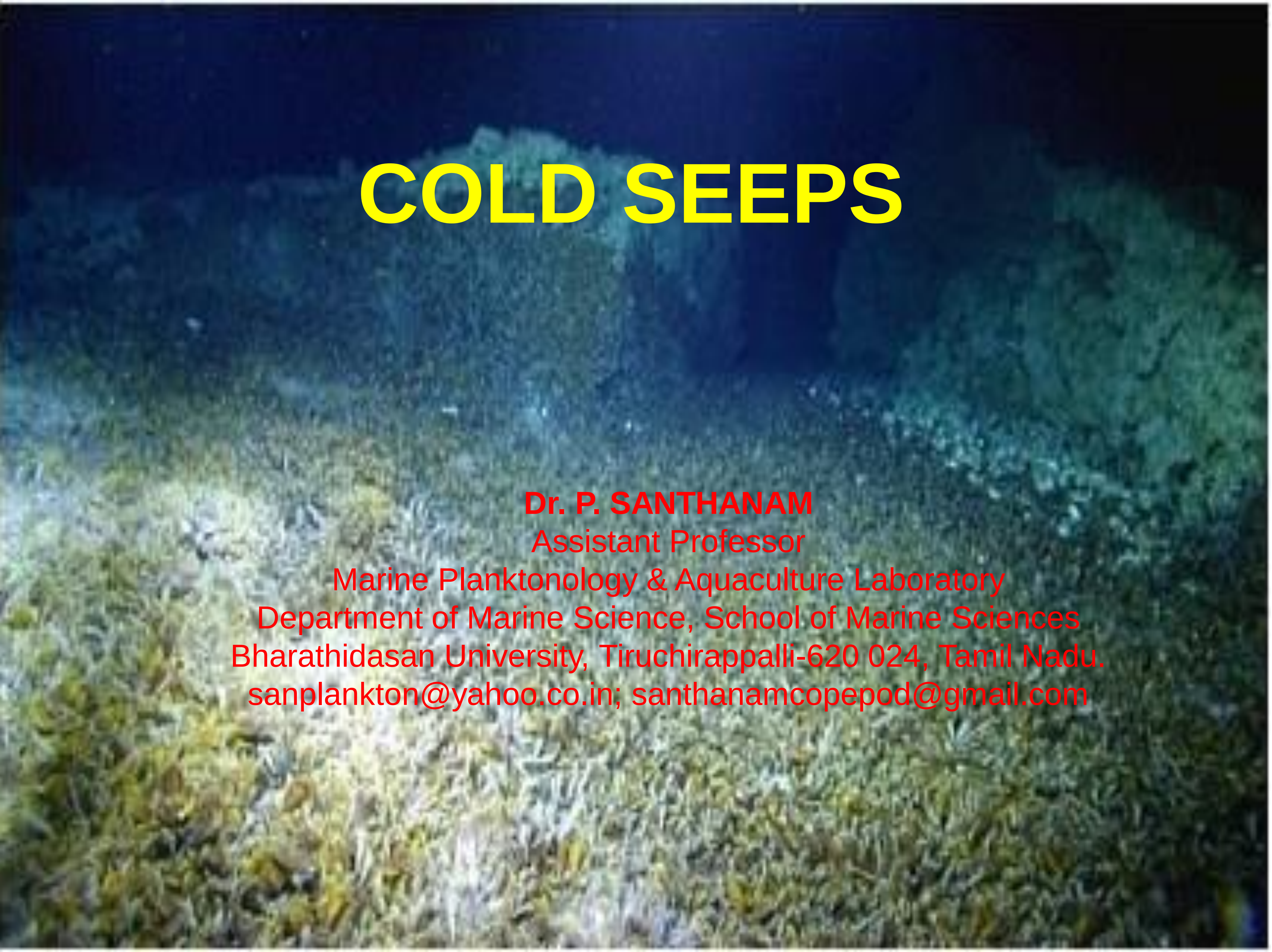

COLD SEEPS

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COLD SEEPS

A **cold seep** (sometimes called a **cold vent**) is an area of the ocean floor where hydrogen sulfide, methane and other hydrocarbon-rich fluid seepage occurs, often in the form of a brine pool.

Cold does not mean that the temperature of the seepage is lower than that of the surrounding sea water.

On the contrary, its temperature is often slightly higher. Cold seeps constitute a biome supporting several endemic species.

COLD SEEPS

Cold seeps develop unique topography over time, where reactions between methane and seawater create carbonate rock formations and reefs.

These reactions may also be dependent on bacterial activity.

Ikaite, a hydrous calcium carbonate, can be associated with oxidizing methane at cold seeps.

TYPES OF COLD SEEPS

Types of cold seeps can be distinguished according to the depth, as shallow cold seeps and deep cold seeps.

