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At the heart of the coral triangle in West Papua: an indonesian-french scientific exploration of a white area with closed-circuit rebreathers (eCCR)

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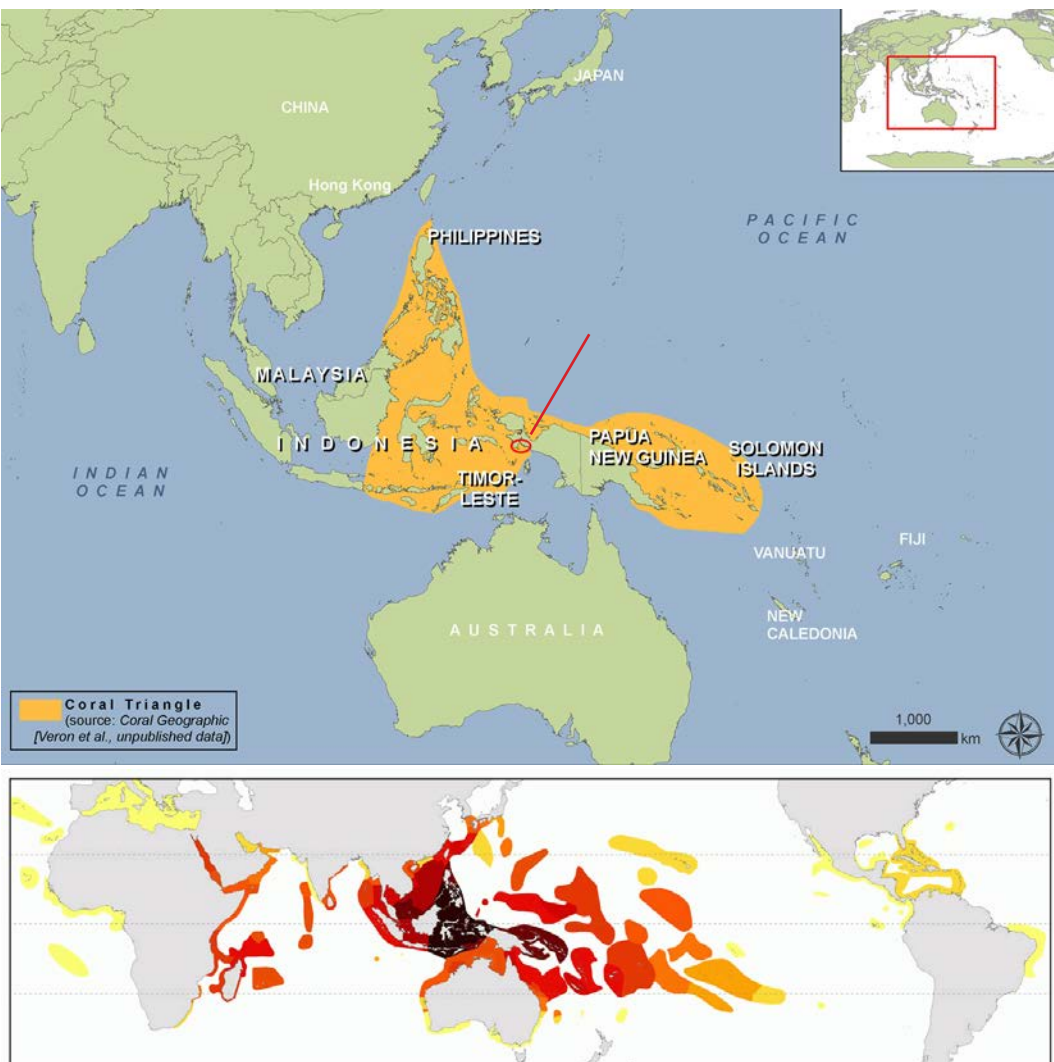


Fig.1 The Coral triangle and the Lengguru area

Fig.2 World map of the coral reef species distribution

(source : Coral Geographic, Veron et al., unpublished data)

Fig.3 Map of the «Lengguru 2014 expedition» diving stations

AIMS

Team of scientific divers including 5 eCCR and 8 open-circuit

Different objectives :

- to explore the reef slope south of Kumawa and Lengguru limestone karsts (exploratory mission)
- to study and sample several biotas : hard corals, gorgonians, echinoderms, mollusks, algae, seagrass (genetic and morphological approaches)
- to observe some groups : reef fishes, rays and sharks, cetaceans (by photoidentification, non-invasive sampling...)
- to describe the habitats

