

Congregation of cusk-eels (*Genypterus chilensis*, Ophidiiformes) at a deep-sea methane seep off Chile

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Congrio Colorado (*Genypterus chilensis* (Guichenot, 1848), Ophidiidae), commonly known in English as the red cusk eel, is often found in rocky habitat and coastal waters along the East Pacific margin. It occurs from northern Peru (5°05' S) to Cape Horn in southern Chile (55°68' S) (Reyes & Hüne, 2012), typically at depths between 2 and 350 m. The species is large, with an average total length of around 60 cm, but attaining lengths around 160 cm (Tascheri et al., 2003), and reaching sexual maturity at 72 cm (Chong & González, 2009). Congrio Colorado is of commercial significance to artisanal Chilean fishers, with catches greater than 2000 tons by 2022 (Servicio Nacional de Pesca y Acuicultura, 2023). It is a menu regular in the seaside restaurants of Chile, and is the subject of a lauded and highly allegorical “Oda al Caldillo de Congrio” [Ode to conger chowder], written by the famous Chilean poet Pablo Neruda (Neruda, 1954). Congrio Colorado is considered a demersal-benthic fish not previously associated with chemosynthetic ecosystems.

A recent oceanographic expedition in October 2024 onboard the RV *Falkor (too)* explored the methane seeps of Central Chile. Multiple carbonate mounds indicative of methane seepage were identified with the aid of shipboard multibeam, sub-bottom profiling, and M3 mapping on the remotely operated vehicle (ROV). The surveys revealed a series of carbonate mounds topped by large *Lamellibrachia* sp. tubeworm bushes offshore of El Quisco, south of Valparaíso at a water depth of 434–438 m. These tubeworms are siboglinid polychaetes that obtain nutrition from symbiotic bacteria reliant on methane and hydrogen sulfide released from within the seep (Dubilier et al., 2008). They form dense three-dimensional structures that provide habitat for many invertebrates and fishes (Tunnicliffe & Cordes, 2021). One of the largest of these tubeworm mounds (37 × 24 m across and approximately 7 m high) was occupied by many *G. chilensis*, tunneled deep among the tubeworms with only their heads protruding

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(Figure 1A,B; Videos S1 and S2). *G. chilensis* were observed to reverse swim into their resting location within the tubeworms (Video S1). Backward swimming in elongated deep-sea fishes, including Ophidiidae, has recently been reported by Priede and Jamieson (2025). Counts of *G. chilensis* made from video of this mound taken on two separate dives on consecutive days (October 17 and 18, 2024) estimated that 46–48 individual fish were present in the one large mound.

The Congrio mound was located at 33.3716° S, 71.8931° W, 18 km from the coast, and in a seafloor area with clear signs of fishing activity. Lost fishing nets, floats, and lines were observed frequently during the dives. Surveys of four smaller seep mounds to the west and seven mounds to the north revealed only three Congrio, indicating that the fish were clearly

congregating at this one large mound. The Congrio congregation was first observed during a morning dive of *SuBastian*; a subsequent midnight dive on the same mound revealed at least one spider crab (*Libidoclaea granaria*, H. Milne Edwards & Lucas, 1842) atop a Congrio conducting what appeared to be a type of feeding behavior that may serve to clean the fish (Figure 2A).

Based on our observations, the Congrio may be using the methane seep tubeworm bushes for protection or simply as habitat, as their behavior may require tunneling. By tunneling among the tubeworms, the fish may also gain protection from fishing activity, which is common in the region. Previous studies have reported that *Genypterus* spp. use hiding places as refuge from predators or to attack their prey (Chocair et al., 1969; Vega et al., 2015). Occasionally, some conger eels were

