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note

Mass die-off of the cold-water coral *Desmophyllum dianthus* in the Chilean Patagonian fjord region

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ABSTRACT.—In fjords and channels of the Chilean Patagonia, the solitary cold-water coral *Desmophyllum dianthus* (Esper, 1794) can be found in depths as shallow as 7 m as part of a deep-water emerging benthic community. In the Comau Fjord, one of three Chilean fjords where this species is forming large banks with multiple branched pseudo colonies on the steep rock walls, shallow water coral communities have been monitored for more than a decade. In 2012, a mass die-off was observed along 8.4 km of coast line and at least down to 70 m depth. Only specimens of *D. dianthus* were affected while other organisms, including two more scleractinian species, were not visibly damaged. The event coincides with exceptionally high efflux of methane and sulfide enriched water from cold vents in the rock walls at this site. Due to strongly increased salmon farming activity in the last decade, algae blooms have increased in frequency and intensity as a result of elevated primary production. We hypothesize and provide evidence that either harmful substances from the cold vents or hypoxia following an exceptionally strong algae bloom—or the synergistic effects of both—might have caused the mass mortality.

Only fragmentary knowledge on the biology, population dynamics, ecology, and physiology of cold-water corals exists mainly due to the technical difficulties related to deep-water research. The solitary cosmopolitan deep-water scleractinian coral *Desmophyllum dianthus* (Esper, 1794) occurs as shallow as 7 m in the Chilean Patagonian fjord region. In the northernmost fjords of Patagonia it is the matrix species of dense coral banks below 18 m. It thrives on steep rock walls exceeding 80° inclination (Försterra and Häussermann 2003, Cairns et al. 2005) (Fig. 1A). The species is often accompanied by the two much smaller stony coral species, *Caryophyllia huinayensis* Cairns et al., 2005 and *Tethocyathus endesa* Cairns et al., 2005. *Desmophyllum dianthus* tolerates a temperature range between 4 and 17.5 °C (Naumann et al. 2013). Ambient conditions at the coral banks in Comau Fjord are characterized by temperatures ranging from 8 to 12 °C, pH from 7.4 to 8.4, oxygen

concentrations from 91 to 280 μM L^{-1}, and salinities from 31.2 to 34.0 (Fillinger and Richter 2013, Jantzen et al. 2013, Försterra et al. unpubl data).

Cross-Huinay in Comau Fjord (42°23.460´S, 72°27.445´W) is a long-term study site where benthic dynamics have been monitored for one decade. At this site, sulfide and methane enriched water of ambient temperature has been recorded seeping out of crevices at several locations. These seeps fuel a microbial system with fluctuating amounts of filamentous mat-forming chemosynthetic sulfur bacteria of the genera *Beggiatoa*, *Thiomargarita*, and *Thiothrix* (VA Gallardo, University of Concepción, pers comm) living directly above the crevices. Similar dense mats of the genus *Thioploca* are known to occur in the oxygen minimum zone on the continental shelf off the coast of Chile and Peru (Gallardo 1977). Since 2003, small patches (<1 m × 0.5 m) of dead coral specimens overgrown with white filamentous bacteria (Fig. 1B) situated directly above the seeps have been observed by scientific scuba divers. In 2009, recruitment plates were installed at Cross-Huinay in 20 m water depth; the plates were photographed approximately every 3 mo. On 2 March, 2012, all corals colonizing these plates appeared visually healthy. On 21 April, 2012, these specimens of *D. dianthus* appeared stressed with tentacles drooping and on 18 May, 2012, most specimens were dead with no tissue left on the corallite (Fig. 1C). In Cross-Huinay North (42°23.167´S, 56°72.450´W) more than 2000 *D. dianthus* specimens were checked by scientific scuba divers along a transect line parallel to the coast (40 m length between 20 and 35 m water depth) in July 2013. Only 20 surviving polyps were recorded, which indicates a mortality rate of >99%. Specimens of *C. huinayensis* and *T. endesa* (Fig. 1D) and other benthic organisms such as mussels (*Mytilus chilensis* Hupé, in Gay, 1854), limpets [*Nacella magellanica* (Gmelin, 1791), *Siphonaria lessonii* Blainville, 1827)], polyplacophorans (*Tonicia* sp.), brachiopods [*Magellania venosa* (Solander, 1789)], and barnacles (*Balanus laevis* Brugière, 1789) were apparently not affected.