From -100 m to the surface

180 km of coastline from East to West

MATERIALS, METHODS AND ACTION STRATEGY

The 30m length vessel of POLTEK «Airaha2»

and several 4.5m inflatable boats

18 bottles of 50 liters : medical oxygen and helium

350 kg of soda lime

2 compressors for breathing air + 2 oxygen boosters (redundancy)

1 rebreather for spare and training of Indonesian scientists, many spare equipments and consumables

Many bailouts: carbon 6.8 Liters 300 bars, 11 liters S80 aluminium cylinder, all oxygen compatible

Security equipments, communication equipments including embedded satellite personal locator beacons for diver, life and decompressing lines, etc

Several HD camera (photos and videos)

Equipments for observation, measurement and sampling



Use of an unique model of electronical closed-circuit rebreathers (eCCR) : Vision or XPD Inspiration from APDiving

Diluent : gas mixtures for deep dives (40-100m) and air (0-40m)

Manufacture and use of standard gases (diluent: air Tx10/50 or Tx5/75 / bailouts Nx75 Triox40/30 Tx20/50 or Deeper Tx)

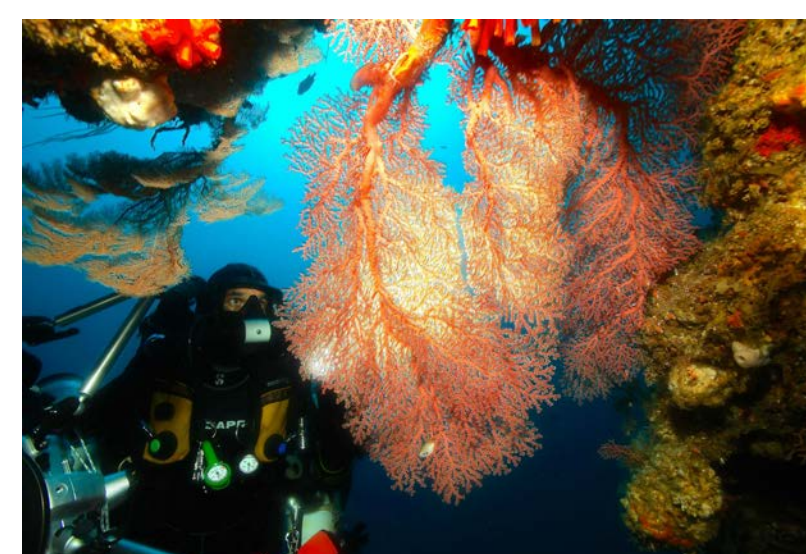
Diving team of 2 or 3 eCCR divers, with mutualisation of the decompression strategy

Training together before the expedition

Diving planification (CCR & bailout, autonomy, what it...)

Careful preparation off the rebreather. Including sealing tests.

Rotation within the team to monitor and rescue on surface : to have an experienced eCCR diver / and a day off (no hyperbaric exposure)



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The Bird's Head Isthmus connecting the Bird's Head Peninsula with the rest of New Guinea is one of the last pristine areas remaining in Southeast Asia. Dominantly covered by limestone karsts, this vast region of **West Papua (Indonesia)** is still a terra incognita. **At the heart of the coral triangle**, the Kumawa and Lengguru limestone karsts and reef slopes are today a **major biodiversity reservoir with high levels of endemism**.

