Seabed videography using indigenously built low-cost deep sea underwater camera

Ocean covers ~71% (361×10^6 km^2) of the Earth's surface, whereas the deep sea (below 200 m water depth[1]) covering ~66% of the planet's surface is the largest biome on Earth. Seabed hosts thousands of marine species ranging from microscopic algae to the largest creatures on Earth. Apart from the individual species, the seabed consists of large ecological units like cold seep, hydrothermal ecosystems and many more mysteries unearthed. Over the past decades, India has been at the forefront of deep-water studies (like underwater autonomous underwater vehicles (AUVs) and remotely operated vehicle (ROVs)) for diverse scientific missions, which were economically expensive[2]. The economic development of underwater videography devices was a challenging element. However, comprehensive mapping of the deep ocean basins can be assessed by deploying advanced underwater cameras and lights. Hence, it is imperative to encourage novel ecosystems, in conjunction with a geological context, to shed light on the diversity and zonation of biological communities. These communities encompass both autotrophs (chemosymbiont) and heterotrophs. The study of the distribution of species in these ecosystems can help understand the geochemical conditions that control their relative abundances. The cold seep sites are known for concentric zonation of multiple species (such as mussels: *Bathymodiolus* sp. and clamps: *Calyptogena* sp.) and are controlled by the availability of seep fluids such as CH_4 and or H_2S (refs 3–5). The scale of the cold seep ecosystems can extend from a few metres to hundreds of metres[4]. In this context, the CSIR-National Institute of Oceanography (CSIR-NIO) attempted to videograph the cold seep site (Figure 1) located in the Krishna–Godavari basin, Bay of Bengal[6,7] with a low-cost in-house designed underwater camera coupled with an altimeter. The camera boasts a resolution of 4056 × 3040 pixels, equating to 12.3 megapixels. It has an aperture of F2.8, a 3.6 mm lens, utilizes a 1/2.3″ image sensor format and is capable of capturing video in 4 K resolution with 1080 pixels coupled with Nvidia Jetson Nano Developer Kit (4 GB).

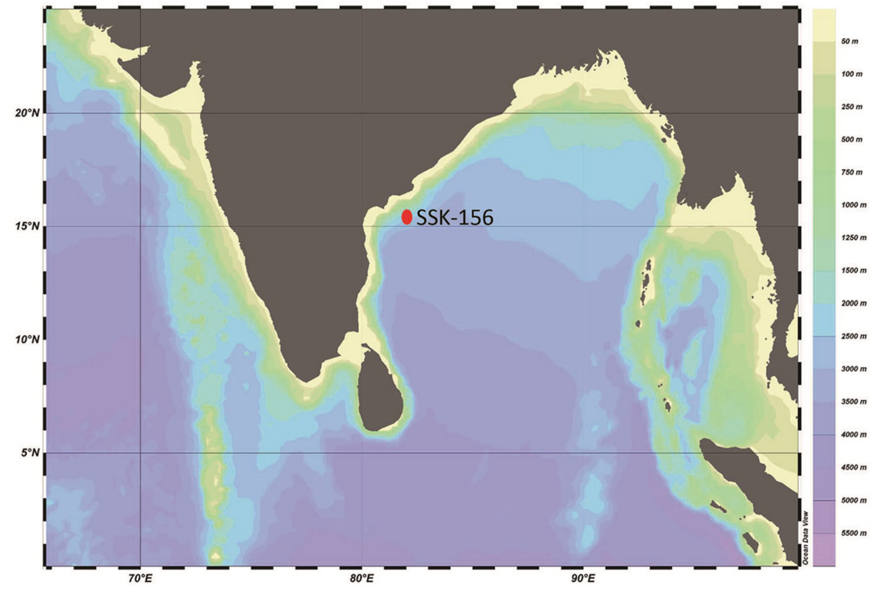

Figure 1. Map showing cold seep location.

