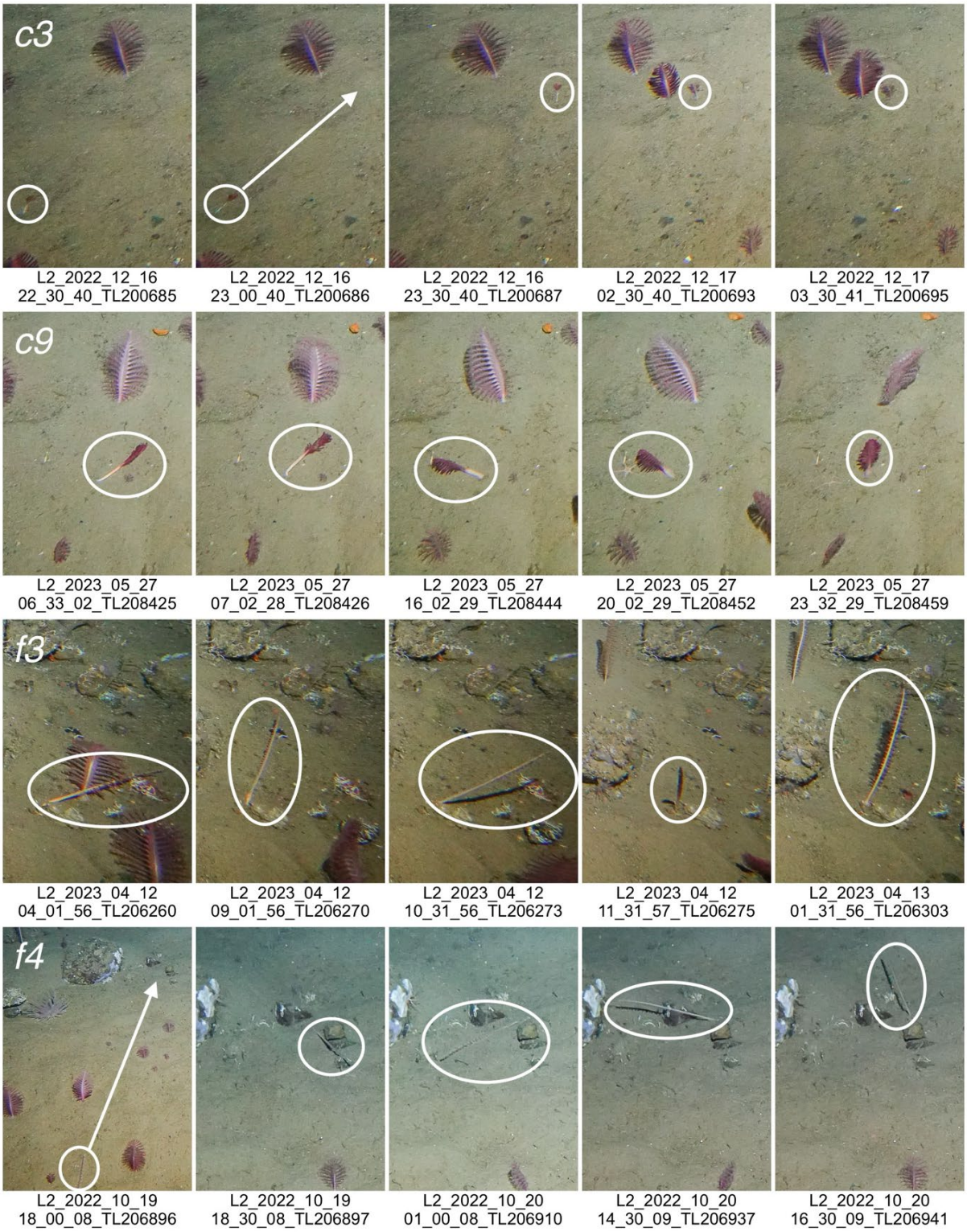


Figure 3. Sequential cropped images taken at lander TL2 of selected new sea pens (white ovals) arriving in the field of view: *c3* entering at 2022-12-16, *c9* at 2023-05-27, *f3* at 2023-04-12, and *f4* at 2022-10-19. Arrows point to new positions in subsequent views. Not shown are the arrivals of small *Pennatula aculeata* sea pens *c6, c7, c10, c14* (see Table 2). Image crops show filenames.

contact with an anemone; see below) and *c3* along with *p20* in February 2023. At site TL3, five very small *P. aculeata* sea pens were tracked. The colony no. *1* was seen to move and then later exit the in November 2022 (Figure 4), while no. *3* shifted position near the end of the series in April 2023.

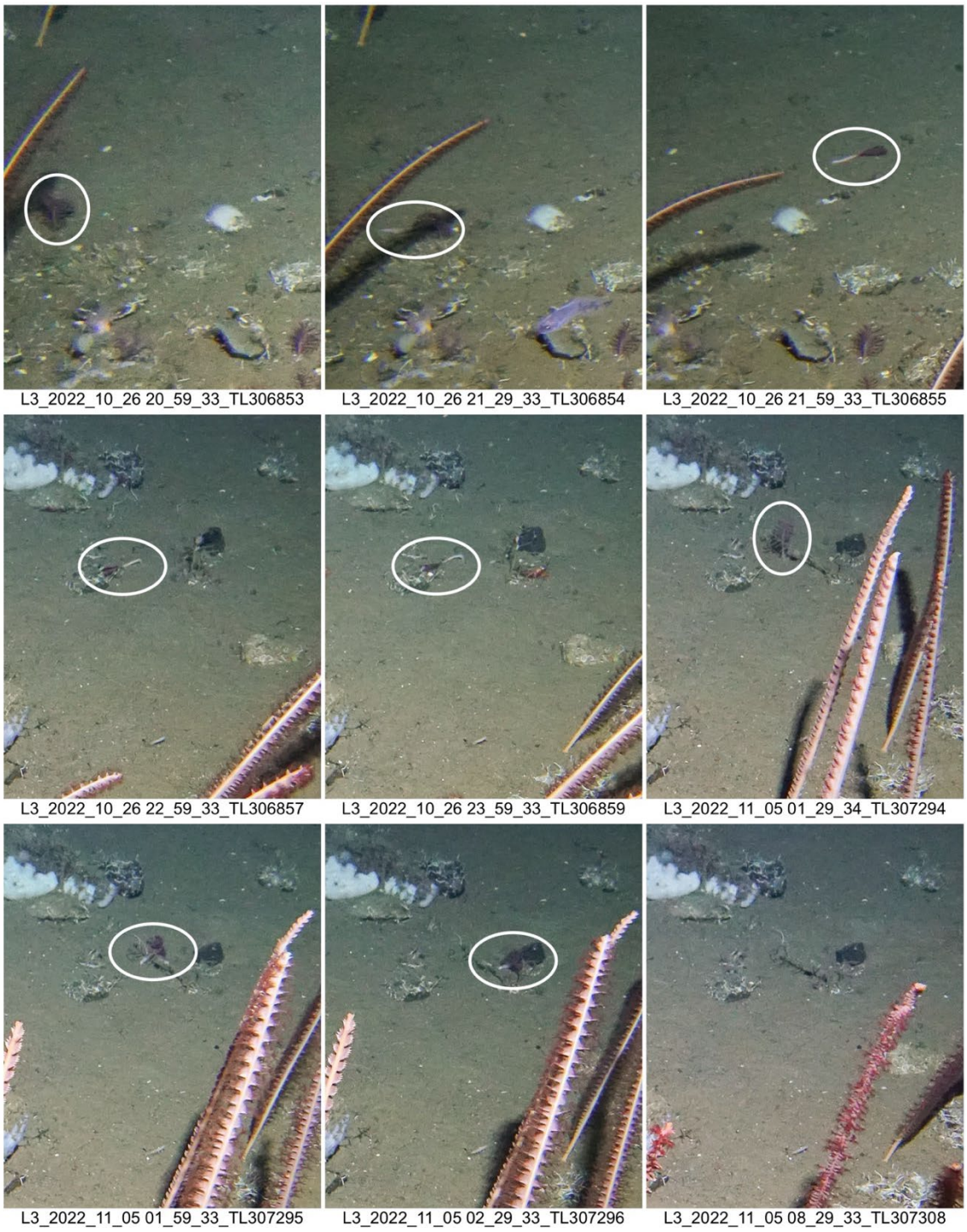


Figure 4. Sequential cropped images taken at lander TL3 of the small *Pennatula aculeata* sea pen no. *1* (white oval) moving left to a new position at 2022-10-26 21:29, then leaving the field of view by 2022-11-05 08:29. Image crops show filenames.

Displacements were also observed for *B. finmarchica*. At site TL2, a medium-sized colony, *f3*, changed position in July and a smaller one, *f5*, shifted in April 2023 (Figure 5). Sea pen *f3* was also a new arrival, first coming into view in April 2023. The medium-sized *f4* was also new, entering earlier in October 2022 (Figure 3). At site TL3, all four seen to move were tracked, even though three were poorly visible as smaller colonies in the background. The only large one that moved, *LL*, was also a new arrival, appearing at the end of October 2022, then re-positioning in November 2022 after which it was not seen to move again (Figure 6). The other arrival was the small *SR* in February 2023. This sea pen, along with the adjacent small one *ST*, moved following disturbance by large crabs, as noted below. The medium-sized *MM*, moved repeatedly in April 2023. This sea pen also behaved differently, always positioned as slanted or leaning on rocks to the right, not bending to the left with changes in current as did the other sea pens (Figure 2B).

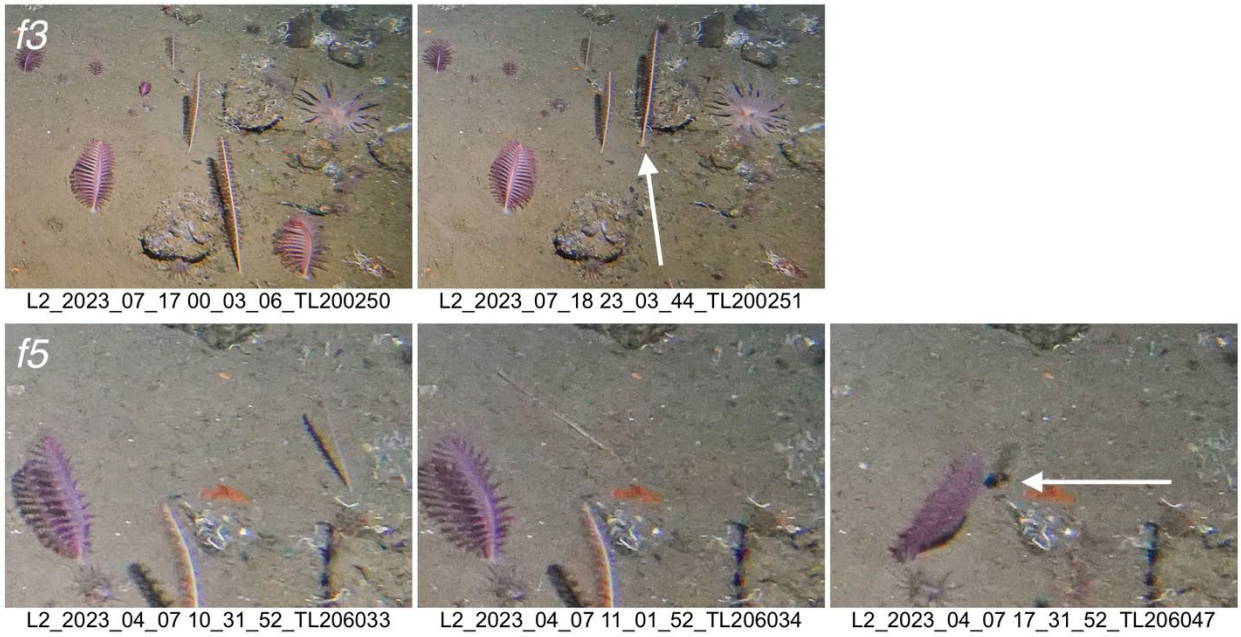


Figure 5. Sequential cropped images taken at lander TL2 of *Balticina finmarchica* sea pens repositioning (direction of white arrow), with *f3* at 2023-07-17 and *f5* at 2023-04-07. Note: the exact stages of movement are uncertain for *f3* as images were only intermittently recorded in July. Image crops show filenames.

