International Joint Laboratories / Laboratoires mixtes internationaux (IJL / LMI)
Call for projects - 2020

Full application form

Deadline for submission: 24th July 2020

The full form should not exceed 20 pages (excluding annexes)

IJL FACT SHEET

Acronym and full title

SEntinel LAboratory of the indonesian MArine biodiversiTy - SELAMAT (ex-INCOBIO)

(*'Selamat' means 'congratulations' in Indonesian*)

Name, position & email adress of each project leader

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France — **Ir. R. Hocdé – UMR MARBEC : MARine Biodiversity, Exploitation and Conservation** (Univ Montpellier, CNRS, IFREMER, IRD) University of Montpellier, Place Eugène Bataillon, 34095 Montpellier Cedex 5 – France - regis.hocde@ird.fr

Laboratories / Departments leading the project

Please list the laboratories – or similar research a/o teaching structures from the South, and from France (under IRD's umbrella)

Indonesia :
- **Research Center for Oceanography** - Indonesian Institute of Sciences **(RCO-LIPI)**, Ancol Jakarta
- Research Center for Deep Sea - Indonesian Institute of Sciences (RCDS-LIPI) Ambon, Maluku
- Sorong Polytechnic of Marine and Fisheries, Sorong, West Papua (Politeknik KP Sorong) – Ministry of Marine Affairs and Fisheries
- University of Papua – Manokwari, Papua Barat (UNIPA)

France :
- **UMR MARine Biodiversity, Exploitation and Conservation (MARBEC)**, Montpellier & Sète (U. Montpellier, CNRS, IFREMER, IRD)
- UMR Institut des sciences de l'évolution de Montpellier (ISEM), Montpellier (U. Montpellier, CNRS, EPHE, IRD)
- UMR Institut méditerranéen d'océanologie (MIO), Marseille (IRD, U. Aix-Marseille, U. Toulon, CNRS)
- UMR Ecologie marine tropicale des océans Pacifique et Indien (ENTROPIE), (IRD, CNRS, Ifremer, U. La Réunion, U. Nouvelle-Calédonie).

Institutions members of the project

Please list the institutions (to which belong the laboratories member of the project, as mentioned above) that will sign the future IJL agreement with IRD

Indonesia :
- Indonesian Institute of Sciences (LIPI), Jakarta, Indonesia

France :
- French National Research Institute for Sustainable Development (IRD), Marseille, France

Teams / laboratories associated to the project (where applicable)

Please list the laboratories or similar structures from the South and from France/Europe associated to the project :

Indonesia :

- Universitas Gadjah Mada (UGM), Faculty of Geography, Department of Geographic Information Science, Bulaksumur, Yogyakarta
- Institute for Marine Research and Observation, Jembrana, Bali (IMRO), Center for Marine Research, Agency for Marine and Fisheries Research and Human Resources, Ministry for Marine Affairs and Fisheries
- Biak Fisheries Academy, Papua (APB), Ministry for Marine Affairs and Fisheries
- Musamus University Merauke, West Papua (UNMUS)

France :

- UMR Botanique et modélisation de l'architecture des plantes (AMAP), (CNRS,CIRAD, INRAE, IRD, U. Montpellier
- UMR Centre d'écologie fonctionnelle et évolutive (CEFE), (CNRS, IRD, U. Montpellier, INRAE, EPHE, SupAgro, Montpellier
- UMR Patrimoines locaux, environnement et globalisation (PALOC), IRD, MNHN, SU, Paris

Institutions associated to the project (where applicable)

Please list the laboratories or similar structures from the South and from France/Europe associated to the project :

Indonesia :

- Research & Development Agency (RDA), West Papua Provincial Government

Disciplinary field(s)

Marine biology, coral-reef ecology, ethnobiology, population genetics, phylogeography, population genomics, molecular phylogenetics and evolution, eDNA, sustainability science

Key-words

Biocultural interactions, biodiversity, citizen science, cMOOC, data science, DNA barcoding, ecological sentinels, eDNA metabarcoding, elasmobranchs, ecological connectivity, Indo-Pacific, local knowledge, mangrove trees, migratory species, observatory, open data, participatory approaches, reef fishes, research training, scleractinian corals, sentinel species, spawning ecology, toxic microalgae

The **SELAMAT IJL proposal** follows the **INCOBIO IJL project submitted in 2019**, for which we have been invited to resubmit this year.