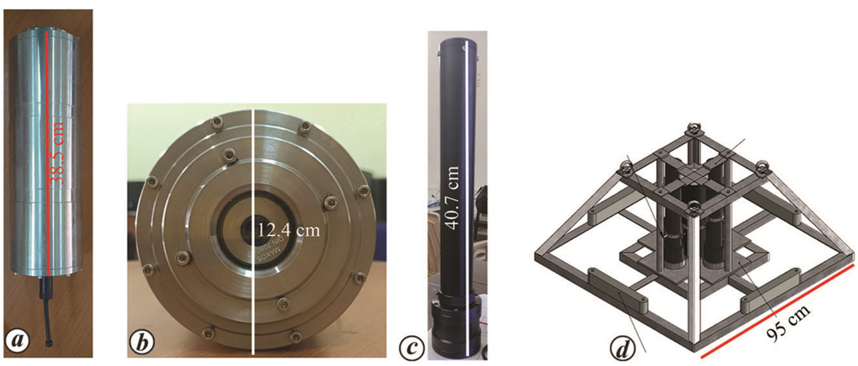

Figure 2. ***a***, Lateral view of underwater camera. ***b***, Front view of underwater. ***c***, LED light. ***d***, 3D-schematic of MS galvanized frame for deploying the underwater camera and lights.

Camera built-up and operations

The underwater camera setup consists of (i) conductivity temperature and depth unit (CTD: Sea-Bird Scientific) coupled with an altimeter (TELEDYNE PSA-916), (ii) an underwater camera (depth rated 2000 m) coupled with four lights. The underwater camera and lights were assembled using an in-house designed mild steel (MS) galvanized frames (Figure 2). The camera assembly was attached to CTD frame using a stainless-steel chain of 10 m length to avoid the possibility of collision of the CTD with the seabed. The altimeter mounted on the camera frame was connected to the CTD using a 10 m long cable. The underwater camera and the lights used for seabed videography were fabricated at Vikra Ocean Tech Private Limited, Chennai, India. The underwater camera and the lights are powered by rechargeable batteries. The triggering of the lights was controlled by a mini-computer using an inbuilt program, based on the deployment depth. The camera hull diameter and length are 124 × 385, made up of SS 316 L material, which is corrosion and high-pressure resistant (Figure 3). The technical specifications of the underwater camera and lights are given in Tables 1 and 2.

The underwater camera and lights were passed through pressure testing up to 200 bar for 60 min at the National Institute of Ocean Technology (NIOT), Chennai. The underwater camera was also tested at different water depths (400, 800, 1200 meters below sea level (mbsl)) for 3 h for pressure tests on-board *Research Vessel Sindhu Sankalp*. For better video quality, the underwater camera assembly was maintained at a height of 1–2 m above the seabed using the altimeter signal. After successful pressure testing at multiple water depths, the underwater camera was deployed up to ~1756 m water depth (Figure 1) and operated for 3 h.

Table 1. Specifications of underwater camera

Camera hull specification	Diameter and length: 124 × 385
	Material: SS 316 L
Image sensor	Sensor model: IMX477
	Shutter type: Rolling shutter
	Sensor resolution: 4056 × 3040 pixels, 12.3 MP
	Image sensor format: Type 1/2.3″
	Pixel size: 1.55 μm × 1.55 μm
	Frame rate: 4K@30fps h.264/h.265
Lens assembly	Model no.: M23390H08
	Optical format: 1/2.3″
	Focal length: 3.9 mm
	Aperture: F2.8
	Field of view (FOV): 75° (H) on Raspberry Pi high-quality camera, 50° (H) on Raspberry Pi V1/V2 camera
	Mount: M12 mount
	Back focal length: 4.49 mm
	MOD: 0.3 m
	Dimension: Φ14 × 18.67 mm
	Weight: 5 g
	Focus distance: 80 mm to infinity
Camera board	Board size: 38 mm × 38 mm
	Hole pitch: Compatible with 29 mm, 30 mm, 34 mm
Interface	MIPI 2-lane/4-lane, D-PHY V1.2
Supply voltage	1.05 V (digital), 1.8 V (interface), 2.8 V (analog)
Chroma	Colour, RGB
ADC resolution	10-bit, 12-bit