Cold seeps can also be distinguished in detail, as follows:

Oil/gas seeps

Gas seeps: methane seeps

Gas hydrate seeps

Brine seeps are forming brine pools

Pockmarks

Mud volcanoes

OIL/GAS SEEPS

A **oil seep** is a place where natural liquid or gaseous hydrocarbons escape to the earth's atmosphere and surface, normally under low pressure or flow.

Seeps generally occur above either terrestrial or offshore petroleum accumulation structures.

The hydrocarbons may escape along geological layers, or across them through fractures and fissures in the rock, or directly from an outcrop of oil-bearing rock.

Naturally occurring oil seep near McKittrick, California, United States

GAS HYDRATE

Clathrate hydrates, or **gas clathrates**, **gas hydrates**, **clathrates**, **hydrates**, etc., are crystalline water-based solids physically resembling ice, in which small non-polar molecules (typically gases) or polar molecules with large hydrophobic moieties are trapped inside "cages" of hydrogen bonded, frozen water molecules.

BRINE POOL

A **brine pool** is a large area of brine on the ocean basin.

These pools are bodies of water that have a salinity three to eight times greater than the surrounding ocean.

For deep-sea brine pools, the source of the salt is the dissolution of large salt deposits through salt tectonics.

The brine often contains high concentrations of methane, providing energy to chemosynthetic animals that live near the pool. These creatures are often extremophiles.

Brine pools are also known to exist on the Antarctic Shelf where the source of brine is salt excluded during formation of sea ice.

Deep-sea and Antarctic brine pools can be toxic to marine animals.


HERMIONE

These craters mark the formation of brine pools, from which salt has seeped through the seafloor and encrusted the nearby substrate.

POCKMARKS

- **Pockmarks** are craters in the seabed caused by fluids (gas and liquids) erupting and streaming through the sediments.

- Pockmarks were discovered off the coasts of Nova Scotia, Canada in the late 1960s by Lew King and Brian McLean of the Bedford Institute of Oceanography. Pockmarks are uncommon on the land surface, and are expected in the ocean.

MUD VOLCANO

- **Mud volcano** or **mud dome** refers to formations created by geo-exuded mud or slurries, water, and gases.
- There are several geological processes that may cause the formation of mud volcanoes.
- Mud volcanoes are not true igneous volcanoes as they produce no lava.
- The Earth continuously exudes a mud-like substance, which may sometimes be referred to as a "mud volcano".
- Mud volcanoes may range in size from merely 1 or 2 meters high and 1 or 2 meters wide, to 700 meters high and 10 kilometers wide.
- Smaller mud exudations are sometimes referred to as mud-pots.
- The largest (man made) mud volcano is "Lusi" in Java, Indonesia, which is 10 kilometres (6 mi) in diameter.

FORMATION AND ECOLOGICAL SUCCESSION

Cold seeps occur over fissures on the seafloor caused by tectonic activity. Oil and methane "seep" out of those fissures, get diffused by sediment, and emerge over an area several hundred meters wide.

Methane (CH_4) is the main component of what we commonly refer to as natural gas. But in addition to being an important energy source for humans, methane also forms the basis of a cold seep ecosystem.

Cold seep biota below 200 m typically exhibit much greater systematic specialization and reliance on chemoautotrophy than those from shelf depths.

Deep-sea seeps sediments are highly heterogeneous. They sustain different geochemical and microbial processes that are reflected in a complex mosaic of habitats inhabited by a mixture of specialist (heterotrophic and symbiont-associated) and background fauna.

CHEMOSYNTHETIC COMMUNITIES

Biological research in cold seeps and hydrothermal vents has been mostly focused on the microbiology and the prominent macro-invertebrates thriving on chemosynthetic microorganisms. Much less research has been done on the smaller benthic fraction at the size of the meiofauna (<1 mm).

Community composition's orderly shift from one set of species to another is called ecological succession:

The first type of organism to take advantage of this deep-sea energy source is bacteria. Aggregating into bacterial mats at cold seeps, these bacteria metabolize methane and hydrogen sulfide (another gas that emerges from seeps) for energy. This process of obtaining energy from chemicals is known as chemosynthesis.

Bacterial mat consisting of sulfide-oxidizing bacteria *Beggiatoa* spp. at a seep on Blake Ridge, off South Carolina. The red dots are range-finding laser beams.

CHEMOSYNTHETIC COMMUNITIES

During this initial stage, when methane is relatively abundant, dense mussel beds also form near the cold seep.

Mostly composed of species in the genus *Bathymodiolus*, these mussels do not directly consume food. Instead, they are nourished by symbiotic bacteria that also produce energy from methane, similar to their relatives that form mats.

Chemosynthetic bivalves are prominent constituents of the fauna of cold seeps and are represented in that setting by five
families: Solemyidae, Lucinidae, Vesicomyidae, Thyasiridae and Mytilidae.