The area with dead corals extends over 8.4 km along the western shore of Comau Fjord between 42°22.429´S, 72°28.591´W (south of Caleta Soledad) and 42°26.439´S, 72°27.335´W (north of Porcelana), and at least down to 70 m water depth [(scuba diver observations and video records taken by a remotely operated vehicle (ROV)]. During a ROV survey on 11 November, 2004, bacterial mats down to 100 m water depth were observed at Cross-Huinay North (Försterra and Häussermann, unpubl data). In 2012 and 2013, seeping of chemically reducing fluids at Cross-Huinay North was much stronger than previously observed, which manifested in a larger extension and higher number of bacterial mats (before 2012 mats were rare and restricted to areas < 1 × 0.5 m, but since 2012 they were common and each patch at least twice the size) and a strong sulfidic smell at the surface. During ROV observations in October 2012 and March 2013 down to 80 m depth, flocks of filamentous bacteria up to 2 cm length from the same kind as those from the mats and flocks of elemental sulphur were recorded floating in the water; high fluxes of seep water were also evidenced by the blurry effect caused by refraction due to the different density of the venting fluids.

Sulfide and methane concentrations, measured directly from seep fluids venting from crevices at Cross-Huinay North and sampled directly out of the seeps with syringes by scientific scuba divers between 0 and 38 m depth ranged from 17 (SD 10) to 359 (SD 163) μM and from 0.3 (SD 0.03) to 11.4 (SD 15.8) μM, respectively. The maximum values of methane were measured from seeps at 38 m water depth (up to 43