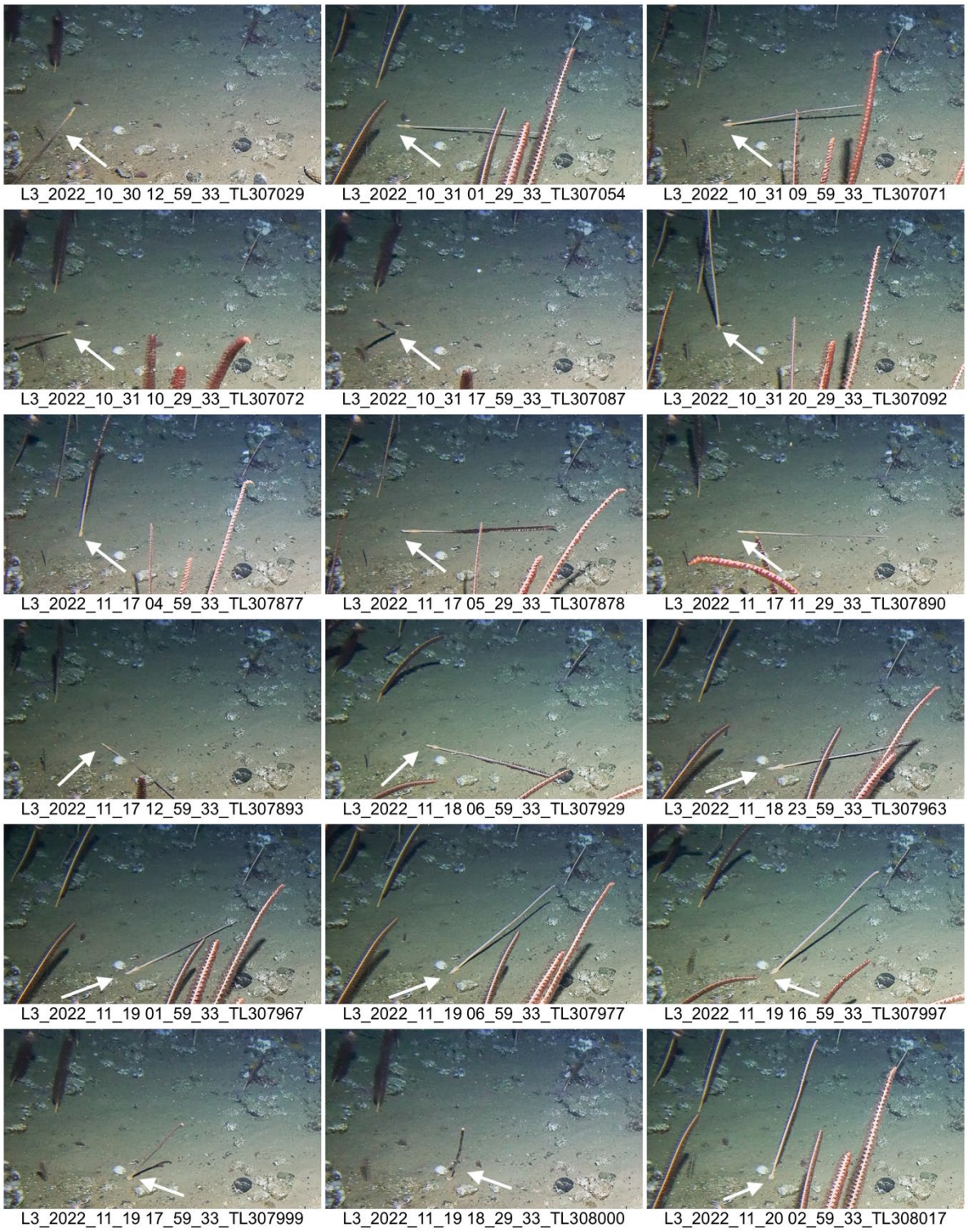


Figure 6. Sequential images taken at lander TL3 of a large *Balticina finmarchica* sea pen (*LL*, arrow) appearing in view at the left side on 2022-10-30, moving a short distance to the right side after 2022-11-17, retracting at least half its height as it anchors in place, then fully extending again by 2022-11-20. Movements by smaller sea pens (*MM, SR, SR*) were poorly visible in and are not presented here (see Table 2). Image crops show filenames.

Horizontal Displacement of Other Species

During the tracking of individual sea pens in cropped images, other sedentary species were noticed to move at lander TL2. A deeplet sea anemone (*Bolocera tuediae*) moved upwards in view from the middle lefthand side in mid-December 2022, then exited on the lefthand side at the end of January 2023. A similar looking anemone, either the same that had departed or a new one, entered into view from the lefthand side in June 2023, then re-positioned in the lower right corner of the image frame for the remainder of the image series (Table 3, Figures 7, 8). Several colonies of cup corals (*Flabellum alabastrum*) appeared and disappeared over time but were poorly visible because they were in the background, a the top of the image. One colony was tracked when entering the field of view in the lower righthand side at the end of December 2022. It made several movements upwards in the field in January and February 2023, to exit from view on the lefthand side after March 2023 (Table 3, Figure 9).

Table 3. Horizontal displacement behaviour of an actinarian (deeplet sea anemone) *Bolocera tuediae* and a scleractinian (ivory cup coral) *Flabellum alabastrum* at lander TL2.

Species	Enter	Reposition	Exit
Bolocera tuediae		2022-12-17	2023-01-26
	2023-06-08*	2023-06-08	
Flabellum alabastrum	2022-12-25	2023-01-24	
		2023-02-06	
		2023-02-22	2023-03-16

*unknown if the anemone that exited was the same one that later entered the field

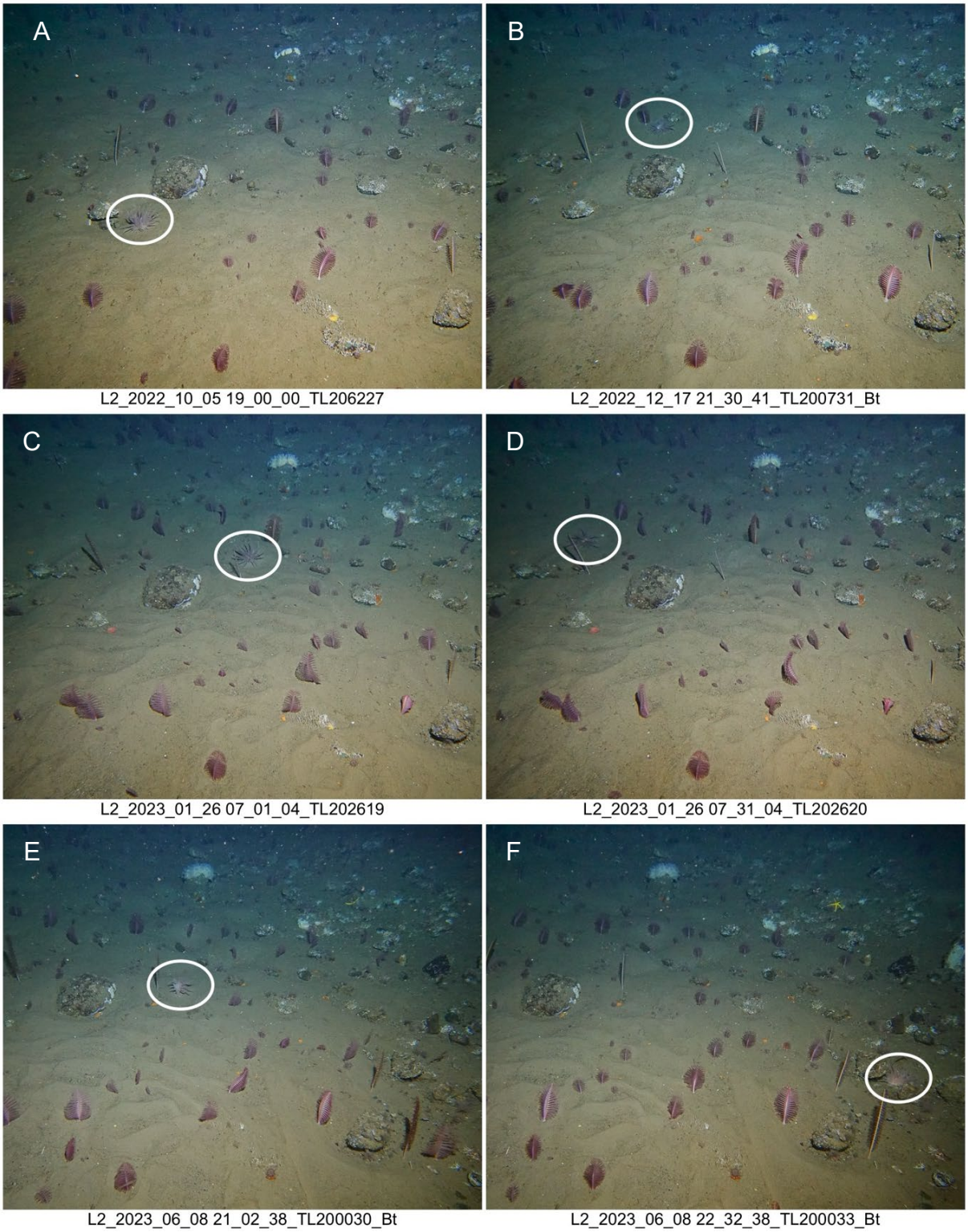


Figure 7. Scenes of a sea anemone *Bolocera tuediae* (white oval) at lander TL2 (A) that began movements after 2022-12-17 (B, C), exited from view on 2023-01-26 (D), then re-appeared on 2023-06-08 (E), to anchor itself in the lower righthand side (F). The re-appearance was not confirmed if it was of the same anemone that exited. Images show filenames.



Figure 8. Closer (cropped image) views of movements by a sea anemone, *Bolocera tuediae*.