A mussel bed at the edge of the brine pool

CHEMOSYNTHETIC COMMUNITIES

The microbial activity produces calcium carbonate, which is deposited on the seafloor and forms a layer of rock.

During a period lasting up to several decades, these rock formations attract siboglinid tubeworms, which settle and grow along with the mussels.

Like the mussels, tubeworms rely on chemosynthetic bacteria (in this case, a type that needs hydrogen sulfide instead of methane) for survival.

True to any symbiotic relationship, a tubeworm also provides for their bacteria by appropriating hydrogen sulfide from the environment.

The sulfide not only comes from the water, but is also mined from the sediment through an extensive "root" system a tubeworm "bush" establishes in the hard, carbonate substrate.

A tubeworm bush can contain hundreds of individual worms, which can grow a meter or more above the sediment.

"Roots" of tubeworms also provide a supply of hydrogen sulfide from the sediment to the bacteria inside these tubeworms.

CHEMOSYNTHETIC COMMUNITIES

Cold seeps do not last indefinitely. As the rate of gas seepage slowly decreases, the shorter-lived, methane-hungry mussels (or more precisely, their methane-hungry bacterial symbionts) start to die off.

At this stage, tubeworms become the dominant organism in a seep community. As long as there is some sulfide in the sediment, the sulfide-mining tubeworms can persist.

Individuals of one tubeworm species *Lamellibrachia luymesi* have been estimated to live for over 250 years in such conditions.

Symbiotic vestimentiferan tubeworm*Lamellibrachia luymesi* from a cold seep at 550 m depth in the Gulf of Mexico. In the sediments around the base are orange bacterial mats of the sulfide-oxidizing bacteria *Beggiatoa* spp. and empty shells of various clams and snails, which are also common inhabitants of the seeps.

Tubeworms, soft corals and chemosynthetic mussels at a seep located 3,000 m (9,800 ft) down on the Florida Escarpment. Eelpouts, a Galatheid crab and an alvinocarid shrimp feed on mussels damaged during a sampling exercise.

END OF COLD SEEP COMMUNITY

Finally, as cold seeps become inactive, tubeworms also start to disappear, clearing the way for corals to settle on the now exposed carbonate substrate.

The corals do not rely on hydrocarbons seeping out of the seafloor. Studies on *Lophelia pertusa* suggest they derive their nutrition primarily from the ocean surface.

Chemosynthesis plays only a very small role, if any, in their settlement and growth.

While deepwater corals do not seem to be chemosynthesis-based organisms, the chemosynthetic organisms that come before them enable the corals' existence.

This hypothesis about establishment of deep water coral reefs is called hydraulic theory.

DISTRIBUTION

Cold seeps were discovered in 1983 by Dr. Charles Paull on the Florida Escarpment in the Gulf of Mexico at a depth of 3,200 meters (10,500 ft). Since then, seeps have been discovered in other parts of the world's oceans.

They have also been grouped into several biogeographic provinces: Gulf of Mexico, Atlantic, Mediterranean, East Pacific, West Pacific and under an ice shelf in Antarctica.