1. Executive summary of the project (2 pages max.)

Encompassing the heart of the world's marine biodiversity hotspot (the Coral Triangle), the Indonesian archipelago hosts nearly 20% of the world's coral reefs, 5% of seagrass meadows and 20% of mangrove forests. The exceptional level of marine biodiversity and endemism of the Coral Triangle is due to a combination of factors, including the complex marine currents and history of sea level changes, vicariance and dispersal at various spatio-temporal scales, diversity of habitats from karsts to many types of coral reefs, plate tectonics, and stable climate conditions during the Quaternary. However, this diversity is still incompletely known and already threatened by increasing human pressures. Documenting and monitoring the marine biodiversity of Indonesia is therefore crucial to sustainable fisheries management, ecosystem services management, and conservation.

The SEntinel LAboratory of the indonesian MArine biodiversiTy - International Joint Laboratory (SELAMAT IJL) aims to study the interactions between marine biodiversity, environmental changes and human societies through ecological sentinels. Ecological sentinels are species that indicate a qualitative or quantitative change in the properties of the ecosystems of which they are part. Sentinel species and sentinel ecosystems have been chosen according to already available knowledge and to the possibility of sustained observations to act as early warning of the impact of local and global pressures. A variety of species such as microalgae (e.g., toxic algae), invertebrates (e.g., Scleractinian corals), mangrove trees and marine vertebrates including large predators can be viewed as sentinels as defined above. Both local and global environmental stressors may affect their life histories, population dynamics, and genetic diversity. Such disturbances can in turn affect ecosystem services and human health.

The SELAMAT IJL project is based on a strong, long-term collaboration between partners. The project is led by the Research Center for Oceanography - Indonesian Institute of Sciences (RCO-LIPI) in Jakarta and the UMR MARine Biodiversity, Exploitation and Conservation (MARBEC) in Montpellier and Sète (U. Montpellier, CNRS, IFREMER, IRD). The SELAMAT IJL involves 28 scientists from Indonesia including 24 members and 4 associate members, and 23 scientists from France including 10 members and 13 associate members.

The SELAMAT IJL will **set up four functional and sustainable platforms for the study of marine biodiversity and its services in the Indonesian archipelago**:

> **Platform 1: A national observation network for fieldwork and monitoring of sentinel species and ecosystems** -- The IJL plans to strengthen a national research observatory to collect and monitor several sentinel species and ecosystems in the Indonesian archipelago. The IJL will improve RCO-LIPI facilities to study and monitor sentinel ecosystems in the archipelago and acquire environmental data in the long-term.

> **Platform 2: Marine molecular genetic laboratory at RCO-LIPI dedicated to laboratory research and capacity building** -- The Selamat IJL will upgrade facilities of the existing marine molecular genetic laboratory at RCO-LIPI in Jakarta. The samples collected by the RCO's researchers, observation network, and other related research projects will be analyzed in the laboratory for population genetic and genomic research purposes. The platform will also be used for training the Indonesian researchers who involve this project.

> **Platform 3: An e-platform cMOOC for IJL's management, training and capacity building** -- Scientific training is an essential component of the SELAMAT IJL project. Our objectives are to strengthen the research capacity of the Indonesian counterparts and the members of the observation network through the implementation of a connective massive open online course (cMOOC) and specific scientific training needed to support Platform 2.

> **Platform 4: Biocultural interactions platform** -- A platform on biocultural interactions and local knowledge for the study and the monitoring of sentinel species and ecosystems. The platform will build synergies between natural and social sciences and local communities through the long-term observation of sentinel species and ecosystems.