Table 2. Specifications of underwater LED light

LED light driver specification	
Parameter	Value
Input voltage	12–20 V
Output power	72 W (max)
Output current	2 A (max)
Output voltage	36 V
Efficiency	>90%
PWM frequency range	5–50 kHz
Dimension	70 mm * 50 mm
LED source specification	
Parameter	Value
Input voltage	34–36 V
Current	350 mA
Lumen/watt	118/W
Power	14 W
Total luminous	1652 lumen
Battery specification	
Parameter	Value
Battery type	Lithium ion
Voltage	4S 12 V
Current capacity	7200 mA
Total power	90 (W)
Charging voltage	12.6 V
Charging current	3A (max)
LED light body	
Body size (dia*length)	90 × 497
Material	Aluminium 6061

Cost of the setup

The cost of a battery-powered underwater camera for 2000 m depth was Rs 199,850 and a set of four batteries that powered underwater 15 W light-emitting diode (LED) lights was Rs 240,000 (Rs 60,000 each) for the videography of cold seep region. With respect to advanced ROVs and AUVs, whose procurement may cost up to Rs 60–70 crore and availability is also difficult, the indigenously built underwater camera and lights setup is a more economical option for seabed videography.

Findings and discussions

Cold seeps are incredibly productive ecosystems where fluids containing CH_4 and H_2S emanate from the surface sediments. This supports chemoautotrophic production, offers a range of ecosystem benefits, such as supplying intricate habitat formations and fostering abundant primary production[8]. Typically, methane seeps are identified by the presence of symbiont-bearing megafauna like tubeworms and mussels (*Bathymodiolus*, *Calyptogena*, *Acharax*, etc.), which creates an ecosystem which predominantly thrives on the seeping fluids (CH_4, HCO_3, H_2S) and sustains a diverse array of other heterotrophic species[9]. Here, we use an underwater videography system to observe the cold seep site[6,10] (TRISUL) located in the Krishna–Godavari basin, Bay of Bengal. The ship was drifting over the cold seep location during the operation. Several organisms including fish, shrimps, bivalves, polychaete tubes, echinoderm and other benthic habitats, were recorded along with radial bioturbation marks, burrows and clusters of unidentified nodules (Figure 4 *a*–*e*). Based on the video recordings, five winged Echinodermata, Dumbo octopus, Cod fish (order: Gadiformes; Family: Macrouridae) with radiating eyes, and sea cucumber were identified. Apart from these organisms, the nodule clusters observed on the seabed may possibly be a concentration of chemosynthetic organism shells in the studied cold seep region (Figure 4 *e*). Occurrence of shell beds of chemosynthetic organisms is common in cold seep regions[11,12]. The observed cluster of nodules from the videos needs further detailed investigation and sampling in the study region. A Siboglinidea polychaete (*Sclerolinum* sp.) cluster was also located in the cold seep site (Figure 5 *a*). Siboglinidea polychaete is a

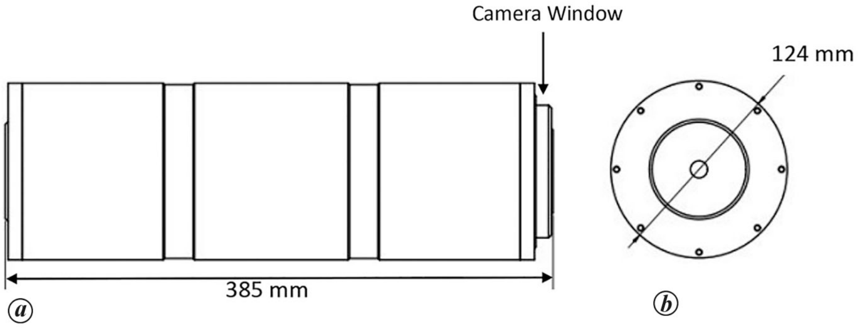

Figure 3. ***a***, Line diagram of underwater camera. ***b***, Front view of the underwater camera.