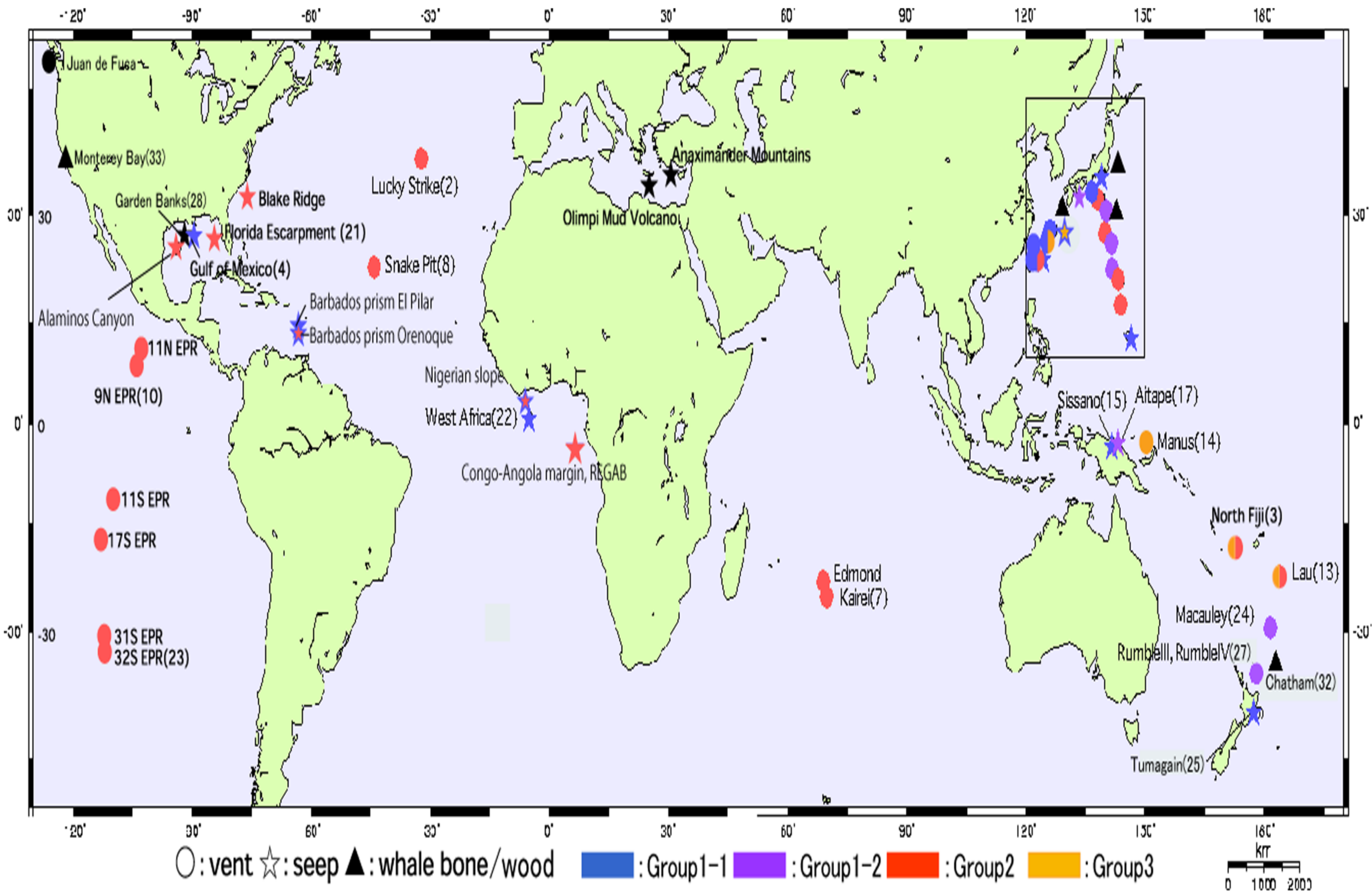
Those localities include the Monterey Canyon just off Monterey Bay, California, the Sea of Japan, off the Pacific coast of Costa Rica, in the Atlantic off of Africa and in waters off the coast of Alaska.

The deepest seep community known is found in the Japan trench at a depth of 7,326 m (24,035 ft). With the recent discovery of a methane seep in the Southern Ocean, methane seeps are now known in all oceans.

Cold seeps are patchily distributed and they occur most frequently near ocean margins from intertidal to hadal depths.

Methane seeps are common along continental margins in areas of high primary productivity and tectonic activity, where crustal deformation and compaction drive emissions of methane rich fluid.

MAP OF SOME COLD SEEPS



ENVIRONMENTAL IMPACTS

Major threats that cold seep ecosystems and their communities face today are seafloor litter, chemical contaminants and climate change.

Seafloor litter alters the habitat, by providing hard substrate where none was available before or by overlying the sediment, inhibiting gas exchange, and interfering with organisms on the bottom of the sea.

In most studies, plastic items accounted for much of the debris, sometimes as much as 90% or more of the total, owing to their ubiquitous use and poor degradability.

Weapons and bombs have also been discarded at sea and their dumping in open waters contributes to seafloor contamination.

Another major threat to the benthic fauna is the presence of lost fishing gear, such as nets and longlines, which contribute to ghost fishing and can damage fragile ecosystems such as cold-water corals.

Environmental Impacts

Chemical contaminants such as persistent organic pollutants, toxic metals (e.g., Hg, Cd, Pb, Ni), radioactive compounds, pesticides, herbicides, and pharmaceuticals are also accumulating in deep-sea sediments.

Topography (e.g. presence of canyons) and hydrography (e.g., cascading events) play a major role in the transportation and accumulation of these chemicals from the coast and shelf to the deep basins, affecting the local fauna.

Recent studies have detected the presence of significant levels of dioxins in the commercial shrimp *Aristeus antennatus*[and significant levels of persistent organic pollutants in mesopelagic and bathypelagic cephalopods.

Climate driven processes and climate change will affect the frequency and intensity of cascading, with unknown effects on the benthic fauna.

Another potential effect of climate change is related to energy transport from surface waters to the seafloor.

Primary production will change in the surface layers according to sun exposure, water temperature, major stratification of water masses, for example and this will affect the food chain down to the deep seafloor, which will be subject to differences in quantity, quality, and timing of organic matter input.

As commercial fisheries move into deeper waters, all of these effects will affect the communities and populations of organisms in cold seeps and the deep sea in general.