



OPEN ACCESS

EDITED BY

Ricardo Serrão Santos,
University of the Azores, Portugal

REVIEWED BY

Filipe Porteiro,
University of the Azores, Portugal
Yanhui Dong,
Ministry of Natural Resources, China

*CORRESPONDENCE

Camilla M. Marnor
✉ camilla.marnor@bergwerk.com

RECEIVED 15 July 2025

ACCEPTED 03 September 2025

PUBLISHED 19 September 2025

CITATION

Marnor CM, Souche A, Hartz EH,
Jæger ML and Schmid DW (2025)
Deep-sea sedimentary cave
structures: geology or fish-made?
Front. Mar. Sci. 12:1666456.
doi: 10.3389/fmars.2025.1666456

COPYRIGHT

© 2025 Marnor, Souche, Hartz, Jæger and Schmid. This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](#). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Deep-sea sedimentary cave structures: geology or fish-made?

Camilla M. Marnor^{1*}, Alban Souche¹, Ebbe H. Hartz²,
Maja L. Jæger³ and Daniel W. Schmid¹

¹Bergwerk AS, Sandefjord, Norway, ²Aker BP ASA, Lysaker, Norway, ³Department of Earth Science, Center for Deep Sea Research, University of Bergen, Bergen, Norway

At the Central Mohns Ridge, numerous large cave-like structures were observed in deep-sea sediments at approximately 1200 and 1600 m depth. The glacial eelpout (*Lycodes frigidus*) was found inhabiting some of these caves, with one individual observed guarding a clutch of eggs. This paper examines the origin of these structures, questioning the hypothesis put forward previously that they are formed by geological processes such as catastrophic fluid vent escapes. No significant disruption of the sedimentary layering was observed, and the caves have a semi-horizontal orientation and are of limited size. We propose that these caves are actively excavated or modified by fish for habitation and protection, a behavior documented in other zoarcids and in other fish families. This observation represents, to our knowledge, the first documented case of parental care by egg guarding inside a cave for *L. frigidus*.

KEYWORDS

Lycodes frigidus, Zoarcidae, deep-sea caves, parental care, predator avoidance, burrowing behavior, fluid escape, bio-construction

1 Introduction

Across the deep seafloor, the formation of large holes and cave-like structures in fine-grained sediments has been attributed to powerful geological forces. Observations from the continental rise off Lofoten, Northern Norway, at depths of around 2200 m have documented extensive systems of such caves (Bellec et al., 2010; Bøe et al., 2012). The prevailing scientific explanation posits a geological origin, suggesting they are “venting-tunnels” or “pockmark caverns” created by the catastrophic escape of fluids and gas, such as methane, from the sediment (Hovland and Judd, 1988; Bøe et al., 2012). These events are thought to be triggered by pressure changes that destabilize gas hydrates, leading to a violent fluidization of sediments and the creation of complex subterranean conduit systems (Hovland et al., 2002).

This study presents new observations that challenge this purely geological explanation. During remotely operated vehicle (ROV) surveys in the Central Mohns Ridge area, we discovered similar cave structures that were sometimes occupied by the glacial eelpout (*Lycodes frigidus* Collett, 1879, family Zoarcidae). This benthic deep-sea fish is widely

distributed in the Arctic Ocean and common in the Norwegian Sea, yet little is known about its behavior and life cycle (Møller and Jørgensen, 2000; Mecklenburg et al., 2018). It typically occurs at depths between 475–3580 m in water temperatures of -0.6 to 1.6°C (Hildebrandt et al., 2011; Mecklenburg et al., 2018), and feeds on benthic fauna (Bjelland et al., 2000) while being preyed upon by the Arctic skate [*Amblyraja hyperborea* (Collett, 1879)] (Byrkjedal et al., 2015). Spawning is believed to take place in autumn or winter (Prouse and McAllister, 1986; Hildebrandt et al., 2011).