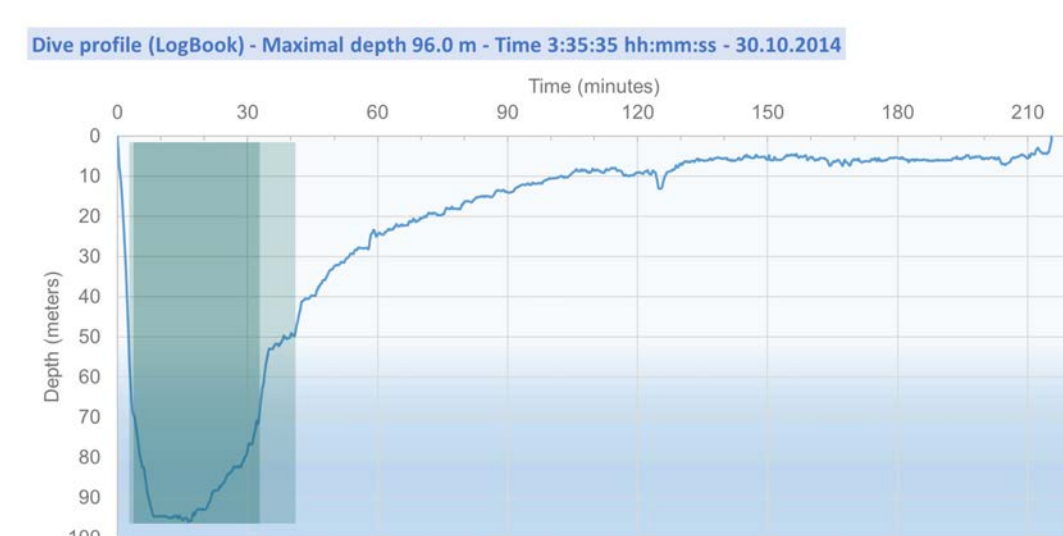
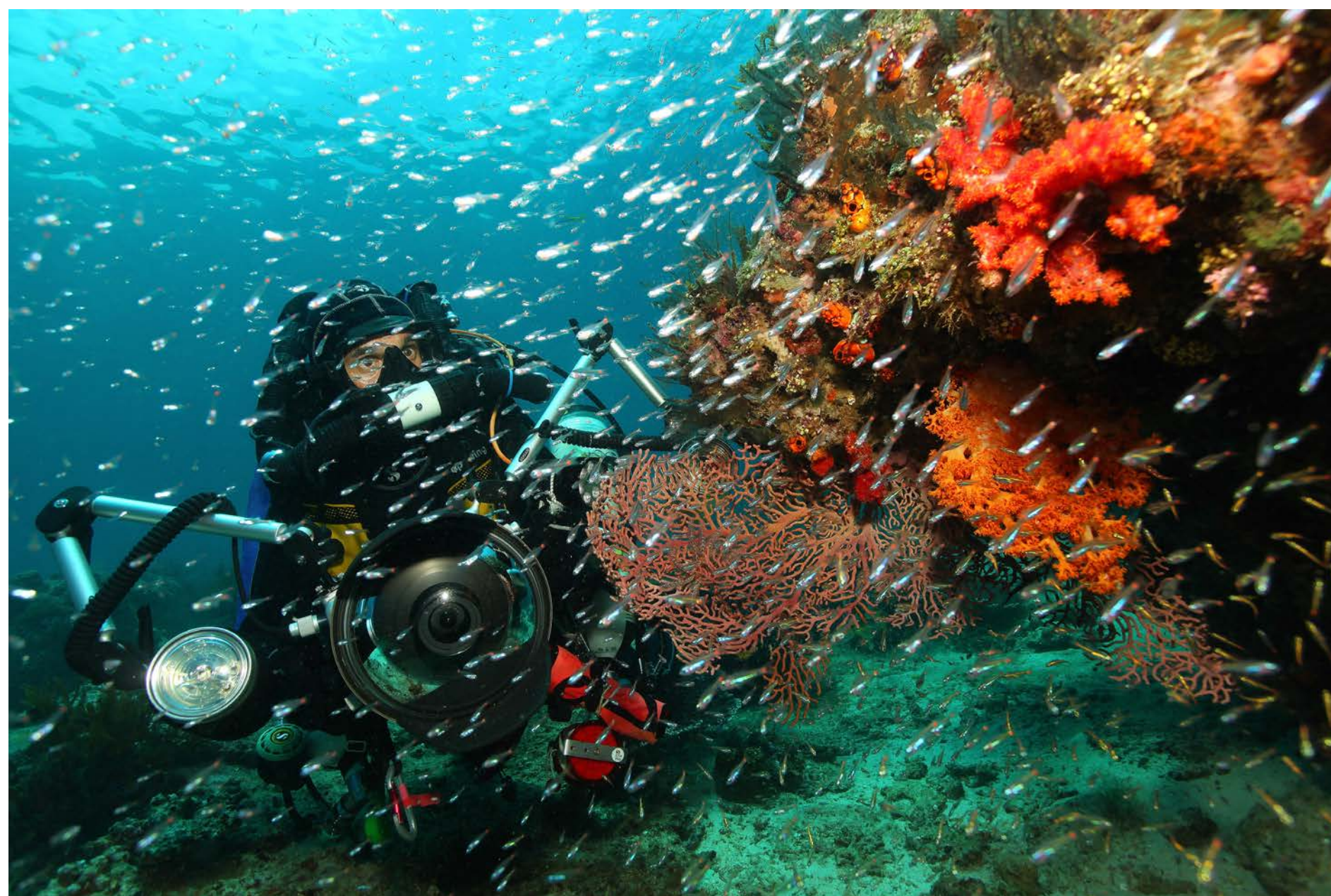
The French-Indonesian 'Lengguru 2014' expedition was headed by IRD and P2O-LIPI, RCB-LIPI and POLTEK. Exploration and sampling effort were concentrated on several reef slopes from -100 m to the surface using **closed-circuit rebreathers (eCCR)** and open circuits. **'Lengguru 2014' expedition was the first French oceanographic campaign organized by a national and academic research organization to use the rebreather**.