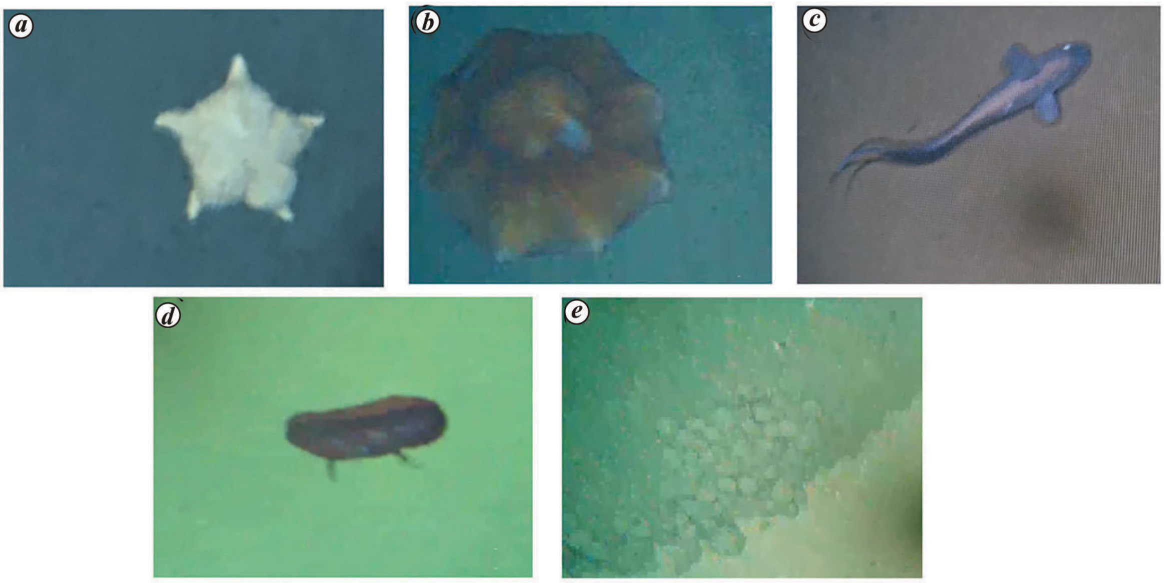

Figure 4. Photographs of multiple demersal organisms recorded using underwater camera operated at cold seep site (1756 m water depth). ***a***, Five winged Echinodermata. ***b***, Dumbo octopus. ***c***, Cod fish (order: Gadiformes; Family: Macrouridae) with radiating eyes. ***d***, Sea cucumber. ***e***, Probable concentration of chemosynthetic shells in cold seep region.

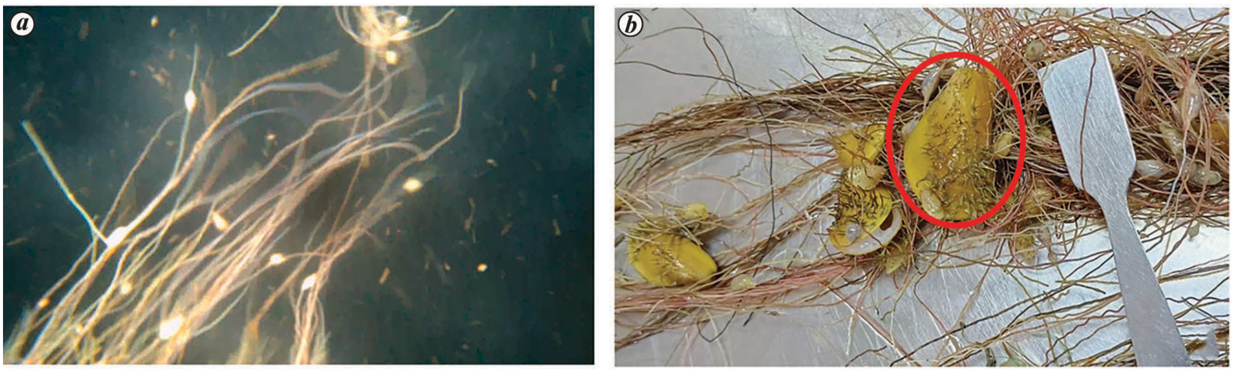

Figure 5. ***a***, Siboglinidae tubes captured by the underwater camera. ***b***, Sampled Siboglinidae tubes. Harboured *Bathymodiolus* specimen on the tubes are indicated by red circle.