More specifically, the **two main research axes of this 'sentinel laboratory'** are:

1. Sentinel species structure and dynamics throughout the Indonesian archipelago -- We will implement the monitoring of a diverse set of sentinel or key species at different scales from local to regional: sharks (2 species) and stingrays (2 species), Scleractinian corals (with a focus on *Pocillopora* species), mangrove trees (3 species) and toxic dinoflagellates responsible for ciguatera food poisoning CFP (3 genera). During the five years of the project, we will examine the genetic diversity of these sentinel species, their population connectivity, population dynamics and evolution. For this, we will make use of genomics or metagenomics and modelling approaches (Platform 2). These activities will be enforced by a set of transversal and complementary approaches i.e. field interviews, fine scale remote sensing-based mapping of mangrove and coral reef habitats, terrestrial and underwater visual census surveys, long-term acquisition of abiotic parameters, with the support of Platform 1 and using the expertise of local communities (Platform 4). These conditions will guarantee a yearly overview across the archipelago.

2. Sentinel ecosystems interactions and dynamics in three observatory sites -- The sentinel ecosystems are located in long-term observatory sites which the SELAMAT IJL members have also chosen as their main field sites, in link with the IJL laboratory to analyse specimens (Platform 2) and train partners in specific techniques or methods (Platform 3). Integrated fieldwork and research project activities will be funded by external funds to be raised by IJL members. Local communities (Platform 4) will be strongly involved in these observatory sites. Observatory sites were selected according to contrasted levels of anthropogenic pressure and to the contiguity of both coral reefs and mangrove sentinel ecosystems. The proximity of partner marine stations is also a criterion as this will facilitate logistics and training. Six marine stations owned by the Indonesian partners in Ambon, Ancol, Bali, Lampung, Manokwari and Sorong will support the implementation of integrated studies (multiple-taxon approach, remote sensing vs. fieldwork, key environmental indicators).

Making full use of the four platforms and based on specific scientific goals, the SELAMAT IJL will support integrated research activities and research capacities to address the resilience of Indonesian marine socio-ecosystems to global change. Capacity building will be reached through the realisation of focused collaborative scientific objectives. Our project will allow the development of observation of sentinel species and ecosystems through different approaches. This will be of interest to the Indonesian scientific community, and could constitute a blueprint for the development of similar approaches in other countries.

2. Description of the partnership and of the governance of the IJL (2 pages max.)

2.1. Short description of the main and associated partners and of the research teams that will implement the project

MARBEC, MARine Biodiversity, Exploitation and Conservation, is a research unit whose objective is the study of marine biodiversity in lagoon, coastal and offshore ecosystems, at different integration levels, molecular, individual, population and community aspects and the way humans use this biodiversity. MARBEC comprises staff from four French research institutes / universities: IRD, Ifremer, Université de Montpellier and CNRS. MARBEC focuses on three main objectives : 1/ To describe marine biodiversity, understand its dynamics and the functioning of marine ecosystems; 2/ To analyze the impact of anthropogenic pressure on these ecosystems and develop responses scenarii to global change ; 3/ To reconcile exploitation (especially fisheries and aquaculture), and conservation and respond to societal expectations (expertise, innovation, remediation).

RCO-LIPI: The main mission of the **Research Center for Oceanography-Lembaga Ilmu Pengetahuan Indonesia (RCO-LIPI)** is to contribute to maintain and restore the health of Indonesian marine ecosystems in order to provide livelihood for people, and meet societal needs in the context of global change. The RCO-LIPI research objectives are: (1) understanding and valuing marine biodiversity, (2) development of the concept of ocean health to support food sustainability, and (3) understanding the role of ocean under climate change condition.

For the last three decades, IRD has invested considerable effort to develop joint research programs with Indonesian partners from LIPI and KKP aimed at addressing the assessment of the biodiversity in reef twilight zone in West Papua (Lengguru program), the aquaculture potential of local species (Catfish-Asia and Fish-Diva programs), the sustainability of pelagic fisheries in the Java Sea (PELFISH program), the phylogeography of vulnerable elasmobranchs (PARI program), the connectivity of mangroves by oceanic currents in Indonesia (PEPS 'Mangroves' and INDESO programs) and Harmful Algal Bloom programs. Capacity building was provided through several successful PhD projects (Sadhotomo 1998; Gustiano 2003; Sudarto 2003; Kadarusman 2012; Arlyza 2013; Fahmi 2013; Nugraha 2015; Rahmania 2016), and is being continued with I.B. Vimono's current PhD project (2020-2023) (See appendix 13).