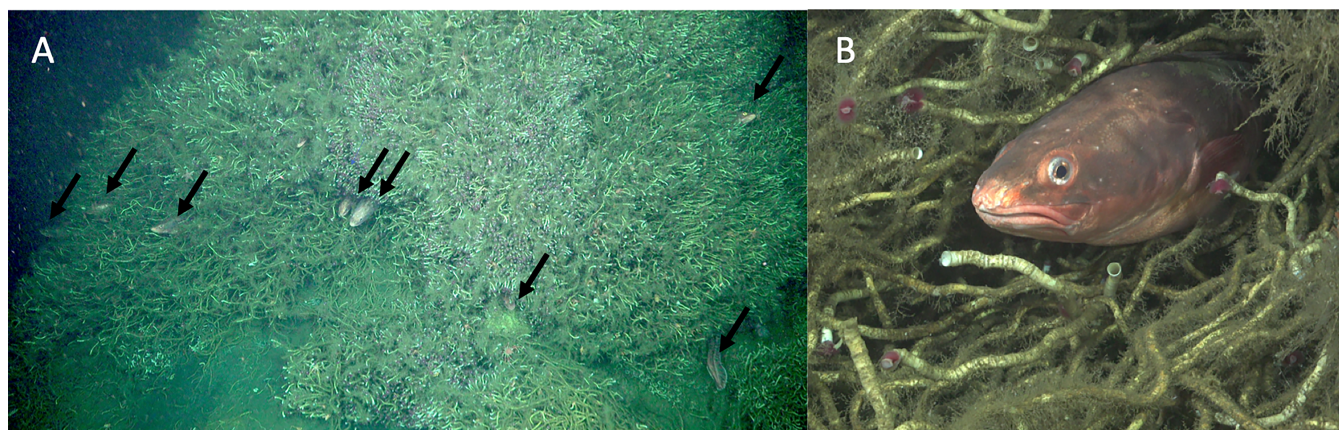


FIGURE 1 (A) A massive tubeworm bush at El Quisco methane seep off central Chile (434 m). *Genypterus chilensis* tunneled into the bush are shown with black arrows. (B) Close-up of protruding *G. chilensis* head. Fuzz covering the tubeworms are hydroids. Images are video screen shots from FK241011, *SuBastian* dive 729, October 17, 2024; 33°37' S; 71°89' W; video credit: Schmidt Ocean Institute.

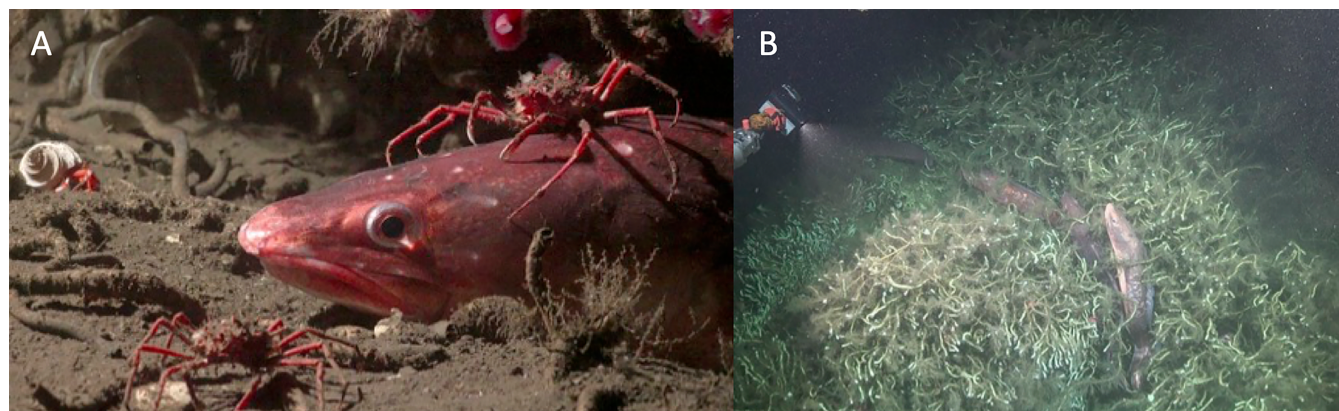


FIGURE 2 El Quisco methane seep. (A) A spider crab (*Libidoclaea granaria*) apparently cleaning *Genypterus chilensis* at El Quisco methane seep. Image is a video still from FK241011, *SuBastian* dive 730, October 18, 2024; 33°37' S; 71°89' W; video credit: Schmidt Ocean Institute and BBC Natural History and Factual Productions. (B) Four *Genypterus chilensis* lined up in a *Lamellibrachia* sp. tubeworm bush. Image is a video still from FK241011, *SuBastian* dive 729, October 17, 2024; 33°37' S; 71°89' W; video credits: Schmidt Ocean Institute.

observed swimming slowly, in some situations, forming a line (Figure 2B) but never consuming tubeworms. *G. chilensis* is known to feed on many species of crustaceans and fish, and a few mollusks (Chong et al., 2006). A preferred diet item is *Grimothea monodon* (red squat lobster), formerly *Pleuroncodes monodon* (Chong et al., 2006), a species that was seen during our dives at El Quisco but is not a seep-obligate. However, no direct feeding by *G. chilensis* was observed during our dives, and it is unknown whether *G. chilensis* feeds on seep species or feeds elsewhere.

The observed aggregation of *G. chilensis* also could represent a spawning aggregation. Spawning aggregation has been reported for *Genypterus capensis* (kingclip) off South Africa (Henriques et al., 2017). A recent finding of significant genetic substructure of Congrio Dorado (*Genypterus blacodes*) within central Chile, and no mixing between southern and central populations despite long-lived pelagic larvae (Córdova-Alarcón et al., 2019), raises questions of spawning aggregation or natal homing (i.e., returning to the site of birth to reproduce), although the latter would be less likely given floating eggs released by *G. chilensis*.