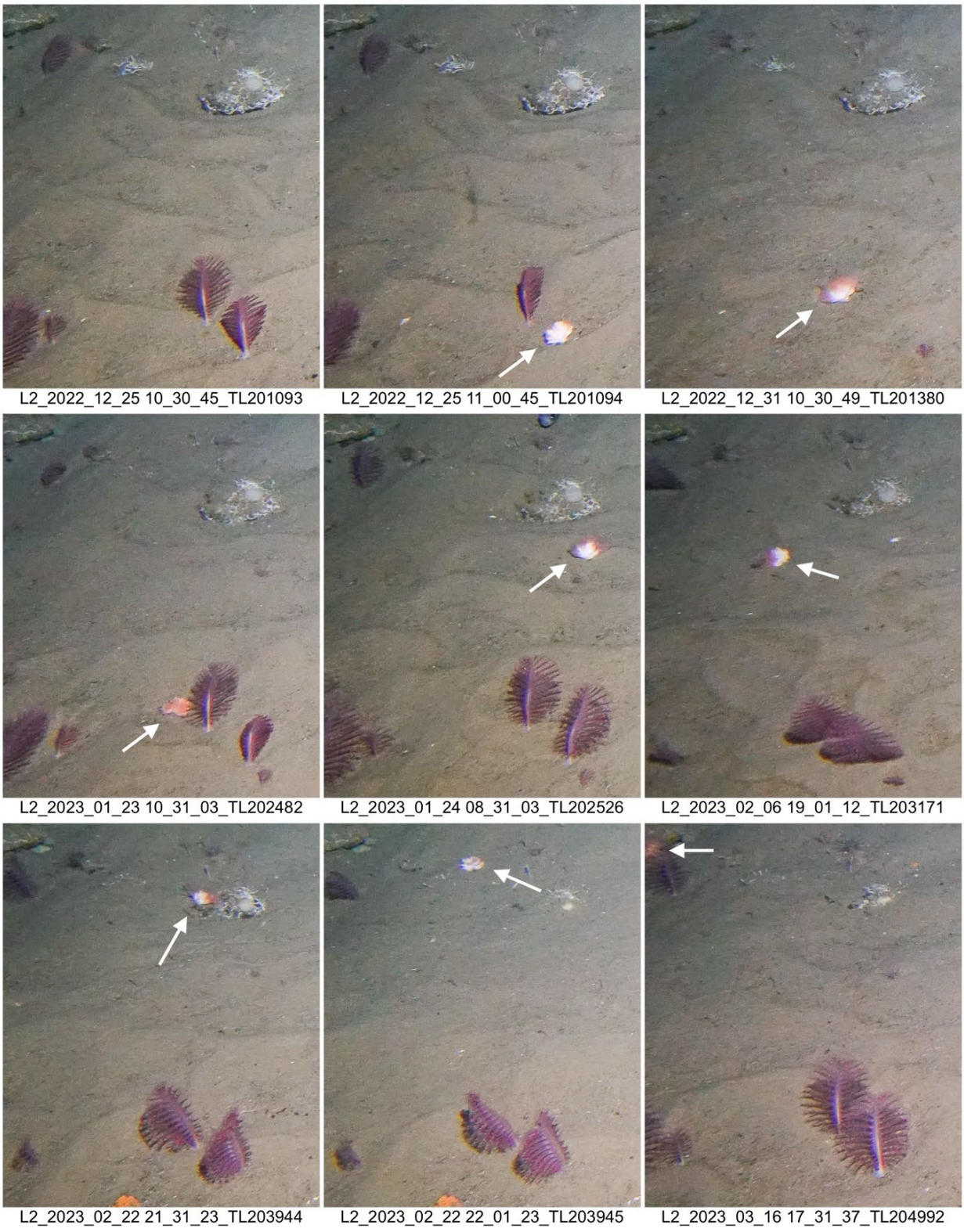


Figure 9. Scenes of short distances travelled over several weeks by a colony of *Flabellum alabastrum* (white arrow) at lander TL2 as it appeared at the bottom of the field of view in late December 2022 then exited by mid-March 2023 (bottom right). Image crops show filenames.

Sea Pen Colony Retractions and Polyp Behaviour

Colonies of *P. grandis* and *B. finmarchica* were observed to contract polyps but only partially retract in their height above the seabed (Table 4). At site TL2, the *P. grandis g1* would simultaneously contracts its polyps and retract the colony to about half of its rachis height (Figure 11). At site TL3, the colony *Pg* was less visible in the distant background, but was still seen to retract in height, perhaps also by half its expanded height (Figure 10). Examining *g1* in further detail, the colony would partially retract in height and contract polyps for very short periods (10 consecutive images or 5 hours), punctuated by very long sequences when expanded (Figure 11). Comparing between sites, the sequences when contracted were similar for the two colonies of *P. grandis* showing longer periods of contraction in October 2022, November 2022, and January 2023, and conversely there were some similarities of long periods with polyps remaining extended, as in mid-January 2023 (spaces between circles in Figure 12). Overall, the *P. grandis* at site TL2 was contracted for 3.6% of images, compared to 4.4% for the colony at TL3 (Table 4).

Table 4. Image counts of examined sea pens with closed polyps at lander sites TL2 and TL3.

Species	Site	Sea pen ID	No. visible	No. closed	% closed
Balticina finmarchica	TL2	*f1*	12054	3366	27.9
		f2	12054	1740	14.4
		f3	3007	373	12.4
		f4	11340	2971	26.2
	TL3	group	9107	374	4
		LL	7915	348	5
		SL	9107	1506	16.5
Ptilella grandis	TL2	*g1*	9317	334	3.6
	TL3	*Pg*	9107	403	4.4

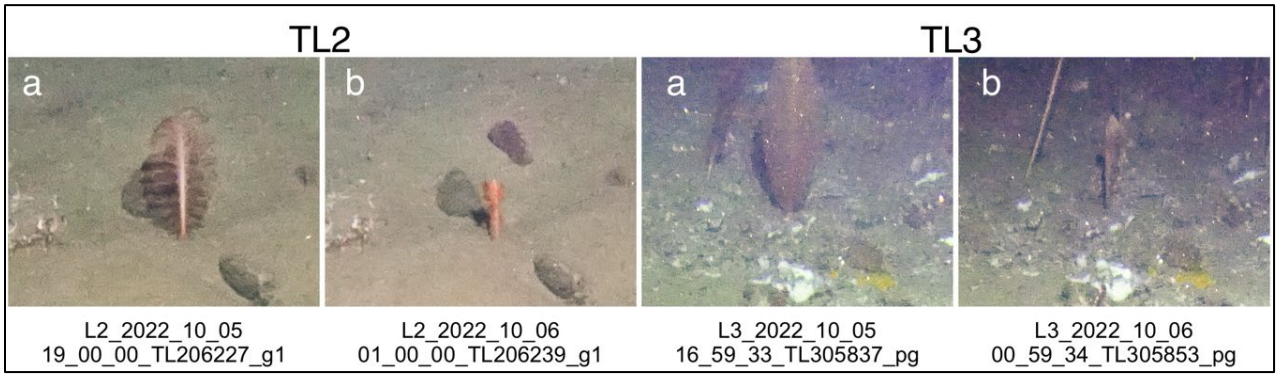


Figure 10. Sequential cropped image examples of the states of the sea pen *Ptilella grandis* (at centre in each image), with a) expanded polyps and full height or b) contracted polyps and reduced height, at landers TL2 and TL3. Image crops show filenames.

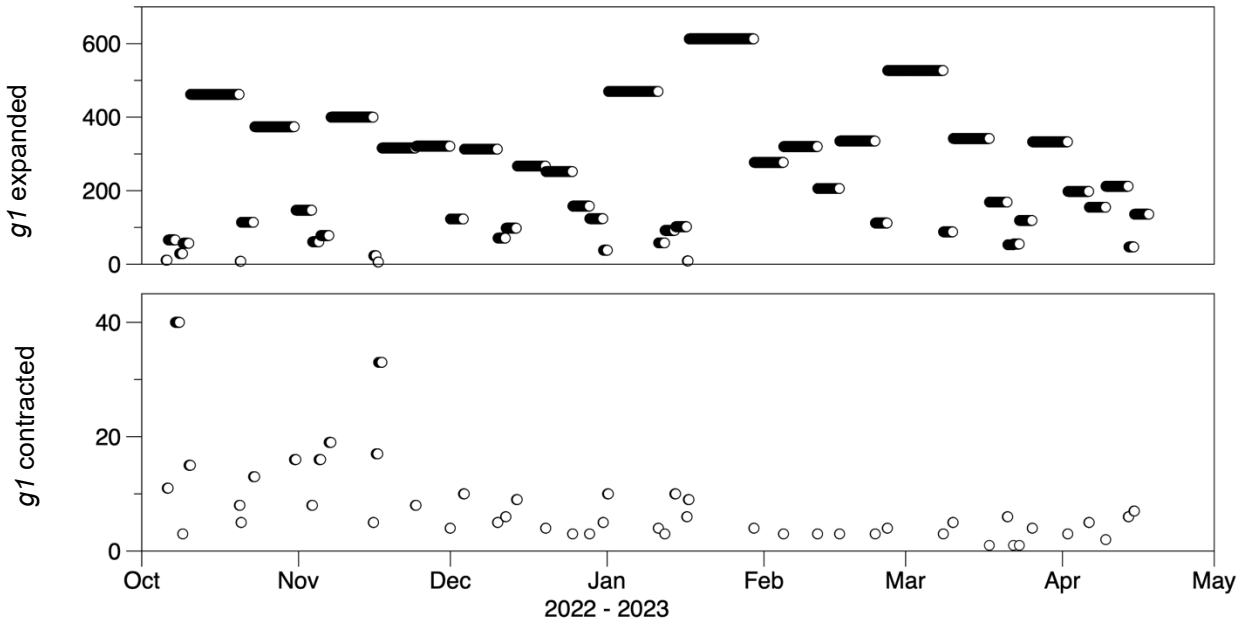


Figure 11. Periodograms for sequences of consecutive images of the *Ptilella grandis* sea pen *g1* at lander TL2 for when polyps were either seen as expanded (above) or contracted (below) from October 2022 to April 2023. The images are plotted vertically for the count of images in the sequence and horizontally by date.

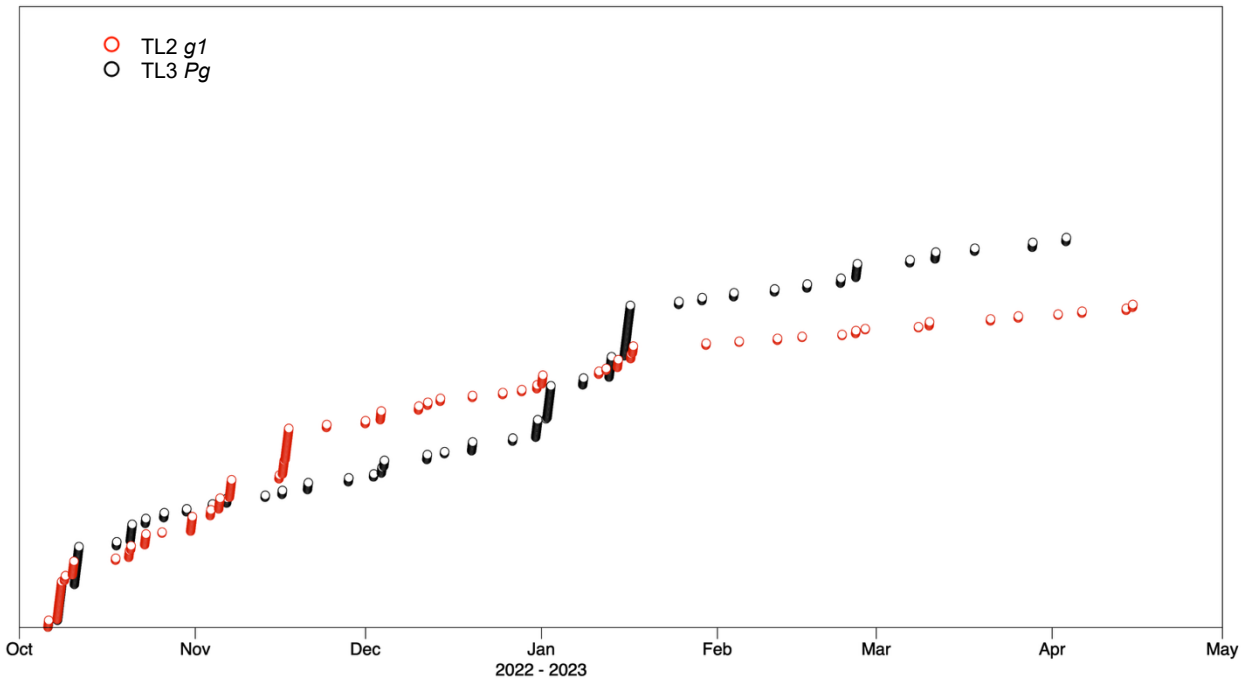


Figure 12. Periodograms for sequences of uninterrupted images, indicated by the vertical rise in circles, of *Ptilella grandis* when polyps were contracted, indicating similar long periods for TL2 *g1* (red circles) and TL3 *Pg* in (black circles), in October 2022, November 2022, and January 2023.