Fish can significantly alter the seabed topography through impressive digging behavior [e.g. pufferfish (Kawase et al., 2013), tilefish (Twichell et al., 1985), and icefish (Purser et al., 2022)]. The use of burrows and other structures for reproduction and shelter is well documented for the family Zoarcidae (Kendall et al., 1983; Ferry-Graham et al., 2007), and nesting behavior has recently been suggested for another *Lycodes* species (Kennedy et al., 2024). Based on these observations, we present an alternative hypothesis that *L. frigidus* may contribute to the creation or modification of deep-sea caves, along with the first documented case of egg-guarding by this species.

2 Method

During the DeepInsight cruise with RV Kronprins Haakon in March 2025, surveys were conducted in the Greenland and Norwegian Sea as part of the EMINENT project (eminent-project.com). The objectives of the cruise were to map potential seafloor massive sulfide (SMS) resources and associated biology through physical sampling and ROV video surveys. The ROV ÆGIR6000 was deployed, equipped with a 4K video camera, HD cameras, LED lighting, two manipulators, and parallel laser pointers (10 cm separation). The laser pointers, as well as photogrammetry models based on the ROV video material, were used for estimating sizes of objects of interest. The photogrammetry results were compared with the laser distances, and the maximum deviation was found to be $\pm 5\%$. Depending on the model mesh resolution, which is variable throughout the model, we can determine distances down to a few centimeters. The position of the ROV was determined with an accuracy of 5–20 m using an integrated navigation system (HiPAP, DVL, and INS) (Pedersen et al., 2025). The observations presented here are from dives 22 and 23 in the Grøntua and DeepInsight Hill areas. Additionally, similar structures have been observed in ROV video material from previous cruises, conducted by the Norwegian Offshore Directorate (NOD) in 2024 and the EMINENT project in 2023.

3 Results

At approximately 1600 m depth (72.4924°N , 1.5054°E), nine cave-like structures were observed in fine-grained sediments (Figure 1). The cave entrance widths ranged from 26 cm to 170 cm, narrowing inwards, and the caves extended down to depths ranging from 50 to 100 cm (Figure 1F). Importantly, the back-walls

of the caves, where visible, showed no evidence of rupture or fracturing, as laminae in the sediment could be traced continuously in 3D (Figures 1A, F). There were no signs of mineralizations, nor was there any evidence of bacterial mats associated with the caves. A single *L. frigidus* was observed in caves 2 (Figures 1A, B) and 6 (Figures 1D, E), with one guarding a pile of white eggs that were partially hidden behind a rock (Figure 1B). The fish total length (TL) was estimated to 38 cm for the one guarding the eggs and 36 cm for the other fish. Numerous small holes (approximately 1–2 cm diameter) were visible on cave walls and the surrounding seafloor, with some having small anemones protruding from them. Some caves had anemones on the seafloor extending almost as far as could be seen into the cave. Others had dislodged single sponges or piles of different sponges at the cave entrance and inside the cave (Figures 1A, C, D). The sponges represented sponges that were observed nearby in the area, including glass sponges in the family Rossellidae, demosponges in the order Tetractinellida, and carnivorous sponges (family Cladorhizidae), all at various stages of decomposition. Associated with these piles were also living shrimps, amphipods, anemones, and sea stars.

The observation areas from Dive 22 and 23 are part of a several-kilometer-wide area where these caves are present, located approximately 20 km from the Mid-Ocean Ridge (MOR) on oceanic crust aged ~ 3.5 Ma (see Supplementary Figure S1 for an overview map). A cave-like structure from Dive 22, observed at approximately 1200 m depth (72.5159°N , 1.4526°E), was located about 3.2 km north-west of the main cluster of caves from Dive 23 (Figure 2A). The cave entrance was estimated to be 60 cm wide. An ROV manipulator with a camera was inserted into the cave to inspect the interior (Figure 2B). An individual *L. frigidus* (TL 50 cm) was observed on the sediment about 10 m from the cave (Figure 2C). An *Amblyraja hyperborea* (TL 85 cm) was observed about 65 m away (Figure 2D).