The SELAMAT IJL project is based on a strong, long-term, ethical and trust-based collaboration between partners. A general agreement addressing the present organization and objectives of the IJL was obtained in November 2019 during a seminar in Ancol Jakarta between the Direction of RCO-LIPI and the governance of the IJL.

This IJL project takes its roots in a joint research program on marine biodiversity in West Papua, initiated between the RCO-LIPI, the POLTEK KP Sorong, MARBEC and ISEM research units in 2014 through the Lengguru program initiative. The UNIPA, RCDS-LIPI, MIO and ENTROPIE research units joined the venture in 2017. Furthermore, a new CIBSEEA 2020-2023 project on ciguatoxins was recently funded by a MUSE call of the University of Montpellier. It allows the involvement of the franco-indonesian team working on Harmful Algal Bloom (HAB) in Indonesia since 2014, to develop their skills to the ciguatoxins axis proposed in the frame of the IJL. The involvement of local citizens as observers of the environment, announced in the IJL's letter of intent, was consolidated and formalized in 2020.

The Center for Fisheries Research (CFR-MMAF), Agency for Marine and Fisheries Research and Human Resources of the Ministry for Marine Affairs and Fisheries, and its Technical Counterpart Agency, the Research Institute of Tuna Fisheries Denpasar Bali (RITF-MMAF) are invited to join the SELAMAT IJL. Currently, an Implementing Agreement between CFR and IRD concerning research actions on tropical tuna has been validated by both parts and has been signed on 10th July 2020. Even though tropical tuna will not be considered as a sentinel species within the SELAMAT IJL, the platforms of the SELAMAT IJL (observations, surveys in ports, training…) will offer complementary tools and training opportunities to support future projects in partnership with CFR and RITF on tropical pelagic ecosystems.

The SELAMAT IJL involves 28 scientists from Indonesia (15.95 ETP), including 24 members and 4 associate members of LIPI's research center for oceanography (RCO-LIPI) (14 persons), Research Center for Deep Sea (RCDS-LIPI) (4 persons), Sorong Polytechnic of Marine and Fisheries Sorong West Papua (2 persons), University of Papua – Manokwari Papua Barat (UNIPA) (4 persons). Four other institutions are associated: Universitas Gadja Mada (1 person), Institute for Marine

Research and Observation (IMRO) (1 person), Biak Fisheries Academy (1 person) and Musamus University of Merauke (1 person).

In France, SELAMAT IJL will involve 23 scientists (5.4 ETP), including 10 members and 13 associate members, of IRD-UMRs MARBEC (11 persons), ISEM (5 persons), MIO (2), PALOC (2), AMAP (1), CEFE (1) and Entropie (1).

The IJL has enrolled a number of experts, each involved less than 10%, who will provide support for the training of Indonesian counterparts in French laboratories and for the valorisation of data (See appendix 2).

The sex ratio of the IJL team is 50/50 (% of female/male) for the project leaders, 30/70 for Scientific committe, 35/65 for IJL members, 35/65 for Indonesian side and 35/65 for French side.

2.2. Description of the scientific or academic platform upon which the project is based

The aim of the SELAMAT IJL is to establish a set of functional and sustainable platforms for the study of marine biodiversity and its uses in the Indonesian archipelago: (1) a national observation network for the monitoring of sentinel species; (2) a marine molecular genetic laboratory platform dedicated to research capacity building; (3) an e-platform cMOOC for IJL coordination, training and capacity building; (4) a biocultural interactions platform enlightening local knowledge for the study and the monitoring of sentinel species and sentinel ecosystems.

Joint research projects (ongoing and future) that make full use of these four platforms will be developed (see § 3.1.). These projects will address the response of marine sentinel species and ecosystems to global change.

2.2.1. Platform 1: A national observation network for fieldwork and monitoring of sentinel species and ecosystems

The IJL will help build a national research observatory to monitor sentinel species and sentinel ecosystems. The IJL will **strengthen the DIVA network to collect and monitor sentinel species at the scale of the Indonesian archipelago**. Moreover, the IJL will help to **turn some geographically close partner marine stations to study and monitor three observatory sites as "sentinel ecosystems", and to acquire sustained environmental monitoring data**.