Relative to the *P. grandis* sea pens, the tall and slender *B. finmarchica* sea pens were less visible for polyp contractions, mostly noticed by the width of dark shadows cast by the colony on the seabed. For site TL2, sea pen *f5* was small and poorly visible but all other *B. finmarchica* sea pens were individually examined (Figure 13). Contracted states at TL2 were more frequent for

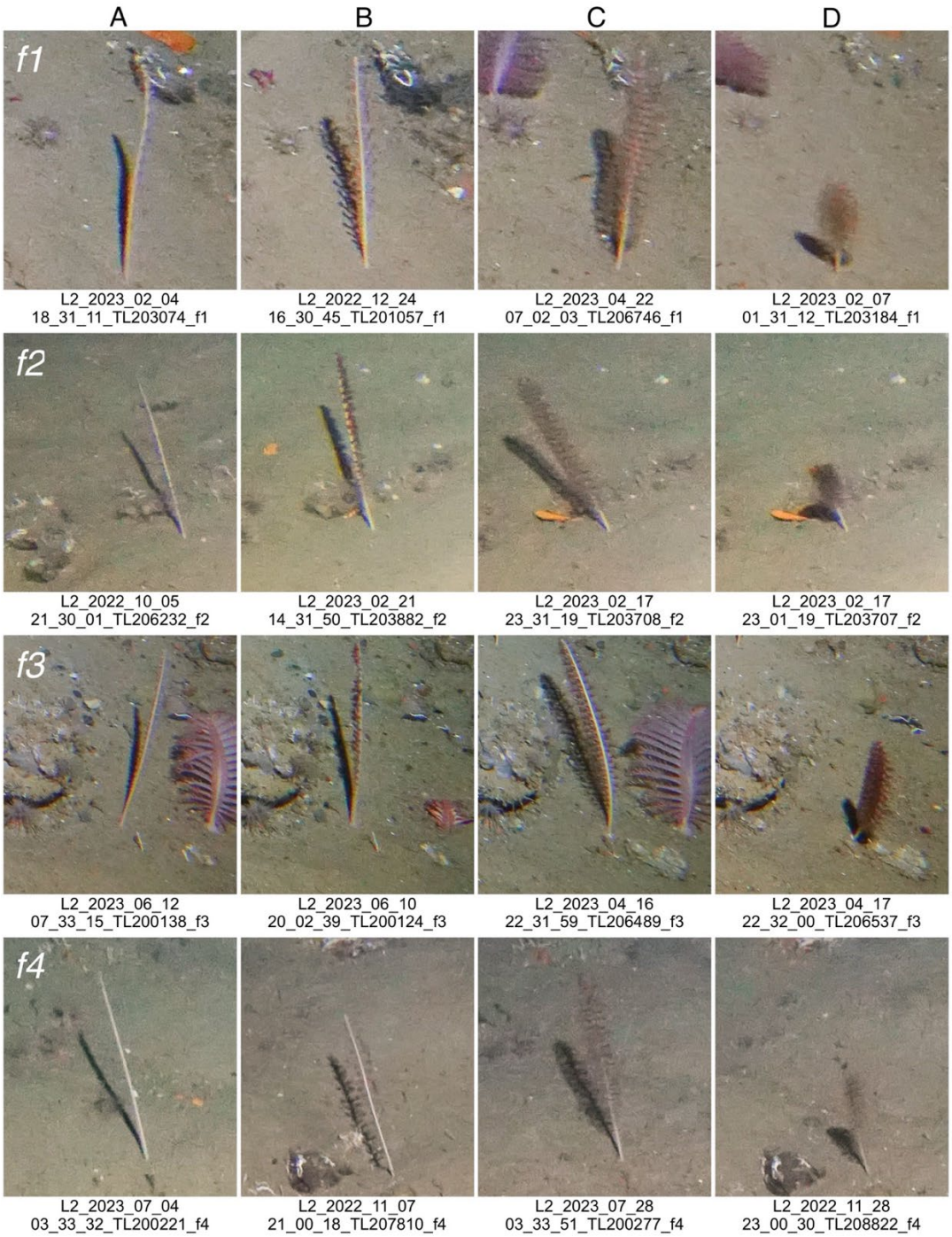


Figure 13. Examples of states at lander TL2 for *Balticina finmarchica* sea pens (*f1, f2, f3, f4*) with polyps A) contracted, B) partially contracted, C) fully expanded, and D) expanded with reduced height. Image crops show filenames.

B. finmarchica than with *P. grandis*, observed in 12 to 28% of images by sea pen (Table 4). Unlike polyp contractions, generally the reductions in colony height (retractions) were very rarely observed, shown here as examples of at least one instance for each tracked colony in Figure 14. Unlike with *P. grandis*, colony height reductions were also usually seen with expanded polyps. Another kind of height reduction seen was when a large *B. finmarchica* sea pen was re-positioning for re-anchoring, as occurred at both sites, TL2 (Figure 4) and TL3 (Figure 7). At site TL3, only selected colonies of *B. finmarchica* were tracked individually for polyp contractions. The large sea pen *LL* was of special interest, being a new arrival in the field of view. The other tracked colonies also moved but were small and poorly visible, except for *SL* that appeared sufficiently clear in the foreground. The colony *LL* was similar in contraction frequency to those of *P. grandis*, with 5% of images seen in a contracted state of polyps, while the small *SL* was like those of site TL2 with 16.5% of images in a contracted state (Table 4). To complement the individual frequencies at site TL3, the group of large *B. finmarchica* in the foreground was also reviewed, with 4% of images considered as showing a group state of contracted polyps, similar in frequency to the large sea pen *LL* (Table 4). Apart from frequencies, the two species differed in the duration when in a state, with *P. grandis* viewed as contracted for longer uninterrupted sequences while the *B. finmarchica*, as the individual *LL* or the group, would open and close more often (shorter uninterrupted sequences). However, there were also some similarities, as when both species stayed expanded continuously, particularly in mid-October and mid-November 2022, with the gaps between symbols in Figure 14 indicating periods when no images of the colonies were seen in a contracted state.

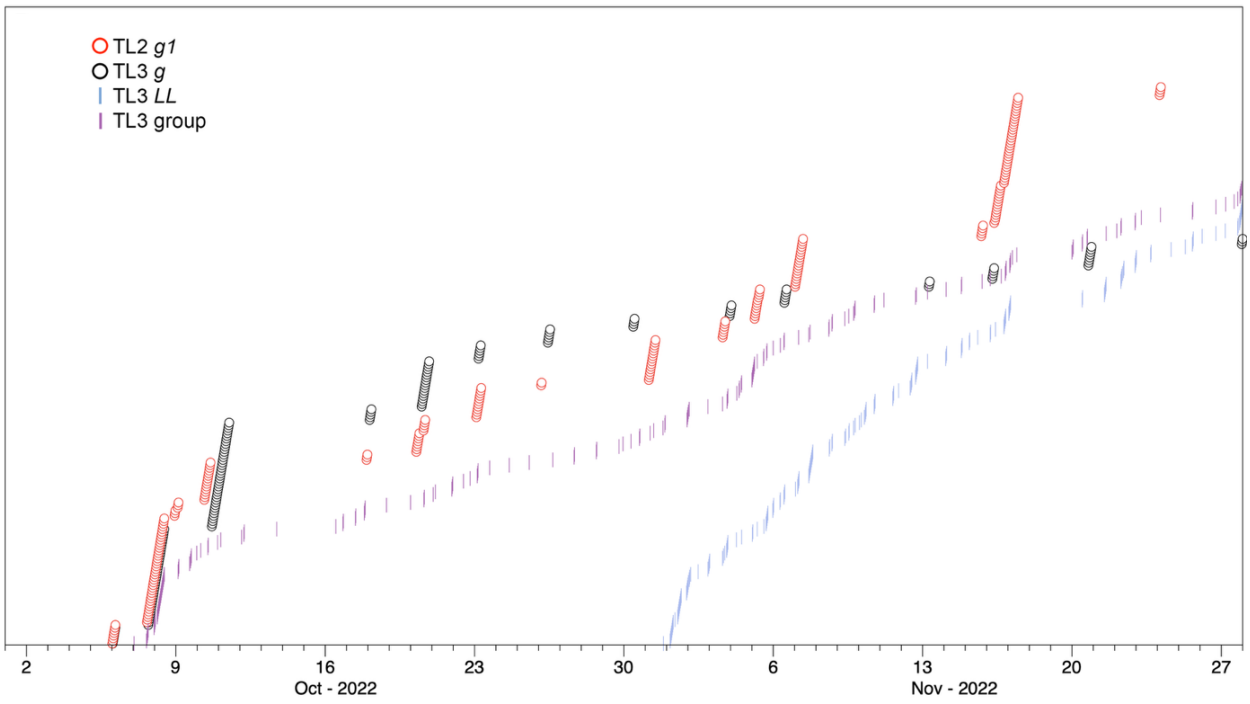


Figure 14. Periodograms for sequences of uninterrupted images (vertical rise in symbols) when sea pen had contracted polyps, comparing *Ptilella grandis* (TL2 *g1* = red circles; TL3 *Pg* = black circles) and *Balticina finmarchica* (TL3 *LL* = blue bars; group = purple bars) in October and November 2022.

Reactions of Sea Pens to Interspecific Encounters

Interactions with a Predatory Species

A set of behaviours was observed with the arrival of a predator species, a *Hippasteria phrygiana* sea star, at lander TL2.The sea star was observed in a succession of 18 images (9 hours) from 23:32 on 2023-04-17 to 08:02 on 2023-04-18, entering the field of view from the lower lefthand side and moving up in an arc before leaving on the righthand side (Figure 15). The sea star moved considerably between images until nearing the righthand side of the frame at 04:32, after which it only made small movements until leaving the image frame. A sea star later appeared in the background of the top righthand corner in eight more images on 2023-04-26, however these distant views were unclear and not assessed for interactions. On its trajectory, the sea star was seen to touch an arm to the *B. finmarchica* sea pen *f2* and passed over the location of the *P. grandis* and seven small *P. aculeata* sea pens (Figure 16). The sea star did not remain in position for more than one image, and thus the duration of contact with a sea pen was short but uncertain, as it may have occurred between three images (before, during, after) for 30 to 90 minutes.

The reactions to the sea star differed by species, as summarized in Table 5. The *B. finmarchica* sea pen *f2* contracted polyps upon contact, then expanded after the sea star moved on in the next image. The *P. grandis* sea pen *g1* disappeared, presumably having left the field of view in the 30-minute interval between two images, as the sea star approached then sat atop its former location. The small to very small *P. aculeata* sea pens that had the sea star cover their location also disappeared upon contact, apart from *c7* that retracted to a trace level, remaining visible. However, all *P. aculeata* sea pens eventually re-appeared as expanded, showing no indication of damage. The time spent withdrawn, as estimated from sequential images, ranged from 2 to 4.5 hours for the four smallest sea pens, and 7 to 14 hours for the last two sea pens contacted.

Table 5. Sequential timestamps of images at 30 min intervals for nine sea pens interacting with a *Hippasteria phrygiana* sea star at TL2 on 2023-04-18. The interactions were full retractions into sediment, except for *c7* that retracted down to a trace level, *f2* that retracted polyps only, and *g1* that did not reappear and is presumed to have exited the field after the last image.