4 Discussion

Our observations provide compelling evidence for a biological role in the origin of deep-sea sedimentary caves, challenging the exclusive geological model. The catastrophic fluid escape hypothesis is typically associated with specific geomorphological evidence, such as fields of pockmarks, evidence of sediment fluidization, or distinct vertical conduits leading to horizontal tunnels (Hovland and Judd, 1988). The caves we observed did not appear to be part of a larger pockmark field and lacked the chaotic or eruptive features expected from a violent fluid blowout. Instead, they appeared as stable, established structures, suggesting a more persistent formation and maintenance process. There is no morphological evidence that the caves were formed by fluid escape. Most notably, the caves are deep and have ‘roofs’, contrasting with fluid-escape driven pockmarks that are shallow (large diameter to depth ratio), and venting systems that typically cause cones protruding from the seafloor.

In addition to the morphological criteria, there are no obvious reasons why the holes could be made by fluid escape. The

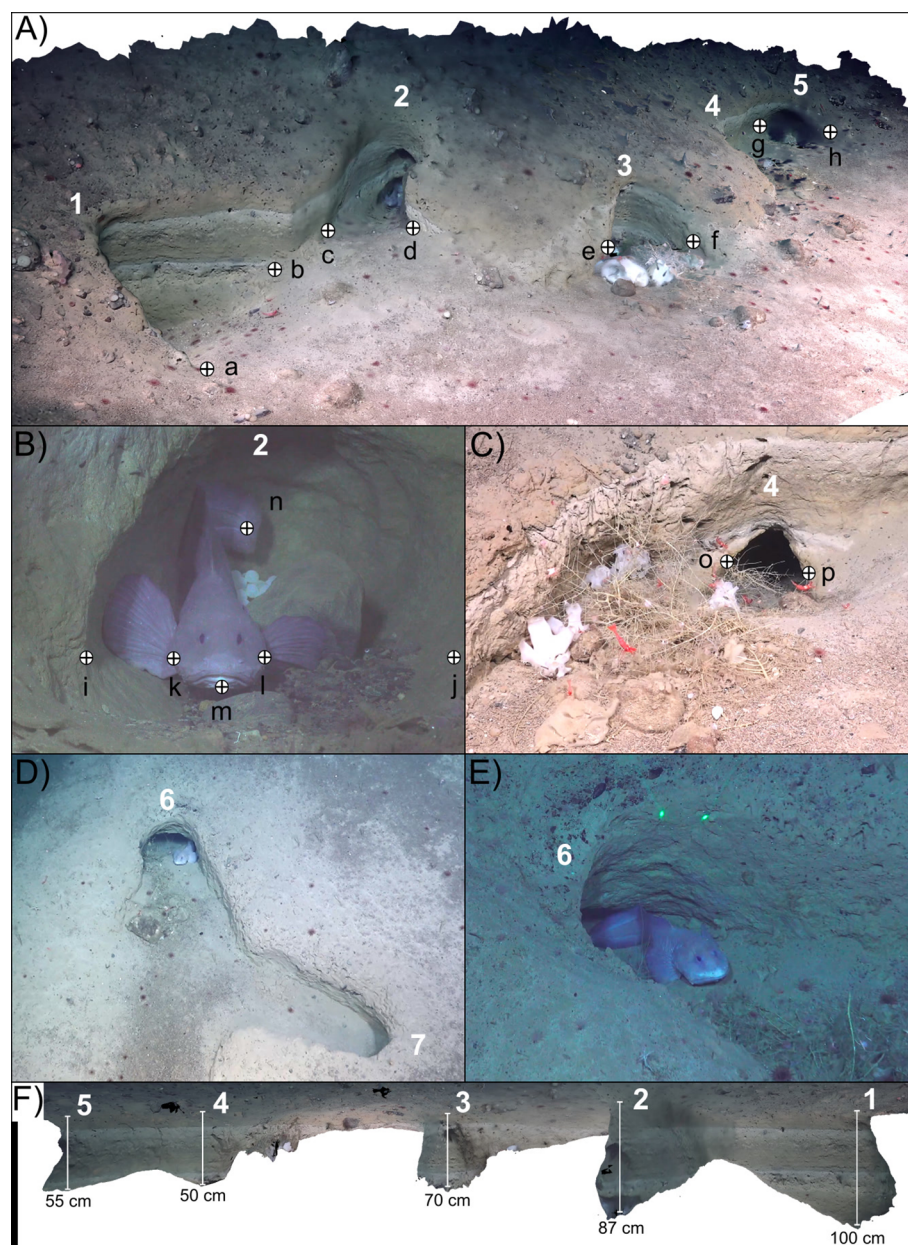


FIGURE 1

Cave-like structures in sediment from Dive 23, at approximately 1600 m depth. The white dots with black crosses labeled with small letters show the reference points used for size estimations. **(A)** Photogrammetry overview reconstruction of cave openings 1 to 5. **(B)** *Lycodes frigidus* guarding eggs in cave 2. **(C)** A pile of dislodged sponges with shrimps and