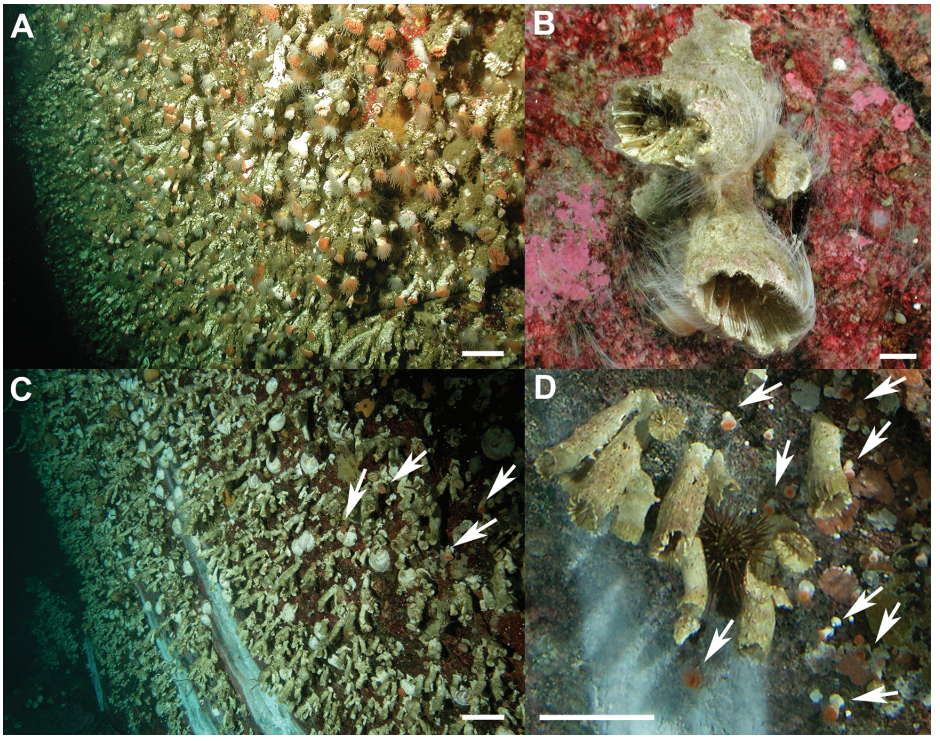

Figure 1. Cold-water coral banks in the Comau Fjord. (A) An intact coral bank at Cross-Huinay North in September 2004. (B) A small, dead pseudo-colony of *Desmophyllum dianthus* overgrown by filamentous bacteria. (C) The coral bank seen in A in July 2013. Note: three patches (white bands) of filamentous bacteria grow above the crevice below the coral bank; surviving *Desmophyllum dianthus* polyps marked with arrows. (D) Specimens of the species *Caryophyllia huinayensis* (arrows) survived. The surrounding polyps of *D. dianthus* are dead. Scale bars: A, C, D: 10 cm; B: 1 cm. Photos: V Häussermann and G Försterra.

μM). At sites without seeps, sulfide values were nearly one order of magnitude lower (up to 1.6 μM), values close to the substrate in vicinity to sites with vents were 2.8 (SD 2.7) μM. Methane in the column water was mostly undetectable, except in water close to the substrate in 100 m depth, where it reached values up to 0.1 (SD 0.06) μM.

Similar patterns were observed for DIC; very high values were measured in vent fluids (3721–11,471 μM) compared to concentrations in water close to the substrate, where DIC clearly originates from organic matter degradation in marine waters (3216–3708 μM).

This indicates that additional inorganic carbon is emerging from crevices with very negative isotopic composition ($\delta^{13}C_{DIC}$) (–10.2‰), which lies closer to the freshwater isotopic signal (–13.8‰; measured in a waterfall close to Cross Huinay). In contrast, the water close to the substrate showed positive $\delta^{13}C_{DIC}$ values (0.3‰–0.4‰). In addition, isotopic evidence indicates that some meteoric water is affecting the hydrothermal water composition. The $\delta^{2}H$ and $\delta^{18}O$ in water from seeps at 38 m water depth (approximately –10‰ and –2‰, respectively) is showing more negative values than deep marine water measured at the control site where no fluids were present (1.5‰ and 0.8‰, respectively). The values fall in a line between very negative values

measured in the waterfall (−45.9 and −7.7‰; for δ^2H and $\delta^{18}O$ respectively) and positive values in deeper fjord waters.

The pH in the fluids was moderately low, with values of 7.4, while it was between 7.8 (Jantzen et al. 2013) and 8.1 (Zapata-Hernández et al. 2014) in water samples close to the substrate. This is consistent with the increase of DIC concentrations in the fluids that probably correspond to weathering carbonatic rocks.

Oxygen close to the seeps (<50 cm) ranged from 158 to 168 μM and salinity varied between 33.3 and 34, the latter slightly higher than near substrate water measurements distant to the seeps (32).

Since Norwegian deep-water corals are often found close to cold seeps, Hovland (1990) hypothesized that they rely upon seep-derived nutrition. Using stable isotopes, Becker et al. (2009) reassessed this hydraulic theory and argued that they rather depend on other seep-related features such as the occurrence of carbonate reefs, suitable for their settlement, and uneven bottom topography.

The salmonid production in the Hualaihué Province, to which the Comau Fjord belongs, increased from 1746 t yr^{-1} in 1995 to 59,219 t yr^{-1} in 2012. Primary productivity has increased during the last two decades by at least a factor of two, probably due to anthropogenic eutrophication caused by aquaculture (Mayr et al. 2014). During the last decade, algae blooms have become more frequent and more intense (Försterra and Häussermann unpubl data). Die-offs of extensive algal blooms can rapidly deplete dissolved oxygen and thus cause hypoxic events (Breitburg 2002). Vaquer-Sunyer and Duarte (2010) showed a synergistic effect of hypoxia and the presence of sulfide in accelerating mortality of benthic macrofauna. We hypothesize that either the outflow of high amounts of harmful substances from the cold vents, or a hypoxic event following an extraordinary algal bloom, or the combination of both have caused the mass mortality.