Methane seep mounds and their associated tubeworm bushes are not simply a physical structure; they are also unique geochemical habitats that may present both challenges and opportunities. The sulfidic conditions within the tubeworm bush could act to kill fish parasites; the need for external aid to avoid parasites might also explain the observed spider crab cleaning/feeding activity. Alternatively, the tubeworm uptake of hydrogen sulfide could detoxify the setting, making it more suitable for the fish.

Methane seep ecosystems—populated by animals reliant on chemicals from beneath the sea floor—provide valuable services by sequestering methane-derived carbon that otherwise might enter the atmosphere, and by supporting fish and shellfish of commercial value (Åström et al., 2020; Baco et al., 2009; Grupe et al., 2015; Le et al., 2022). Other commercial fish and shellfish species, including the Patagonian toothfish (*Dissostichus eleginoides*) commonly known as Bacalao, have been associated with Chilean seeps off Concepción (Sellanes et al., 2012). One Patagonian toothfish was observed at El Quisco seeps during FK241011. Several kilometers south of the El Quisco seep site, large numbers of Humboldt squid (*Dosidicus gigas*) were observed in the Maipo Canyon near another large tubeworm mound during this cruise.

There are seven families of fishes known to be associated with vent and seep ecosystems, with zoarcids being the most speciose (Priede, 2017). The only ophidiid reported is *Ventichthys biospeedoi*, from SE Pacific

hydrothermal vents, but it is not described as associated with tubeworms (Nielsen et al., 2006). Several zoarcids, *Pachychara sulaki* and *Pyrolycus jaco*, are associated with methane seeps, with the latter observed nestling in tubeworms at a hydrothermal seep off Costa Rica (Frable et al., 2023). Other fish observed associated with the El Quisco tubeworms include *Antimora* cf. *rostrata*, *Guttigadus kongi*, and a *Psychrolutes* species. The observation of the ophidiid *G. chilensis* congregating in tubeworm bushes is novel and supports the growing recognition that methane seeps provide critical habitat for fisheries species, enhance biodiversity regionally, and thus merit consideration for protection and conservation. Many benthic marine invertebrate taxa were also observed in this ecosystem, confirming that methane seeps enhance benthic biodiversity (Cordes et al., 2010).

The discovery of a key fishery species, *G. chilensis*, in association with methane seeps should induce consideration of protection of seep habitat by Chilean regional and state governments. Commercially valuable groundfish and shellfish are associated with methane seeps off Canada, Washington, Oregon, and California; these areas have been designated as Essential Fish Habitat (meriting protection) by the Pacific Fisheries Management Council (PFMC, 2019, 2023) and are considered as Ecologically and Biologically Significant Areas (EBSAs) by the Canadian Department of Fisheries and Oceans (DFO, 2017). *G. chilensis* is subject to considerable fishing pressure in Chile. Catches have increased from <1000 tons in 1998 to >2000 tons by 2022; 75% of individuals caught are not yet sexually mature (Córdova-Alarcón et al., 2019). Currently, *G. chilensis* is an overexploited resource; however, fishing gear innovations have been developed to improve this condition (Torres et al., 2022). Repopulation plans have been implemented and advances in cultivation have been achieved (Vega et al., 2015). *G. chilensis* has not been evaluated for the IUCN red list, but a related species (*G. blacodes*—pink cusk-eel), which is subject to intense commercial fishing and has experienced significant population declines in Chile, Argentina, and New Zealand, has been listed as “Vulnerable” by the IUCN Red List. Further investigation of the extent to which *G. chilensis* associates with tubeworm reefs is merited to guide conservation and management decisions.

The expedition “Canyons, Seeps and Vents of the Chile margin” brought together seafloor mappers, geologists, microbiologists, oceanographers, marine biologists, ecologists, and taxonomists. Finding the carbonate mounds by mapping led to observations of dense tubeworm bushes, which led to the discovery of *G. chilensis* congregations. The presence of methane

seep fauna was first discovered at El Quisco in 2007 through incidental trawling, and the area was later sampled without visualization in 2010. This expedition is the first to provide direct images and video of the El Quisco seep site, allowing the observation of novel fish behavior at seep ecosystems. Our observations extend the knowledge of *G. chilensis* behavior and ecology to methane seeps, provide new bathymetric and geographic information for the species, and confirm the presence of a flourishing methane seep ecosystem close to the coast that is subject to significant anthropogenic pressures from fishing, navigation, and pollution. The potential importance of the El Quisco seep site for a major fishery species suggests that it deserves consideration as a marine protected area.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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