The scientific diving operations were made under the responsibility of the French research institute IRD. Nevertheless, the French regulation presently only allows the use of rebreather for recreational uses. The main author participates as an expert for the Ministry of Labor to reform the law with specific applications to scientific purposes. This scientific expedition was therefore permitted in phase advance.

The Lengguru 2014 expedition was organized in complete autonomy for 6 weeks. It required extensive preparation and logistics, as well as some strengthened safety procedures for scientific dives.

Forty vertical transects have been performed from -100 meters depth to the surface, silently with great autonomy and optimized decompression. The exploration of flooded karsts by cave diving has been also possible with rebreather. It does not bubble and offers such autonomy. The **use of eCCR offers together scientific benefits and enhanced diving safety**.

The 'Lengguru 2014' Expedition provided a **science-based assessment of functional, genetic and morphological diversity for several marine biotas** (echinoderms, hard corals, gorgonians, mollusks) with prime importance for biodiversity conservation.



Dive profile of a eCCR scientific diver. Lengguru 2014 expedition (West Papua - Indonesia). Date : 30.10.2014. Station : L019. Location : North face of Palau Sokkos. Maximal depth 96.0 meters. Time 3h 35 mn 35 secondes (or 215 mn). **with scientific work along the vertical transect from -96 to -6m including 40 mn beyond 50m in twilight zone including 29 mn beyond 70m**

ADVANTAGES : ENHANCED DIVING SAFETY...

Significant improvement of the **autonomy** / Gas economy / Increased autonomy reserve

Constant oxygen partial pressure => **Optimization of decompression**

Limitation of thermal losses (**breathing of hot, humid air**) => Decreased risk of decompression accident, no risk of freezing/icing in cold water diving

No bubbles / silence => **Greater attention** to teammates and underwater noises

...AND SCIENTIFIC BENEFITS

Autonomy : **significant increase of the intervention time** : long interventions / reduction of the number of dives required / especially in the 40-50 m zone or more when observations, manipulations or use of instruments require time / realization of vertical profiles from the bottom to the surface

No bubbles / silence => **better fauna approach** / less scare wildlife (behavioral studies, captures, photos and videos...)

Non-destructive approach, respect of biotopes

Exploration of the area up to 100 meters possible due to recyclers and the use of gas mixtures (no accessible to OC divers, ROV and dredges...)

The unexplored twilight zone contains an abundant specific richness totally different from those of the upper zones.

PRINCIPLE OF THE CLOSED CIRCUIT REBREATHER (CCR)