Species	ID	Retraction	Re-appearance	Images not visible
Pennatula aculeata	*c7*	2023-04-18 01:02	2023-04-18 01:32	0
Balticina finmarchica	*f2*	2023-04-18 01:02	2023-04-18 01:32	0
Pennatula aculeata	*p39*	2023-04-18 01:32	2023-04-18 03:32	4
Pennatula aculeata	*p40*	2023-04-18 01:02	2023-04-18 05:32	9
Pennatula aculeata	*p41*	2023-04-18 01:02	2023-04-18 03:32	5
Ptilella grandis	*g1*	2023-04-18 02:32	-	-
Pennatula aculeata	*p26*	2023-04-18 03:02	2023-04-18 06:32	7
Pennatula aculeata	*p45*	2023-04-18 03:32	2023-04-18 11:02	15
Pennatula aculeata	*p30*	2023-04-18 04:32	2023-04-19 03:32	28

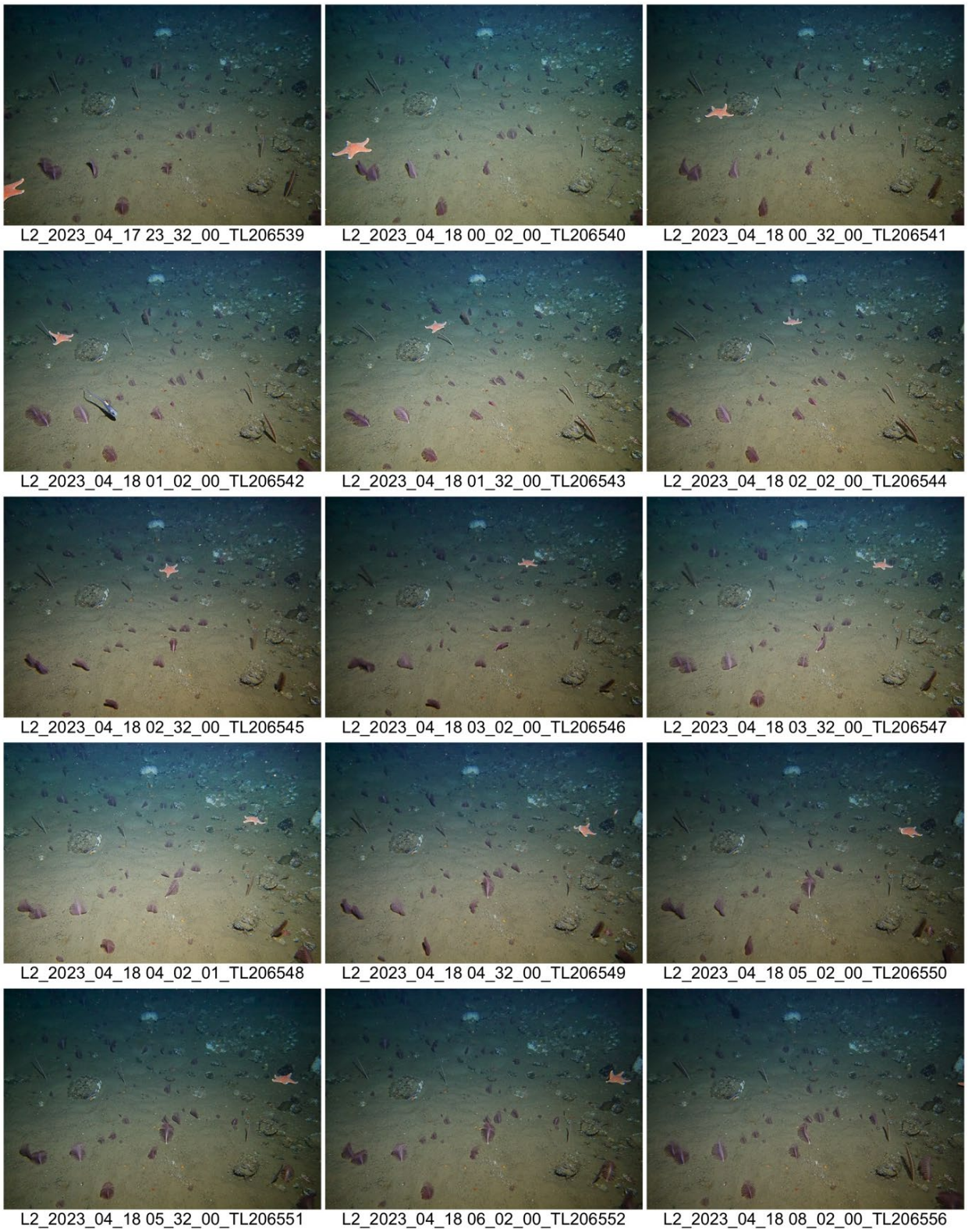


Figure 15. Sequence of a *Hippasteria phrygiana* sea star traversing the *Pennatula aculeata* sea pen field at lander TL2, entering into view by the left side at 2023-04-17 23:32 and exiting by the right side at 2023-04-18 08:02. Images show filenames.



Figure 16. Examples of interactions with *Hippasteria phrygiana* at lander TL2, showing scenes A) before contact, B) upon contact, C) disappearance, and D) recovery by sea pens of *Pennatula aculeata* (*p39, p40, p41, p26, p45, p30*), *Balticina finmarchica* (*f2*), and *Ptilella grandis* (*g1*). Arrows indicate visible sea pen. Sea pen *g1* did not recover (re-appear). Image crops show filenames.

The passage of a different *H. phrygiana* sea star, having only four full arms, was observed at lander TL3 on 2022-11-19 (Figure 17). The sea star was only observed in a sequence of four images and thus was only present in the field of view for at most two hours, during which time no contact with a sea pen was in evidence, and no changes observed in the state of visible sea pens.

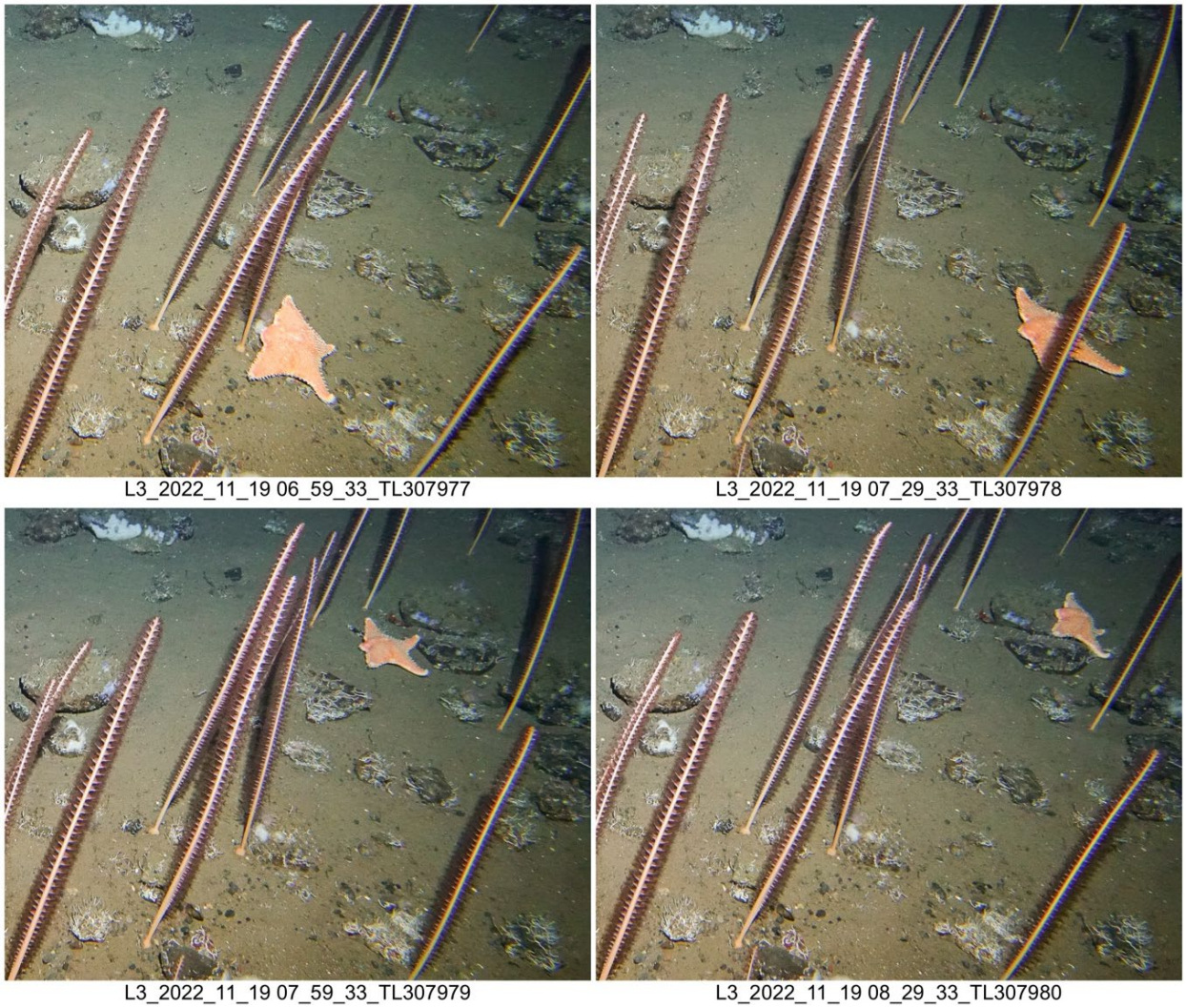


Figure 17. Sequence of four images of a *Hippasteria phrygiana* sea star traversing the *Balticina finmarchica* sea pen field at lander TL3 from 06:59 to 08:29 on 2022-11-19, with no contact or interaction observed with sea pens or other fauna. Image crops show filenames.

Predation, or scavenging, may have been observed at lander TL2 when small *P. aculeata* sea pen *p16* was seen at the onset of the series lying on the seabed next to a rock on the lefthand side (Figure 18). The sea pen appeared moribund as it never re-anchored and gastropod-like organisms appeared in images near or around the colony polyps over the course of several days, until only the bare white rachis of the sea pen remained by the end of October 2022.