Our long-term counterpart Dr. Kadarusman (from Politeknik KP, Sorong) has created a correspondents' network focused on Indonesian aquatic biodiversity. The **DIVA network** involves nearly 50 young lecturers-researchers from ca. 40 Indonesian universities (See appendix 11). The network covers all representative Indonesian bioregions (Fig. 1).

Figure 1. The DIVA network: ca. 50 collaborators from 40 universities and research institutes scattered throughout the 5000-km wide Indonesian-Papuan archipelago and dedicated to the biological sampling and monitoring of sentinel species.

The purpose of the DIVA network initiative in the framework of the Selamat IJL is to coordinate biological sampling of targeted species at the scale of the whole archipelago and to share data acquisition and analysis protocols.

The partner institutions (RCO-LIPI, RCDS-LIPI, Politeknik KP Sorong-MMAF, UNIPA,...) possess several marine stations throughout the Indonesian archipelago. Six of these stations (Ambon, Ancol, Bali, Lampung, Manokwari, Sorong) will support the implementation of integrated studies (multiple-taxa approach, remote sensing *versus* fieldwork, environmental key indicators) of the sentinel ecosystems from three contrasting study areas or 'observatory sites': Java Sea and Sunda Strait, Bali Sea and West Papua (see Fig. 2).

The laboratory will help to initiate a pool of mutualised field instruments and sensors. This pool will be rapidly supplemented by additional acquisitions through the support of related research projects. The objective is to record key abiotic factors such as coastal seawater temperature. The underwater sensors will be autonomous in energy and memory. Some will be mobile for easy uses on shorter periods on the field (e.g. vertical profiles from a boat, deployed with divers). Others will be fixed for longer periods (several months) and replaced regularly. As a first step, Seawater temperature and pressure sensors will be acquired, either as mini-tags or CTDs sensors. In a second step, turbidity, salinity and dissolved oxygen sensors will be implemented.

2.2.2. Platform 2: Marine molecular genetic laboratory at RCO-LIPI dedicated to laboratory research and capacity building

The Selamat IJL will **upgrade facilities in the Marine molecular genetic laboratory** of RCO LIPI in Ancol, Jakarta. Upgrading laboratory equipment will be made according to the needs and will be supported by external funds of the IJL. All chemical materials and consumables used for this platform also will be covered by this project. The platform **will allow the collaborative research members in this project to analyse the historical samples collected by the RCO's researchers, by the observation network, and by the other related research projects**. The platform will also be useful as laboratory **training for the project members**. Through this platform, the IJL will develop and improve science and technology capacity of the Indonesian scientists in marine molecular genetics.

In 2017, Lengguru expedition funds were allocated to donate several lab equipments to the Marine Molecular Genetic Laboratory of RCO LIPI in Ancol, Jakarta. We initiated the acquisition of large-scale genomic DNA extraction facilities. With now a capacity to process an average of a thousand samples per week, the platform will be the operational center for our joint research activities. Several young researchers from RCO-LIPI and technical staff from the other institutions are dedicated to the platform, ensuring its long-term viability. The IJL will support the ongoing activities of the laboratory for continuous deposit of original and mirror (i.e. shared among partners) DNA extracts towards a **DNA Marine Biobank** initiative led by RCO-LIPI. Several activities such as DNA sequencing and genotyping analysis will be conducted in the laboratory through a specific laboratory training program to allow the Indonesian marine researchers to understand the complete procedures in molecular genetic studies including collecting tissue samples, extracting, PCR, sequencing and genotyping procedures. Further DNA sequencing and genotyping most of the samples collected from this project will be analyzed through available DNA sequencing and genotyping service companies to optimise budget capacities of the research programs involved in the IJL. Specific training sessions will be organized for all researchers of the platform with the aim to standardise all methods used for the acquisition and treatment of molecular data. Based on Indonesian regulation, all genetic sample and sequence data resulting from this platform belong to Indonesia and will be possible to be shared with the counterparts under a specific material transfer agreement.

2.2.3. Platform 3: An e-platform cMOOC for IJL's management, training and capacity building

Scientific training is an essential component of this IJL project. Our objectives are to strengthen the research capacity of the Indonesian counterparts of the IJL and of the members of the DIVA network through (1) the implementation of a connective massive open online course (cMOOC; Cisel & Bruillard 2012) and **(2) specific scientific training on Platform 2**.