anemones in front of cave 4. **(D)** Two other cave openings in the same area. **(E)** *L. frigidus* in cave 6. **(F)** Photogrammetry-based rear bottom view showing the sedimentary strata and the depth extent of caves 1 to 5. The laser points are separated by 10 cm. The distances obtained from photogrammetry reconstruction are: a-b: 170 cm; c-d: 65 cm; e-f: 72 cm; g-h: 62 cm; i-j: 40 cm; k-l: 10 cm; m-n: 38 cm; c-n: 160 cm; o-p: 26 cm.

sedimentary layer is thin, and crystalline outcrop is common in the area, so compaction-driven porewater extrusion can be excluded. There is no biogenic source for organic carbon, which is the common origin for e.g. methane expulsion in hydrocarbon provinces at shallow to intermediate water depth (Hovland and Judd, 1988; Sen et al., 2019; Gupta et al., 2022). Nor is there any evidence for the bacterial mats typical for cold seeps and hot vents (Sen et al., 2019; Früh-Green et al., 2022). Furthermore, the pressure-temperature conditions lie far within the hydrate

stability field (Schmidt et al., 2022) for hydrocarbon vapor, and CO₂ will be supercritical (Engineering ToolBox, 2001) and thus have a density similar to seawater. Finally, the hydrothermal venting of H₂O, H₂, H₂S, CO₂ and CH₄ typical for the mid-oceanic ridge system, and its associated mineralization and vent fauna (e.g., Pedersen et al., 2010; Früh-Green et al., 2022) bears no resemblance to these off-axis caves.

We propose that *Lycodes frigidus* actively create or modify these caves. This argument is supported by several lines of