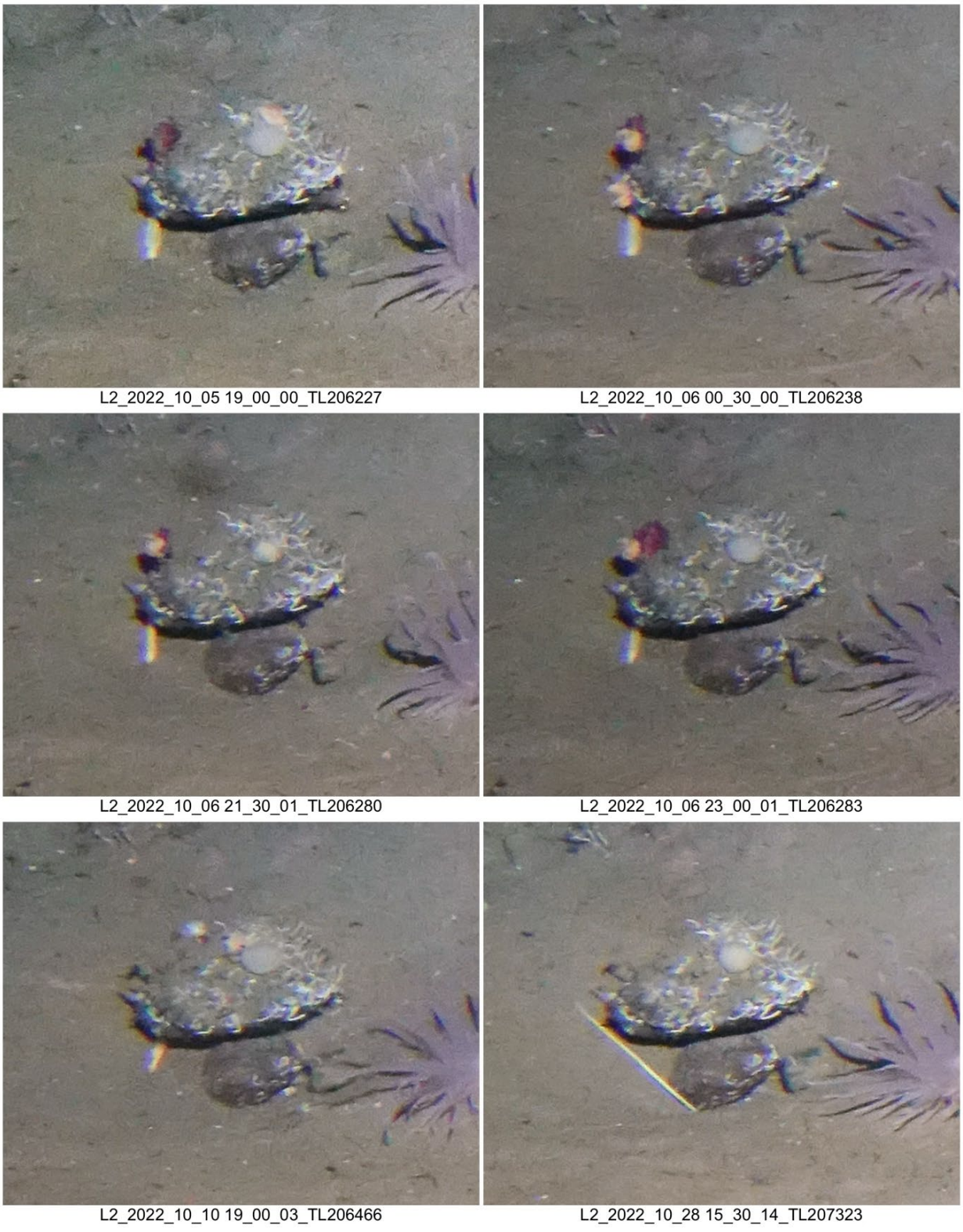


Figure 18. Sequence at lander TL2 of presumed scavenging by small organisms (pale orange forms around the rock) on the *Pennatula aculeata* sea pen *p16* on the seabed at the start of the image series at 2022-10-05, until only a bare, white rachis remains by 2022-10-28. Image crops show filenames.

Tactile Interactions with Other Species

Contact between other fauna and sea pens was occasionally observed (Table 6). The lander sites were previously noted for the presence of motile species such as demersal fishes like White Hake (*Urophycis tenuis*), Atlantic Halibut (Hippog*lossus hippoglossus*), Redfish (*Sebastes* sp.), Thorny Skate (*Amblyraja radiata*), and Monkfish (*Lophius americanus*); shrimp like *Atlantopandalus propinqvus*; and crabs like *Lithodes maja*, *Cancer borealis, Homola vigil*, and *Pagurus politus* (Nozères et al. 2024; De Clippele et al. 2025). Both large and small individuals were generally observed to swim, sit, or walk between the sea pens without apparent interaction. On rare occasions, when a large fish or crab went over a smaller colony of *P. aculeata*, the sea pen would retract partially or completely, then expanded back into view after a period once the animal had moved away. This occurred six times at site TL2 (Table 6; details in Appendix Table A1).

Table 6. Summary of non-targeted interactions of other species with contacted sea pens.

Site	Sea pen species	ID	Interacting species	Sea pen interaction
TL2	*Pennatula aculeata*	*c10*	*Cancer borealis*	Retracted then re-positioned
		c14	*Bolocera tuediae*	On disk of anemone then gone
		p30	*Lithodes maja*	Retracted then returned
		p1	*Hippoglossus hippoglossus*	Retracted then returned
		p5	*Urophycis tenuis*	Partial retraction
		p11	*Urophycis tenuis*	Retracted then returned
TL3	*Balticina finmarchica*	*SR*	*Cancer borealis*	Displaced then re-positioned
		ST	*Lithodes maja*	Displaced then re-positioned

Selected examples of interaction are presented in images here. One occurred with the very small *P. aculeata c10* when a large *Cancer* crab dug into the sediment by the colony during a sequence of eight images on 2023-04-03 (Figure 19). The sea pen was not visible in the following three images, then it re-appeared 90 min later. An event was also seen at site TL3 with the very small *B. finmarchica* sea pen *SR* that was perturbed by another digging *Cancer* crab. The other large crab species, *L. maja*, appeared to disturb small sea pens by walking over them rather than from digging, as was seen to happen to the *B. finmarchica* sea pen *ST*. Similarly, the reactions by sea pens to White Hake and Atlantic Halibut may have been due to their large size physically perturbing the colony upon contact. The other fish species were not observed to contact or interact with the sea pens. As an example of smaller fauna, *Atlantopandalus propinqvus* shrimp were observed climbing on *B. finmarchica* sea pens at the TL3 site. While shrimp were occasionally seen sitting near a rock or a sea pen, this climbing behaviour was only observed in four images, three times in December 2022 and once at the end of January 2023 (Figure 20), with no visible reaction (*e.g.,* polyp closure) noted for the sea pen.

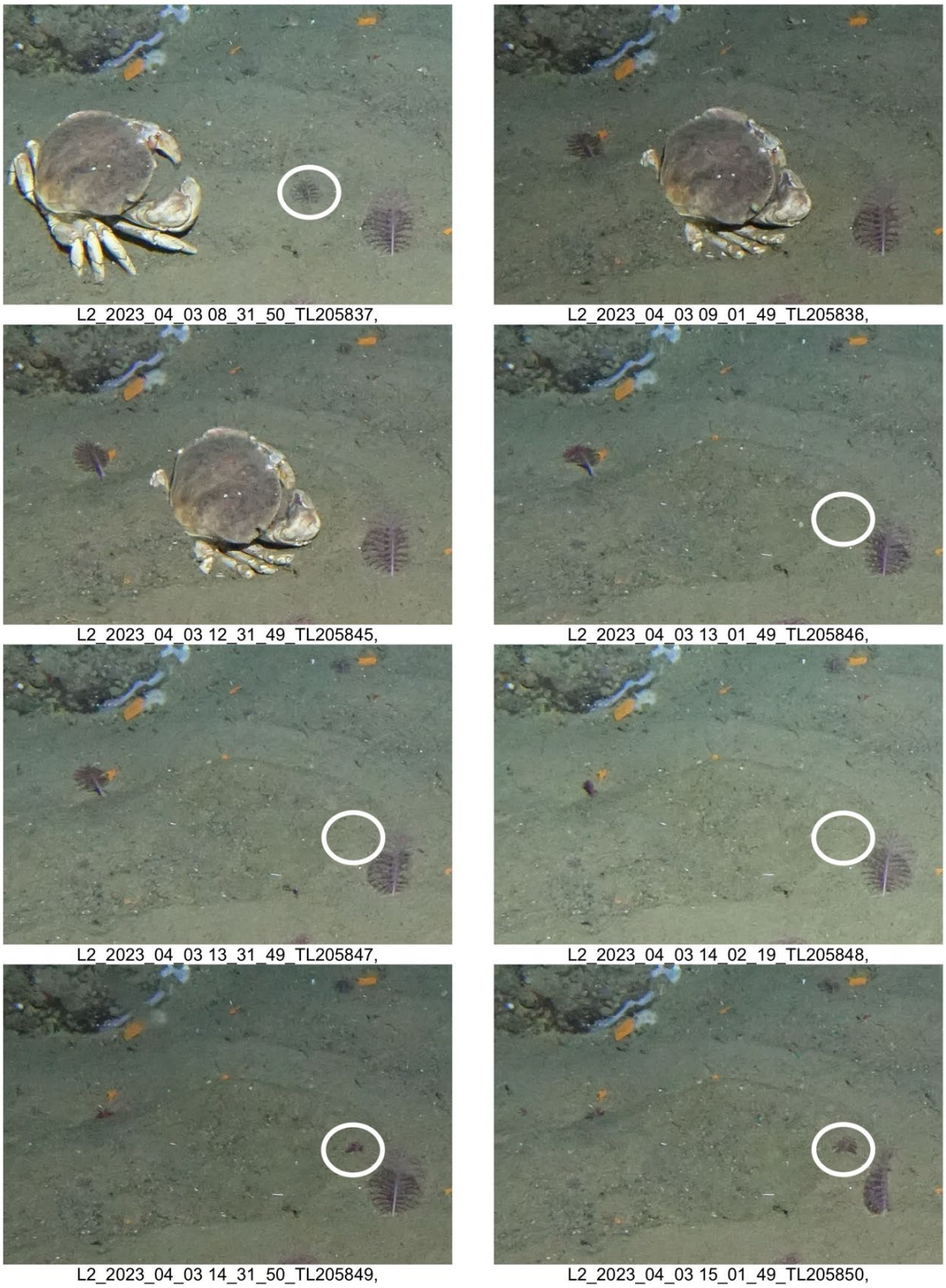


Figure 19. Sequence at lander TL3 of images of a large crab (*Cancer borealis*) positioning itself over the very small *Pennatula aculeata* sea pen *c10* (white oval) that withdrew into the sediment, then re-appeared after the crab moved on. Image crops show filenames.



Figure 20. Scenes at lander site TL3 with an *Atlantopandalus propinqvus* shrimp (white circle) perched on a large *Balticina finmarchica* sea pen, with no noticeable reaction by the sea pen. Image crops show filenames.

An uncertain interaction may have occurred with the *B. tuediae* anemone at site TL2. The anemone had previously moved upwards and away from the camera to a new position in midfield (Figure 7). During a short sequence of images on 2022-12-27, the very small *P. aculeata* sea pen *c14* also moved upwards in the field of view. In one image, the sea pen was observed to be lying astride of the oral disk of the anemone. The sea pen subsequently disappeared in the next image (30 min later), presumably having exited the field of view, but it could not be determined if this was a reaction to the contact with the anemone (Figure 21).



Figure 21. Sequence at lander TL2 of six images of *Pennatula aculeata* sea pen *c14* moving upwards in the field of view, arriving on a *Bolocera tuediae* sea anemone, then disappearing from from view in the next image. Image crops show filenames.

DISCUSSION

Visual Monitoring of Sea Pen Fields

In recent years, benthic species like sea pens, other cold-water corals (classes Hexacorallia and Octocorallia), and sponges (phylum Porifera), have been of special interest for marine conservation in Canada, with efforts to document areas of these important habitat-forming species (Kenchington et al. 2010, Murillo et al. 2016). Monitoring for sea pen distributions takes place either through captures by fisheries research surveys (Murillo et al. 2016, Shantharam et al. 2025), usually on an annual basis, or less frequently and in smaller areas by underwater visual surveys

(Greathead et al. 2007, Palummo et al. 2025, Susini et al. 2025). The monitoring of behaviour, as for example when *P. aculeata* colonies periodically retract into the sediment (Langton et al. 1988, 1990; Nozères et al. 2025, 2026), is important information for interpreting population densities, especially when observed through underwater camera surveys which typically are snap shots of the seabed taken at single points in time. However, horizontal movements had not previously been examined for their potential to affect the monitoring of the deepwater species shown here. Over the months of observation at two fixed sites, only a few colonies (for example, about 10-20% of *Pennatula aculeata*), were observed to move in, around, or out of the fields of view. This indicates that horizontal movements can affect total counts at fixed monitoring stations. It is not known if the patterns seen here were representative of behaviour in other areas or for different periods (years). Nonetheless, minor changes in numbers in a local area over time would not be expected to affect estimates of population densities when monitoring across the sea pen field.