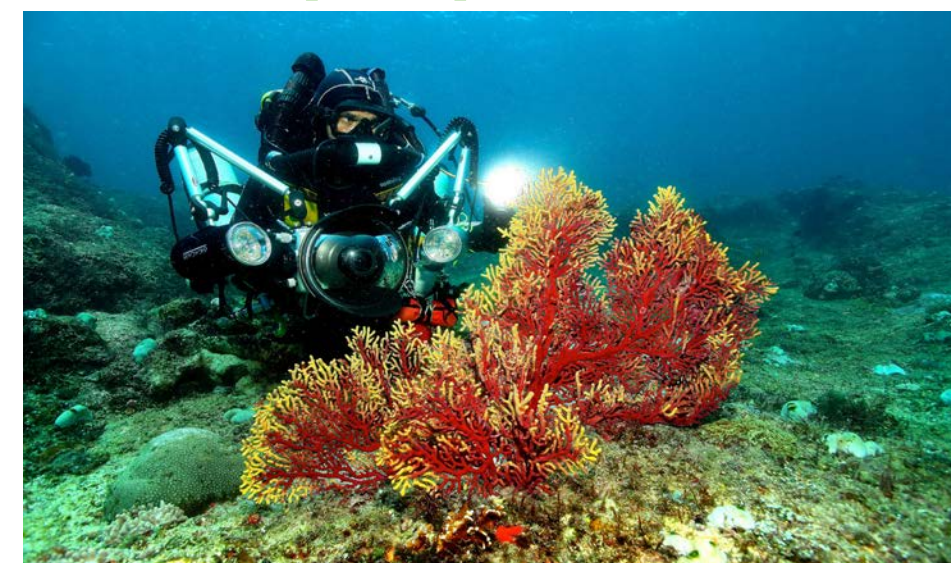
A breathing loop to re-breathe the same gas

Breathing in water at equi-pressure

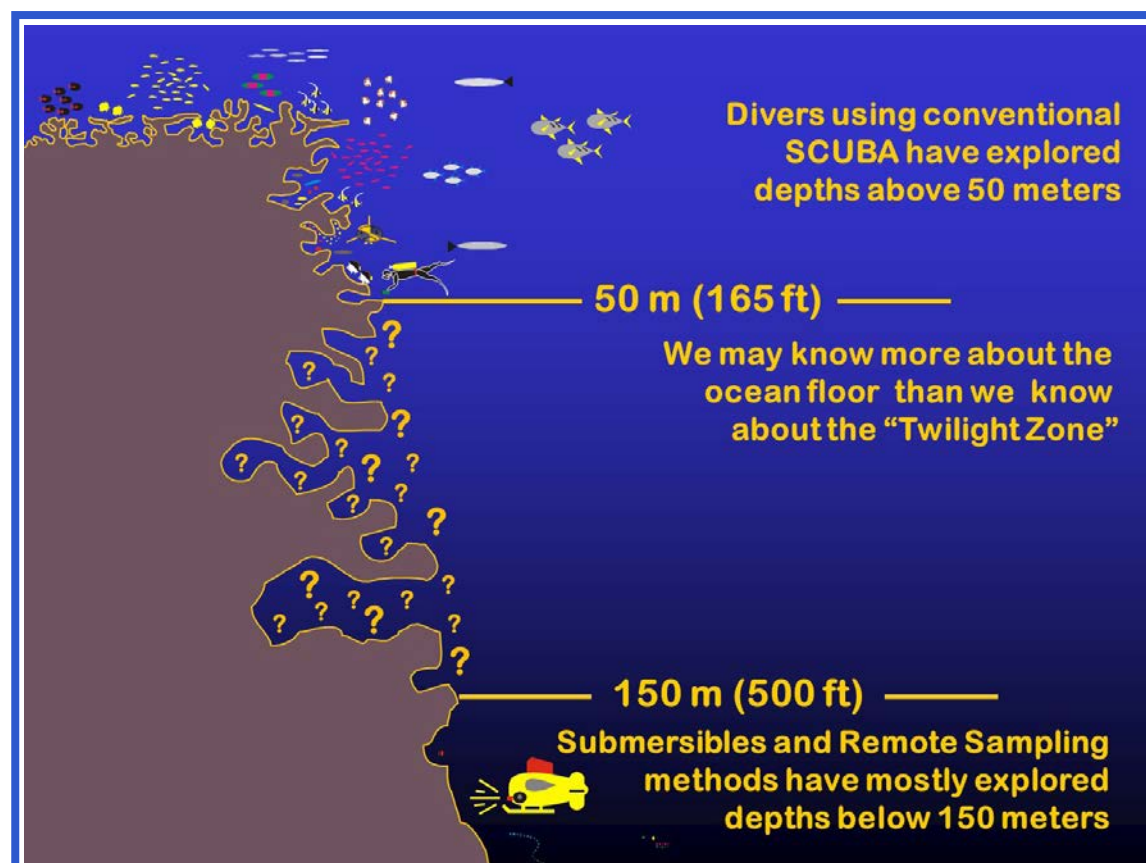
Elimination of CO₂ produced

Supply of metabolized oxygen (O₂)