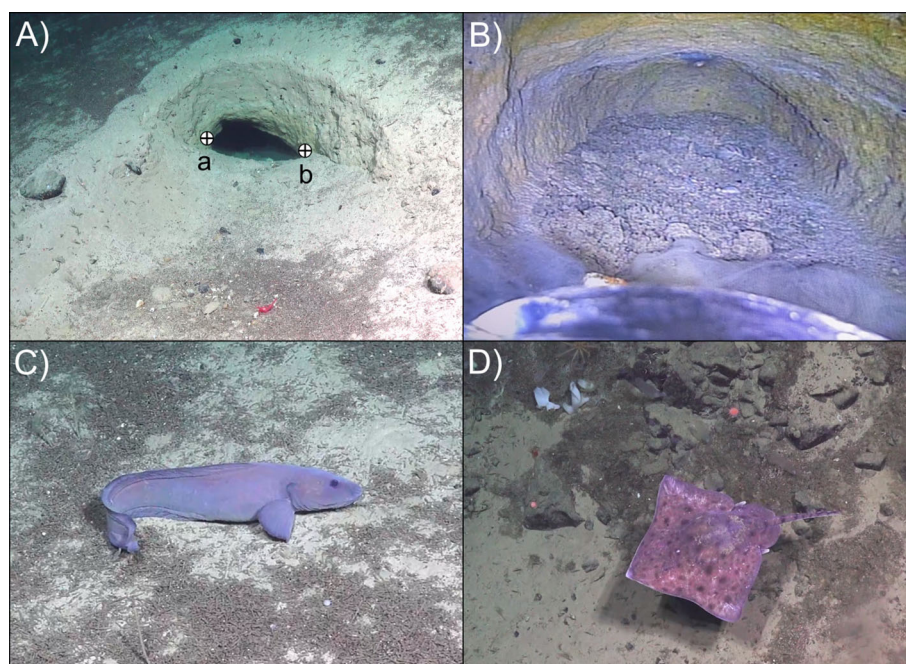


FIGURE 2

Observations from Dive 22 at approximately 1200 m depth. (A) Cave-like structure in sediments where a-b is approximately 60 cm. (B) The inside of the cave structure filmed with an ROV manipulator. (C) *Lycodes frigidus* (TL estimate: 50 cm). (D) *Amblyraja hyperborea* (TL estimate incl. tail: 85 cm; disc width: 48 cm).

evidence. Firstly, the discovery of an individual guarding eggs is a critical behavioral observation. Parental care is known in the Zoarcidae family, and using a secure burrow is a key reproductive strategy for many fish (Blumer, 1982). This is the first direct evidence of such nesting behavior in *L. frigidus*, though it has been inferred for another *Lycodes* species (Kennedy et al., 2024) and observed in other deep-sea species in the family Zoarcidae from the Pacific. Even midwater zoarcids are believed to descend to the seafloor to burrow their eggs in sediments (Ferry-Graham et al., 2007).

Secondly, the caves likely function as a refuge from predation. For example, the Arctic skate (*Amblyraja hyperborea*) is a known predator of *L. frigidus*, being able to consume *L. frigidus* up to 80% of their own TL (Byrkjedal et al., 2015). The two species have overlapping habitats (Hildebrandt et al., 2011; Mecklenburg et al., 2018) and the observation of *A. hyperborea* on Dive 22 confirms that they both occur in the studied area. Given the skate's body dimensions with a broad, thorn-covered disc [$\sim 0.76 \times \text{TL}$ (Kulka et al., 2024)] and TL up to 112 cm (Last et al., 2016), it would be unable to access the narrow cave entrances, providing a secure shelter for the eelpouts and their eggs.

Thirdly, large-scale bio-excavation by fish, while remarkable, is not unprecedented. Male pufferfish in the genus *Torquigener* Whitley, 1930, for instance, use their body and fins to create intricate geometrical structures on the seafloor. These structures serve both as courtship displays to attract females and as nesting sites where the males care for the eggs post-spawning. Notably, these constructions require several days to complete and are

disproportionately large relative to the fish themselves (approximately 2 meters in diameter, compared to a TL of ~ 120 mm) (Kawase et al., 2013; Bond et al., 2020). The tilefish *Lopholatilus chamaeleonticeps* Goode & Bean, 1879 is known for constructing large funnel-shaped burrows on the continental shelf by moving sand and clay, further facilitating burrowing by decapods in the upper part of the burrows (Twitchell et al., 1985). These structures can alter the local seafloor, much like the caves we observed. Given these known analogues, it is plausible that *L. frigidus* is capable of similar excavation. The numerous small surrounding holes, resembling those made by the amphipod *Neohela* S. I. Smith, 1881 [e.g., *Neohela monstrosa* (Boeck, 1861) (Buhl-Mortensen et al., 2016)], likely confirm that the local sediment is amenable to bio-excavation. Caves along the continental slope of Lofoten with similar morphology, and also having decaying biological debris at their entrances, have previously been interpreted to result from fluid escape (Bellec et al., 2010) but may also have the biological origin proposed here. To provide a broader context on the distribution of these structures, we have compiled the known occurrences in a supplementary maps (Supplementary Figure S1). These maps show our primary study sites, additional caves observed along the ROV tracks of Dive 22 and 23, the area previously described by Bøe et al. (2012), and a newly identified location approximately 50 km from the primary sites (termed Cave C in the Supplementary Material), located about 42 km off-axis on oceanic crust aged ~ 7.5 Ma. While a systematic survey has yet to be conducted and our observations only relate to selected, analyzed ROV video material,