Horizontal Displacements of Sea Pens

Apart from impacts on visual monitoring, the movements by sea pens seen here may be evaluated for their context and potential causes, to inform future directed studies. While the two lander sites differed in number and size composition for sea pens, there were some shared similarities and differences in horizontal movements. The observed tendency, at both sites, was for mostly smaller colonies to move in the field, including entering or exiting from view. Analyses of fine-scale distributions and larval settlement have indicated non-random patterns of spacing and potential competition with other sea pens or other fauna like anemones (Susini et al. 2025). There were some indications here that movement may have been associated with optimizing the placement of a colony. We speculate that smaller ones may move more frequently to obtain a better feeding position if in competition with other organisms, whereas larger ones might already occupy a desired location and thus remain in place to grow. However, it is not evident what initiated their displacements and how optimal site placement may be determined. For example, it is unclear if either the movements or the different proportions of species at each site could be the result of deliberate spacing to avoid proximity with other colonies or perhaps the local sediment properties for preferred anchoring.

Related to physical site optimization, sea pens may be moving in reaction to hydrological conditions. The Gully canyon where the landers were deployed is a complex hydrological environment (Shan et al. 2014), with seasonal and circulation patterns that provide inputs to support the sea pen fields but may also be associated with horizontal movements by colonies. For example, in coastal species, shallower water may be too turbulent for both larger sea pens and predators, enabling settlement of smaller sea pens until they can move to deeper water as larger colonies (Kastendiek 1982). Both lander sites were at similar depths of over 300 m and could be expected to have similar current regimes and exposure to predators, and thus the different sea pen groupings might be related to site-specific substrate. Visually, site TL2 seemed to have more open areas while site TL3 had more stones and rocks. For the *B. finmarchica* sea pens, only a few, mostly smaller, colonies were seen at site TL2, with nearly all moving over time. In contrast, site TL3 had many colonies of *B. finmarchica,* but only two moved: the large (*LL*) and medium (*MM*) colony. For the large one, it had first arrived then anchored but then uprooted a short time later. The medium-sized one appeared initially to be poorly anchored while leaning near rocks but

moved to a new site and then behaved more typically, expanding and bending with the water current like the other sea pens.

The sediment and substrate of the lander sites were not evaluated however, some information is available. As noted above, they were fewer rocks and more open areas at site TL2 than at site TL3. Locally, in terms of surficial sediment, the eastern canyon slopes of the Gully sector are expected to comprise of Glacial Diamict, generally a dense, unsorted, homogenous mixture of mud with sand and gravel (Philibert et al. 2022). Locally, there seemed to be at least a surface cover of loose sand because the holes filled in when sea pens pulled up and moved away, leaving no trace of their previous location. An ROV mission led by O. Sherwood (Dalhousie U.) in August 2022 conducted transects and sediment samples in the area prior to the lander deployment (https://meopar.ca/project/project-mori-coral/). In the underwater videos, repeated core sampling of the sandy-cobble moraine habitat left no significant depressions on the seabed as the holes rapidly filled in after coring (C. Nozères, pers. obs.). The sampling occurred along a transect that passed near the positions of the landers. In the open area of the *P. aculeata* field near site TL2, the sediment appeared be more coarse-sandy as it sometimes would fall out from the coring tube when lifted from the seabed. In contrast, in the rock-strewn area of *B. finmarchica* field near site TL3, the sediment appeared to be of finer material, retained in the tube when lifted. Being more abundant in an area with coarser sediment was unexpected observation for *P. aculeata.* Elsewhere, *P. aculeata* sea pens were more frequent in areas with fine silt or mud sediment (Langton and Uzmann 1989). When present in fine sediment, sea pens may leave evidence of their presence, with circular holes on the seabed when sea pens moved (Appendix Figure A1) and thus could leave evidence of their past behaviour, unlike the sea pens observed by the landers here. It is uncertain if the long-term patterns observed in this sandy sediment habitat were representative for these sea pen species when occurring elsewhere in finer sediment.

Historically, displacements by sea pens were sometimes described as swimming, while others suggested it was passive, caused by water currents that dislodge the colonies, or else a mix of the two scenarios, using peristaltic movements in the rachis to move and take advantage of currents (Musgrave 1909, Kastendiek 1976). While the image series was relatively coarse at 30 min intervals, this scale seemed sufficient to show that uprooting and re-anchoring by colonies took considerable time, with the exposure of the peduncle seen across several images and thus hours. If dislodged inadvertently by currents, it might be expected that this gradual process would not occur. As the movements by sea pens were so infrequent, it is difficult to assess if any event was caused by currents. However, the observed events were by single colonies at different times, and not as a group disrupted at once by currents, suggesting active movement rather than direct environmental causes. Additionally, apart from one large *B. finmarchica*, all displacements were by smaller sea pens. Because of the relative size of the anchoring peduncle to the above-bottom rachis, the larger sea pens would be expected to be more vulnerable to being dislodged by currents (Kastendiek 1976). Furthermore, if disrupted by currents, large movements might be expected, whereas most of the observed shifts were over small distances, estimated as a few cm.

While most observed movements were small and gradual, a few events were sudden, covering distances across or out of the field of view between 30 min images, especially for several exits by colonies which were not directly observed and may have involved a combination of colony direct movement and facilitation by water currents. As the observations were not continuous, it

was difficult to evaluate how the entrances and exits occurred so rapidly. Some relatively sessile organisms like sea cucumbers (Echinodermata: Holothuroidea) are known to be able to adjust their movements by changing their body volume and buoyancy through hydrostatic pressure, then using water currents to passively carry them to new locations (Hamel et al. 2019). Sea pens have also been observed to both passively drift above the seabed using buoyancy mechanisms (Birkeland 1974) and actively reshape themselves to a ball formation enabling rapid rolling on the scale of metres (Giusti et al. 2024), as has also been observed here and elsewhere with sea anemones (Marchiò et al. 2025).

Reactions of Sea Pens to Contact with Motile Fauna

While most movements by sea pens had no visible cause, certain behaviours appeared to be reactions to other fauna, as seen during the passage of a predatory *H. phrygiana* sea star at site TL2. In the northeast Pacific, the orange sea pen, *Ptilosarcus gurneyi* (Pennatulidae), is a major food source for several asteroid species (*Hippasteria spinosa, Dermasterias imbricata, Crossaster papposus*, and *Mediaster aequalis*), and nudibranchs (Birkeland 1974). Predation mortality on smaller recruits can be as high as 97% while predation on adults can reach 3.1%, with *H. phrygiana* targeting adults. The sea star *Hippasteria spinosa* is a specialist feeder on *P. gurneyi* which constitutes 98.8% of its diet (Birkeland 1974), even being able to excavate sediment above withdrawn colonies, while other sea stars require the prey to be lying on the surface. Its congener, *H. phrygiana*, observed here, is also known to be a predator of coral species with coral sclerites found in 64% of the stomachs analyzed from specimens off Newfoundland, Canada and predation on *Pennatula* sp. and *Flabellum alabastrum* confirmed in laboratory experiments (Gale et al. 2013). Consequently, behavioural responses by a sea pen to the presence of *H. phrygiana* are expected. For example, *P. gurneyi* showed rapid retraction behaviour in response to physical contact with a specialist asteroid predator (*D. imbricata*) accompanied by colony-wide bioluminescent flashes (Weightman and Aresenault 2002). In this image series, the passage of the sea star at site TL2 resulted in temporary retraction by colonies of *P. aculeata* when it passed over each of their locations, and presumably the exit of the colony *P. grandis* because it was not seen after the sea star reached its location. A colony of *B. finmarchica* protected its polyps by contracting when touched by an arm of the sea star. The passage of another *H. phrygiana* at site TL3 was not seen to make contact or to pass over the location of any sea pen, and no reaction by sea pens was observed. Of note, site TL3 was dominated by tall *B. finmarchica*, with the presence of only a few small *P. aculeata* which is a preferred prey of this predator (Gale et al. 2013).

Predators of sea pens such as sea stars may have easier access to feed on polyps of tall sea pens, as occurs when colonies are damaged by the passage of a bottom trawl net and subsequently lying prone on the seabed instead of being erect (Buhl-Mortensen et al. 2023; see also an image of a *Solaster* star on a *Balticina* sea pen in NOAA 2024). In an investigation with a similar species, *Balticina willemoesi*, nudibranchs preferred to take bites of the polyps rather than the peduncle or the rachis when a sea pen was exposed on the seabed (Malecha and Stone 2009). For this series, the erection of a colony, especially by the larger species of *B. finmarchica*, was observed to require hours if not days to complete, making them more vulnerable for a period, even if not damaged. The events observed here, when a sea pen was seen moving in images while horizontal on the seabed, were not accompanied by the presence of a known predator like a sea star (Gale et al. 2013) or nudibranchs (Birkeland 1974). However, an interesting scene occurred with a very small

P. aculeata that was in the process of moving across the field, then seen atop of the oral disk of the *B. tuediae* sea anemone in a single image, then to have disappeared from all subsequent images. The anemone was not seen to react (bending tips of anemones) in the single image. Shrimp like *Spirontocaris liljeborgii*, *Lebbeus polaris*, and pandalids have been observed to shelter near *B. tuediae*, with the anemone not reacting to occasional contact by the shrimp (Jonsson et al. 2021). A *Spirontocaris*-like shrimp was repeatedly observed near the anemone at lander TL2, without visible reactions by the anemone (Nozères et al. 2024). In contrast, when touched by other crustaceans like krill (euphausiids), *B. tuediae* would react rapidly by curling its tentacles at the prey (Jonsson et al. 2021). It seems unlikely that the sea pen could be consumed within the 30 min between images, and the rachis also discarded out of view. One possibility is that the colony was able to make a rapid escape, being elevated by the anemone, and thus able to take advantage of currents to leave the field of view.

Apart from the sea star, other observed interspecific interactions appeared to be inadvertent, with large crabs and fishes that rested or walked over sea pens, resulting in momentary withdrawals or displacements, usually of very small colonies. At one point, a large crab was seen digging at the position of small sea pen, which could be a potential threat, but it did not seem like deliberate targeting, and the colony again reappeared over time. Others have also observed that sea pens like *P. aculeata* may not react immediately but require continued prodding, as by an arm on a submersible, before retracting into sediment (Langton and Uzmann 1989, Miatta and Snelgrove 2021). Thus, it appears there is a threshold or special set of cues that can result in polyp contraction or colony retraction, if presented with a perceived threat or physical disturbance.

Horizontal Displacements of Other Species

Other significant horizontal movements by fauna normally considered sessile were observed with actiniarians (deeplet sea anemone, *Bolocera tuediae*) and scleractinians (ivory cup coral, *Flabellum alabastrum*) at site TL2. No predator avoidance activity was observed with the coral movements, which is of particular interest as it is a noted prey of the sea star (Gale et al. 2013). A large colony was located near the sea star when it covered over sea pen *p26* (Figure 11), but the sea star was not seen at its position. At other times, a few cup corals were seen to move across the field of view over the course of days and weeks. Compared to sea pens and sea anemones, the cup coral movements were smaller between images, on the order of several cm instead of metres. In a laboratory tank investigation, the corals observed to move on the order of a few cm per month (Buhl-Mortensen et al. (2007). As reported in that study, cup corals are common in the region, though are usually associated with fine silt seabeds with slow currents. The lander sites appeared to have coarser sediments, likely resulting from stronger currents that could also enable relatively rapid movement by cup corals in and out of the fields. An example of rapid movement was seen in a video during sediment sampling in this area in August 2022, when the positioning by the ROV produced currents on the seabed that swept several cup corals back and forth across the field of view (C. Nozères, pers. obs.). Covering greater distances over short periods was also seen by the sea anemone that was usually fixed in place, with only a few images recording its passage across the field. In January, it left the view, then in June a similar anemone reappeared midfield and anchored itself in the lower right corner. As with the sea pens and cup coral, the causes of these rare movement events were not obvious and will be of interest for future study.