mouthless and gutless polychaete hosted in gently contorted chitinous tubes. The diameter of these chitinous tubes is <0.5 mm and ranges from 15 to 50 cm in length. *Bathymodiolus* specimens were harboured to these Siboglinidea tubes (Figure 5 *b*). The *Sclerolinum* polychaete are known to host sulphur-oxidising bacteria in their body[13]. Earlier studies[6] reported a wide range of organisms (chemosymbiotic and heterotrophic) from the Krishna–Godavari basin cold seep regions. The organisms include chemosymbiont Bivalves (genera *Bathymodiolus*, *Acharax*, Conchocele), Polychaetes (Siboglinidae family) and

Gastropods (Provannidae family). The present study enhances potential aspects like envisaging the fishery productivity and trophic structure. It also advocates for further investigating the relationship between deep-sea chemosynthetic ecosystems and economically valuable species. Although we could capture the seabed images along with the demersal organisms, some additional improvements, such as a rise in light intensity and usage of the cruise with a dynamic positioning system, can enhance the video quality. Scaling of the objects will be done in future expeditions. Coupling multiple sensors to monitor various parameters such as depth, temperature, pressure and salinity may give wider information regarding cold seep communities.

Conclusions

The newly developed underwater camera and light assembly is a significant advancement in cost-effective underwater videography and photography. This indigenously built system has been successfully operated in the deep-sea (at 1756 mbsl) on board the CSIR-NIO vessel (*RV Sindhu Sankalp*) and completed one term of investigation of typical targets such as cold seep region. A dynamic positioning system in our research vessel (*RV Sindhu Sadhana*) coupled with additional camera light sources are expected to significantly boost the stability and clarity of visuals for high-resolution seabed and water column operations. This setup has the potential to be commercially operational for multiple underwater studies.

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A note on spodumene bearing pegmatite of Chhotanagpur granite gneiss complex, Garhtara–Dhangaon area, Korba district, Chattisgarh

Garhtara–Dhangaon area is located about 25 km north-east of Korba, Chhattisgarh, T.S.64J/10 (Figure 1). The area lies in the south-western part of Chhotanagpur Granite Gneiss Complex (CGGC) about 25 km south of Tan Shear Zone. Granite gneiss and granitoids containing enclaves of schist, quartzite and amphibolite of CGGC intruded by pegmatitic and aplitic injections are exposed in the area. The pegmatites in the area are simple, homogenous, unzoned, trending northeast–southwest, northwest–southeast and exposed intermittently over an area of 3 km × 1 km. The pegmatites are leucocratic, have a purplish shade, and are inequigranular. The dimensions of pegmatite injections range from 10 to 25 m in length and 1 to 2 m in width, intruding into pink and grey granite.

Petrographically, the granite pegmatites are medium to coarse-grained, showing a hypidiomorphic interlocking texture. They are massive and devoid of any preferred orientation. The pegmatites mainly comprise plagioclase, quartz, perthite and muscovite, which are essential minerals, and spodumene and lepidolite, which are lithium (Li)-bearing mineral phases. Modal percentage composition of rock suggests 28% plagioclase, 22% quartz, 20% spodumene, 12% muscovite, 10% perthite and 8% lepidolite. Spodumene occurs as subhedral tabular crystals showing two sets of perpendicular cleavages and partings (Figures 2 *a* and 3 *a*). Lepidolite occurs randomly as radiating flakes with higher order interference colour (Figures 2 *b* and 3 *b*). The grain size of spodumene and lepidolite ranges up to 1.5 mm and 1.2 mm respectively.

Granite pegmatite samples chemically analysed ($n = 26$) 10 to 10,333 ppm lithium (average of 4499 ppm). Presence of spodumene, lepidolite, columbite, monazite and bearsite (Be–As mineral) in the granite pegmatites are also confirmed by X-ray diffraction (XRD) analysis in Atomic Minerals Directorate for Exploration and Research (AMD), Hyderabad (Figure 4).