this compilation demonstrates that such caves are not isolated features but are found in multiple locations across the region. This wider distribution supports a common biological origin, likely linked to the frequent occurrence of *L. frigidus*, rather than site-specific geological events.

The cave observations documented here not only shed light on how they are made and the parental behavior of *L. frigidus*, but also present other interesting observations such as the piles of dislodged sponges in front of some of the caves. It is surprising to see so many dislodged sponges, and this raises questions regarding the time period between dislodging and our observations. Another question is whether these sponges are found because local currents move them and they get “trapped” by some caves - no obvious pattern could be inferred. Another possibility could be that these sponges are harvested by *L. frigidus* and placed at the cave entrances to hide the cave or for courtship reasons. We also observe that the cave shown in Figure 2B appears to have collected some fluffy material at the cave bottom, including a feather, while the caves that are occupied by *L. frigidus* do not show this fluffy material accumulation, possibly hinting that *L. frigidus* actively cleans and maintains these caves.

To our knowledge, what we present is the first observation of parental care in *L. frigidus* through the use of caves and guarding of eggs. Guarding of eggs by the female or both parents is a known parental care behavior for the family Zoarcidae (Blumer, 1982). Our observation of eggs in March, combined with literature suggesting autumn or winter spawning (Prouse and McAllister, 1986; Hildebrandt et al., 2011) points to a prolonged incubation period of several months. This is consistent with the reproductive strategies of other deep-sea Zoarcids, which have large eggs and slow development rates in cold water (Ferry-Graham et al., 2007). In conclusion, while a geological process may initiate some seafloor depressions, the evidence suggests that the structure, maintenance, and ecological function of these caves could be biologically driven by *L. frigidus*.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

CM: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. AS: Conceptualization, Data curation, Investigation, Visualization, Writing – review & editing. EH: Conceptualization, Project administration, Resources, Writing – review & editing. MJ: Data curation, Writing – review & editing. DS: Conceptualization, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research and/or publication of this article.

Acknowledgments

The authors thank Captain Leif Mork and the crew of RV Kronprins Haakon, the Ægir 6000 ROV team, Chief Scientist Rolf B. Pedersen, and the science party for their support during the research cruise. We also thank Aker BP for supporting this study. We acknowledge the EMINENT project for providing ROV video material and the Norwegian Offshore Directorate for providing both ROV video material and bathymetry data.

Conflict of interest

Authors CM, AS, and DS were employed by the company Bergverk AS. Author EH was employed by the company Aker BP ASA.

The authors declare that this study received funding from Aker BP. The funder, through their employee and co-author (EH), was involved in the study conceptualization (study design), writing - review and editing (preparation of the manuscript), and the decision to submit the work for publication.

Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript. Generative AI was used to improve the language of the manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2025.1666456/full#supplementary-material>