Sea Pen Colony Retractions and Polyp Behaviour

During the review of sea pen displacements, their behaviour when stationary was also observed, with periodic closing of feeding polyps (contractions) and occasional changes in colony height (retractions). These pattens may provide ecological insights into their environmental conditions, to assist with conservation monitoring. In laboratory studies, sea pens would retract into sediment by closing their polyps and expelling the water from the colony (Pavans de Ceccatty et al. 1963, Imafuku 1976). Colony retraction can occur rapidly; in seconds in species such as *Virgularia mirabilis* (Ambroso et al. 2013) and *Protoptilum carpenteri* (Ambroso et al. 2021) or over minutes as observed in *Pennatula rubra* (Chimienti et al. 2018). While the full retraction by *Pennatula* spp. colonies has been previously documented (Langton et al. 1990, Chimenti et al. 2018, Nozères et al. 2025), patterns of colony retraction and associated polyp contraction were observed here for the first time for the larger species of *B. finmarchica* and *P. grandis* (Tables 1, 5). The retractions by colonies of *B. finmarchica* and *P. grandis* were only ever observed to be partial (about half their original height). When in a partially retracted state (reduced colony height), polyps were always closed for *P. grandis*, as was also seen with *P. aculeata*. Conversely, the rare moments when colonies of *B. finmarchica* were seen with reduced height were accompanied by expanded polyps, except for periods when it was moving, when it was always seen with contracted polyps. Height changes when moving was during the process of re-anchoring, presumably having the muscular peduncle pulling it down into the sediment to better seat the colony before expanding to full height and open polyps. Height changes are of significance for areas with disturbance, such as bottom trawl fishing activity, as erect colonies would be more vulnerable to damage (MacDonald et al. 1996). As height changes were both partial and extremely rare events in *B. finmarchica*, it is unlikely this would be of benefit when faced with fishing disturbances. For the other large sea pen species, *P. grandis*, height reduction was more pronounced, but over 95% of the images showed them as expanded (Table 5), and thus it is uncertain if it would reduce their vulnerability to fishing except for these brief periods when retracted.

Regarding the polyp contractions, a first step to understanding their behaviour was by noting the unbroken sequences of images of a colony's polyp state as either expanded or contracted. While they differed in frequencies, a shared trend by *P. grandis* and *B. finmarchica* sea pens was for their polyps to stay contracted for longer bouts in autumn while remaining expanded longer in winter-spring months. These polyps are autozooids, or feeding polyps, and thus are in a non-feeding state when closed. While shallow water species follow circadian rhythms with temperature and light (Buisson 1971, Imafuku 1980), it is unclear why they would close polyps at frequent short intervals when in deep water. Over longer periods, the trend for polyps to be open more often is suggestive of increased food availability in spring, likely following seasonal plankton blooms in March and April (Ross et al. 2017, Jackson et al. 2021). As noted earlier, the study area of the Gully is very dynamic in hydrology, with considerable seasonal and annual variability (Jackson et al. 2021), making it a challenge to draw conclusions on patterns from this study period of 2022-2023. For example, in regional oceanographic monitoring, the year 2022 was exceptional with phytoplankton blooms taking place later and lower in magnitude, while zooplankton biomass was at a record low (DFO 2023) and again very low in 2023 (Galbraith et al. 2024). Apart from feeding, autozooids also produce gametes (eggs or sperm), and so an expanded colony may also be associated with reproduction as gametes are expelled into the water column for external fertilization. Spawning is expected to occur annually after the spring bloom and

feeding, with *B. finmarchica* reported to spawn in April in the Laurentian Channel near the Gully (Baillon et al. 2015), while P. aculeata spawned in summer months in the upstream of the channel in the Gulf of St. Lawrence (Couillard et al. 2021), with presumably similarly timed releases by *P. grandis*. However, it is not known how spawning would be noticed in the image series, nor how it would affect polyp contraction or colony retraction patterns. For the *P. grandis g1* sea pen, image sequences of remaining expanded were shorter in April than in March. Seasonal evaluations were also limited as the image series ended after mid-April when this sea pen disappeared, and was incomplete in summer for *B. finmarchica*, and thus some periods were not evaluated.

CONCLUSIONS

Over a period of several months from autumn to summer, this underwater image series documented movement behaviour by three deepwater sea pen species in addition to that of other deepwater faunal species usually considered sessile such as a sea anemone and a cup coral. The sea pen movements differed by relative size categories, usually observed with smaller colonies, and either self-initiated for re-positioning or to avoid either predation or disturbance by large crabs and fishes. While capable of horizontal movement, the events were relatively rare in frequency, witnessed because of the long time and fine scale (30 min interval) of the image series, and usually consisted of displacements over short distances, though some events had colonies leaving the field of view. The two colonies of *P. grandis* were not directly observed for movement, but their ability to move relatively quickly across several metres was suggested with the exit from view by one colony upon contact with a sea star. In addition to horizontal movements, observations of periodic polyp contraction behaviour of the two colonies of *P. grandis* had indications of some seasonal patterns, such as being contracted longer at similar periods in autumn while remaining expanded more often in winter-spring. Polyp contractions by *B. finmarchica* were more frequent and thus of shorter intervals, though they were broadly similar in seasonal patterns. Future studies, conducted with continuous images or longer periods either in place or in captivity, may provide more insights into the extent as well as the ecological basis of movement behaviours and periodic polyp contractions. For conservation monitoring, because horizontal movements were infrequent, this behaviour is not expected to have considerable impact for visual counts of these species when conducting monitoring surveys.

ACKNOWLEDGEMENTS

We thank all the ship crews and personnel involved in the benthic lander preparation, deployment, and recovery, especially Barry W. MacDonald, and to Camille Lirette for the management of the image files. We also thank the anonymous reviewers of an earlier draft of this manuscript.

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APPENDICES

Table A1: Summary of sea pen interactions observed with other species listed by sequential image filenames and observed sea pen behaviour.

Bolocera tuediae, Deeplet Anemone

L2_2022_12_27 11_30_46_TL201191 – sea pen *c10* nears sea anemone
L2_2022_12_27 13_00_47_TL201194 – *c10* is atop of oral disk of sea anemone.
L2_2022_12_27 13_30_46_TL201195 – *c10* is gone (uncertain if moved or consumed)

Cancer borealis, Jonah Crab

L2_2023_04_03 09_01_49_TL205838 – crab sits on (or near) sea pen *c7*
L2_2023_04_03 13_01_49_TL205846 – crab is gone and *c7* is not visible
L2_2023_04_03 14_31_50_TL205849 – *c7* re-appears expanded

L3_2023_02_25 21_59_38_TL303709 – crab touches sea pen *SR*
L3_2023_02_25 22_29_38_TL303710 – crab buries, *SR* no longer visible
L3_2023_02_26 06_59_38_TL303727 – crab moves away, sea pen begins re-anchoring nearby

Lithodes maja, Northern Stone Crab

L2_2023_04_14 18_31_57_TL206385 – pair walks over sea pen *p30*
L2_2023_04_14 19_31_58_TL206387 – pair moves away and *p30* is fully withdrawn
L2_2023_04_14 20_31_57_TL206389 – *p30* re-appears and begins to expand

L3_2022_12_21 20_29_34_TL300539 – crab nears sea pen *Bf ST*
L3_2022_12_21 20_59_34_TL300540 – sea pen no longer visible
L3_2022_12_22 02_29_34_TL300551 – sea pen re-anchors nearby.

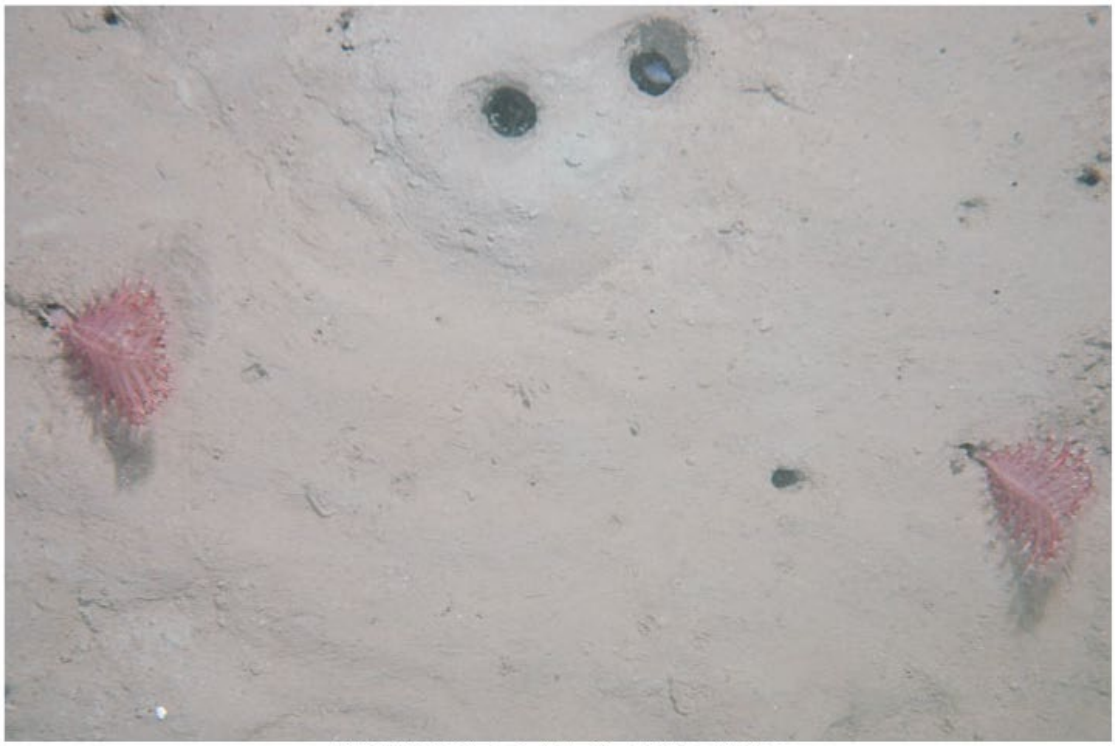
Urophycis tenuis, White Hake

L2_2023_02_20 16_31_21_TL203838 – fish touches sea pen *p5*
L2_2023_02_20 17_01_21_TL203839 – fish is gone and *p5* is partially bent but not retracted

L2_2023_02_08 16_01_13_TL203261 – fish touches sea pen *p11*
L2_2023_02_08 16_31_13_TL203262 – fish gone and *p11* retracted to trace level
L2_2023_02_08 18_01_13_TL203265 – *p11* is fully expanded again

Hippoglossus hippoglossus, Atlantic Halibut

L2_2023_01_24 22_31_04_TL202554 – fish touches sea pen *p1*
L2_2023_01_24 23_01_03_TL202555 – fish is gone and *p1* is mostly retracted
L2_2023_01_25 03_01_04_TL202563 – *p1* is again fully expanded after 4 hours



MCG2006_E_35_0_DSC_0033



MCG2006_E_62_0_DSC_0029

Figure A1. Examples of circular holes seen in the soft-sediment seabed, along with *Pennatula aculeata* sea pens, in the Laurentian Channel, St. Lawrence Estuary. Images show filenames. Credit: DFO-Quebec Region.