& Use of air or gas mixtures



Different kinds : pur oxygen rebreather, closed-circuit rebreather (CCR) or semi-closed circuit rebreather (SCR), mechanical or electronical rebreather... Several manufacturers and many CE certified models. Consensus for multi-gas electronical closed-circuit rebreather (eCCR)



The Twilight Zone (source : Bishop Museum, R.L. Pyle)

Around the world, the Twilight zone between 30/50 and 150 meters depth, or Mesophotic Coral Ecosystems" (MCEs), are largely unexplored

CAVE DIVING

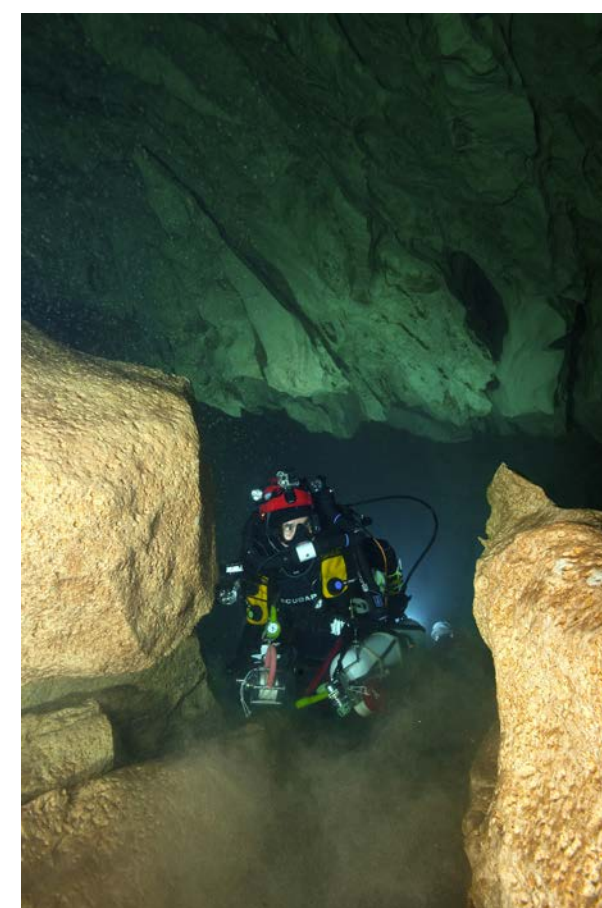
Increased autonomy => Stress reduction in caving

Absence of bubbles => cave dive: less resuspension / decreased risk of collapse of the vault

In Lengguru, the karst is submerged to about -120 m depth. We explored a flooded network upstream of the village of Urusa. Network of labyrinth type, very developed mainly in the horizontal, in brackish water, with a present tide, because connected to the bottom of the Arguni estuary... Near the place of discovery of a blind fish by the Lengguru project in 2010.

Strategy: no performance! Only exploration and study of the network in the limit of 200m from the entrance (with safety/cavern reels).

All the dives for observations, topographic measurements, sampling of organisms are systematically preceded by exploration dives to secure (safety lines).



Incursion limited to 2 experienced divers.

RESULTS & OUPUTS

The use of rebreather in sciences exploration constitutes a new technological paradigm.

- Exploration and sampling effort on several reef slopes (with 40 stations) including the twilight zone (with vertical transects between 100m depth and surface)
- More than 650 specimens collected (hard corals, gorgonian, echinoderms, mollusks, algae, seagrass...)
- DNA barcoding and traditional taxonomy systematically for all samples. Additional and specific molecular markers for some biota.
- Observation and photo identification (several hundreds reef fishes, turtles, cetaceans...)
- A data mangement strategy, with a share scientific database, a photos database of several thousands images.

Besides inventorying organism communities based on DNA barcoding and traditional taxonomy, biologists infer the phylogenetic relationships of sampled taxa along with those originating from peripheral regions for a better understanding of the underlying diversification processes and for helping their conservation.

Such joint scientific venture organized at the heart of the coral triangle and in a global context of biodiversity loss, represents an important contribution to the knowledge of historical and evolutionary processes explaining the unique biodiversity encountered in this still poorly studied region located at the junction of Asia and Australia and at the interface of the Indian and Pacific Oceans. It was also the opportunity to communicate, to increase scientific capacity building, and to raise public awareness through multimedia and photographic exhibitions, seminars and various web supports including a pedagogical program.

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