References

- (2001). *Engineering ToolBox*. Available online at: <https://www.engineeringtoolbox.com/> (Accessed June 27, 2025).
- Bellec, V., Thorsnes, T., Rise, L., Bøe, R., Dolan, M., Selboskar, O. H., et al. (2010). "The Deep-Sea off Lofoten, Vesterålen and Troms," in *The Norwegian Sea Floor - New Knowledge from MAREANO for Ecosystem-Based Management* (Skipnes Press), 60–78.
- Bjelland, O., Bergstad, O., Skjæraasen, J., and Meland, K. (2000). Trophic ecology of deep-water fishes associated with the continental slope of the Eastern Norwegian Sea. *Sarsia North Atlantic Mar. Sci.* 85, 101–117. doi: 10.1080/00364827.2000.10414561
- Blumer, L. S. (1982). *A bibliography and categorization of bony fishes exhibiting parental care*. Available online at: <http://deepblue.lib.umich.edu/handle/2027.42/71841> (Accessed May 27, 2025).
- Bøe, R., Bellec, V. K., Rise, L., Buhl-Mortensen, L., Chand, S., and Thorsnes, T. (2012). Catastrophic fluid escape venting-tunnels and related features associated with large submarine slides on the continental rise off Vesterålen–Troms, North Norway. *Mar. Petroleum Geology* 38, 95–103. doi: 10.1016/j.marpetgeo.2012.08.008
- Bond, T., Mueller, R. J., Birt, M. J., Prince, J., Miller, K., Partridge, J. C., et al. (2020). Mystery pufferfish create elaborate circular nests at mesophotic depths in Australia. *J. Fish Biol.* 97, 1401–1407. doi: 10.1111/jfb.14506
- Buhl-Mortensen, L., Tandberg, A. H. S., Buhl-Mortensen, P., and Gates, A. R. (2016). Behaviour and habitat of *Neohela monstrosa* (Boeck 1861) (Amphipoda: Corophiida) in Norwegian Sea deep water. *J. Natural History* 50, 323–337. doi: 10.1080/00222933.2015.1062152
- Byrkjedal, I., Christiansen, J. S., Karamushko, O. V., Langhelle, G., and Lynghammar, A. (2015). Arctic skate *Amblyraja hyperborea* preys on remarkably large glacial eelpouts *Lycodes frigidus*. *J. Fish Biol.* 86, 360–364. doi: 10.1111/jfb.12554
- Ferry-Graham, L. A., Drazen, J. C., and Franklin, V. (2007). *Laboratory Observations of Reproduction in the Deep-Water Zoarcids Lycodes cortezianus and Lycodapus mandibularis (Teleostei: Zoarcidae)*. Available online at: <http://hdl.handle.net/10125/22603> (Accessed May 27, 2025).
- Früh-Green, G. L., Kelley, D. S., Lilley, M. D., Cannat, M., Chavagnac, V., and Baross, J. A. (2022). Diversity of magmatism, hydrothermal processes and microbial interactions at mid-ocean ridges. *Nat. Rev. Earth Environ.* 3, 852–871. doi: 10.1038/s43017-022-00364-y
- Gupta, S., Schmidt, C., Böttner, C., Rüpke, L., and Hartz, E. (2022). Spontaneously exsolved free gas during major storms as an ephemeral gas source for pockmark formation. *Geochemistry Geophysics Geosystems* 23. doi: 10.1029/2021GC010289
- Hildebrandt, N., Bergmann, M., and Knust, R. (2011). Longevity and growth efficiency of two deep-dwelling Arctic zoarcids and comparison with eight other zoarcid species from different climatic regions. *Polar Biol.* 34, 1523–1533. doi: 10.1007/s00300-011-1011-4
- Hovland, M., Gardner, J., and Judd, A. (2002). The significance of pockmarks to understanding fluid flow processes and geohazards. *Geofluids* 2, 127–136. doi: 10.1046/j.1468-8123.2002.00028.x
- Hovland, M., and Judd, A. (1988). *Seabed pockmarks and seepages: Impact on geology, biology and the marine environment* (London: Graham and Trotman). doi: 10.13140/RG.2.1.1414.1286