The uniquely accessible cold-water coral community at Comau Fjord allows us to follow potential recruitment patterns and ecological succession. To investigate the underlying mechanisms that resulted in the coral mortality, laboratory experiments are being conducted to test if *C. huinayensis* and *T. endesa* are less sensitive to severe hypoxia and sulfide concentrations than *D. dianthus*. *Tethocyathus endesa* is already suspected to tolerate low oxygen values since it is known from 200 m inside the oxygen minimum zone off Concepción (Sellanes unpubl data).

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Literature Cited

Becker EL, Cordes EE, Macko SA, Fisher CR. 2009. Importance of seep primary production to *Lophelia pertusa* and associated fauna in the Gulf of Mexico. Deep Sea Res Pt I. 56(5):786–800. http://dx.doi.org/10.1016/j.dsr.2008.12.006

Breitburg D. 2002. Effects of hypoxia, and the balance between hypoxia and enrichment, on coastal fishes and fisheries. Estuaries. 25(4b):767–781. http://dx.doi.org/10.1007/BF02804904

Cairns SD, Häussermann V, Försterra G. 2005. A review of the Scleractinia (Cnidaria: Anthozoa) of Chile, with the description of two new species. Zootaxa. 1018:15–46.

Fillinger L, Richter C. 2013. Vertical and horizontal distribution of *Desmophyllum dianthus* in Comau Fjord, Chile: a cold water coral thriving at low pH. PeerJ 1.e194. http://dx.doi.org/10.7717/peerj.194

Försterra G, Häussermann V. 2003. First report on large scleractinian (Cnidaria: Anthozoa) accumulations in cold-temperate shallow water of south Chilean fjord. Zool Verh Leiden. 345:117–128.

Gallardo VA. 1977. Large benthic microbial communities in sulphide biota under Peru-Chile subsurface countercurrent. Nature. 268:331–332. http://dx.doi.org/10.1038/268331a0

Hovland M. 1990. Do carbonate reefs form due to fluid seepage? Terra Nova. 2:8–18. http://dx.doi.org/10.1111/j.1365-3121.1990.tb00031.x

Jantzen C, Häussermann V, Försterra G, Laudien J, Ardelan M, Maier S, Richter C. 2013. Occurrence of a cold-water coral along natural pH gradients (Patagonia, Chile). Mar Biol. 160(10):2597–2607. http://dx.doi.org/10.1007/s00227-013-2254-0

Mayr C, Rebolledo L, Schulte K, Schuster A, Zolitschka B, Försterra G, Häussermann V. 2014. Responses of nitrogen and carbon deposition rates in Comau Fjord (42°S, Southern Chile) to natural and anthropogenic impacts during the last century. Cont Shelf Res. 78:29–38. http://dx.doi.org/10.1016/j.csr.2014.02.004

Naumann MS, Orejas C, Ferrier-Pagès C. 2013. High thermal tolerance of two Mediterranean cold-water coral species maintained in aquaria. Coral Reefs. 32(3):749–754. http://dx.doi.org/10.1007/s00338-013-1011-7

Zapata-Hernández G, Sellanes J, Mayr C, Muñoz P. 2014. Benthic food web structure in the Comau Fjord, Chile (~42°S): preliminary assessment including a site with chemosynthetic activity. Progr Oceanogr. http://dx.doi.org/10.1016/j.pocean.2014.03.005

Vaquer-Sunyer R, Duarte CM. 2010. Sulfide exposure accelerates hypoxia-driven mortality. Limnol Oceanogr. 55:1075–1082. http://dx.doi.org/10.4319/lo.2010.55.3.1075