- Kawase, H., Okata, Y., and Ito, K. (2013). Role of huge geometric circular structures in the reproduction of a marine pufferfish. *Sci. Rep.* 3, 2106. doi: 10.1038/srep02106
- Kendall, A. W., Jennings, C. D., Beasley, T. M., Carpenter, R., and Somayajulu, B. L. K. (1983). Discovery of a cluster of unhatched fish eggs of a zoarcid buried 10 to 12 cm deep in continental slope sediments off Washington State, USA. *Mar. Biol.* 75, 193–199. doi: 10.1007/BF00406002
- Kennedy, J., Gunnarsson, Á., Pampoulie, C., and Wienerroither, R. (2024). Nesting behavior of greater eelpout (*Lycodes esmarkii*), identified through a predation event by spotted wolffish (*Anarhichas minor*). *J. Fish Biol.* 104, 1247–1250. doi: 10.1111/jfb.15648
- Kulka, D. W., Miri, C. M., Atchison, S., and Simpson, M. R. (2024). Sibling Species *Amblyraja hyperborea* and *A. jenseni* in Slope Waters of Eastern Canada: An Ecomorphological Description. *Diversity* 16, 479. doi: 10.3390/d16080479
- Last, P., Sèret, B., Stehmann, M., and Weigmann, S. (2016). "Skates, Family Rajidae," in *Rays of the World* (CSIRO Publishing), 204–363. doi: 10.1071/9780643109148
- Mecklenburg, C. W., Lynghammar, A., Johannesen, E., Byrkjedal, I., Christiansen, J. S., Dolgov, A. V., et al. (2018). *Marine Fishes of the Arctic Region* Vol. 1 (Akureyri, Iceland: Conservation of Arctic Flora and Fauna). Available online at: <http://hdl.handle.net/11374/2116>.
- Møller, P., and Jørgensen, O. (2000). Distribution and abundance of eelpouts (Pisces, Zoarcidae) o. West Greenland. *Sarsia North Atlantic Mar. Sci.* 85, 23–48. doi: 10.1080/00364827.2000.10414553
- Pedersen, R. B., Rapp, H. T., Thorseth, I. H., Lilley, M. D., Barriga, F. J. A. S., Baumberger, T., et al. (2010). Discovery of a black smoker vent field and vent fauna at the Arctic Mid-Ocean Ridge. *Nat. Commun.* 1, 126. doi: 10.1038/ncomms1124
- Pedersen, R. B., Thorseth, I., Stubseid, H., Jæger, M., Voje, T., Fredriksen, R., et al. (2025). *Cruise report - DeepInsight2025. Centre for Deep Sea Research, University of Bergen, Norway, Norwegian Offshore Directorate*. Available online at: <https://www.sodir.no/en/facts/seabed-minerals/order-deep-sea-data/> (Accessed March 07, 2025).
- Prouse, N. J., and McAllister, D. E. (1986). The Glacial Eelpout, *Lycodes frigidus*, from the Arctic Canadian Basin, new to the Canadian ichthyofauna. *Can. field-naturalist* 100, 325–329. doi: 10.5962/p.355644
- Purser, A., Hehemann, L., Boehringer, L., Tippenhauer, S., Wege, M., Bornemann, H., et al. (2022). A vast icefish breeding colony discovered in the Antarctic. *Curr. Biol.* 32, 842–850.e4. doi: 10.1016/j.cub.2021.12.022
- Schmidt, C., Gupta, S., Ruepke, L., Burwicz-Galerie, E., and Hartz, E. (2022). Sedimentation-driven cyclic rebuilding of gas hydrates. *Mar. Petroleum Geology* 140, 105628. doi: 10.1016/j.marpetgeo.2022.105628
- Sen, A., Himmler, T., Hong, W. L., Chitkara, C., Lee, R. W., Ferré, B., et al. (2019). Atypical biological features of a new cold seep site on the Lofoten-Vesterålen continental margin (northern Norway). *Sci. Rep.* doi: 10.1038/s41598-018-38070-9
- Twichell, D. C., Grimes, C. B., Jones, R. S., and Able, K. W. (1985). The role of erosion by fish in shaping topography around Hudson submarine canyon. *J. Sedimentary Petrology* 55, 712–719. doi: 10.1306/212F87C9-2B24-11D7-8648000102C1865D