Concretely, this cooperating capacity building and research initiative will operate through a specific website and regular cMOOC on a variety of subjects including experimental design, protocols and methodology, data acquisition, analysis and sharing, scientific writing, publication design, ethical research guidelines, scientific seminars, etc. All cMOOC courses will be presented in a synthetic and pedagogic frame giving to each participant the possibility to reuse the support for its own teaching courses. The functionalities of a cMOOC enable anyone to learn from each other, starting from the projects and knowledge that are built up in order to achieve each participant's initiatives and aims. The cMOOCs are part of a reinforced social approach (see Appendix 10. *What are the differences between a cMOOC and an* *xMOOC?*). The cMOOC will also include specific **seminars and scientific workshops** which will be conducted at RCO-LIPI with its complete facilities of the marine molecular genetic laboratory and the nearby marine station. The seminars will be shared online.

cMOOC, seminars and scientific workshops will also be used to animate the IJL. Regular progress reviews will be performed, including the organization of the yearly SELAMAT IJL day's in RCO-LIPI Ancol.

2.2.4. Platform 4: Biocultural interactions platform: building synergies between academic and folk sciences through the long-term observation of sentinel species and sentinel ecosystems

The purpose of this fourth platform is to mobilize expertise on resources that are highly valued by local inhabitants of the observatory sites, resources that will also be chosen because they reveal ongoing transformations.

Parallel to the work carried out in biology, ecology and genetics on sentinel species and ecosystems that make up the observatory sites, the platform will foster holders of local knowledge to combine their efforts with those of researchers, to better diagnose the ongoing changes in the observatory sites and take part effective adaptation strategies (Lewandowski et al 2015).

The commitment of this knowledge has a twofold objective: on the one hand, to fill the knowledge gaps through a combination of academic and non-academic expertise and, on the other hand, to develop scenarios for maintaining biodiversity in its dual biological and cultural component. As biological and cultural diversity are strongly associated, they must be mutually preserved. For this reason, it is necessary to involve traditional knowledge holders in the assessment of the state of biological diversity and in the elaboration of protocols for monitoring the impact of change on sentinel resources, and in the conception of indicators to be incorporated in biodiversity management plans (Boakes et a. 2016).

The biocultural interactions platform will be initially assessed in two specific regions (West Papua, and Sunda Strait) before being possibly extended to Lombok. Taking fully consideration of the sensitive political context of West Papua, the IJL will closely collaborate with the provincial Research & Development Agency (RDA), which shall mediate a transparent and adequate dialogue between the researchers and their traditional homologues among local communities. The platform will focus its attention on coastal ecotones (coral reef, wetlands, mangroves, estuaries, deltas, brackish waters). These convergence zones, which are spills of pollutants from the mainland, but also the receptacle of marine debris of all kinds, are particularly sensitive to the changes taking place. They are also privileged zones for the exploitation of fishery resources by coastal populations.

The platform will pay particular, but not exclusive, attention to "on-foot" fishing practices from the shore, which target sentinel species and ecosystems. a particularly interesting corpus of resources: reef fishes, molluscs, crustaceans, annelids and mangroves. A special emphasis will be placed on Molluscs which are indeed key bioindicators of coastal change and water quality.

In full adequacy with the Nagoya protocol, the active participation of the holders of a traditional ecological knowledge will proceed along an 'extreme' citizen science approach. Extreme citizen science aims to bring together scholars from diverse fields and indigenous communities to run a citizen science project that will help the local communities deal with issues that concern them. In essence, such an approach is obviously pending on the Free, Prior and Informed Consent (FPIC) of the holders of the mobilized traditional knowledge. The provided methodology and set of tools can be used by any user, regardless of their background and level of literacy, to collect, assay and act on information by using adaptable scientific methods. This joint approach is particularly efficient for monitoring environmental change (Devictor et al. 2010).

The philosophy holds on participatory sensing, monitoring and modelling activities, with communities deciding what measurements are taken and how they are analyzed so that they can participate in and lead subsequent decision-making and actions. Such approach ambitions to change the current state of the art by developing technologies to enable lay people to understand and manage their environment with established scientific methods and models.

These resources lend themselves particularly well to an extreme citizen science initiative:

- They fall into the category of "under-utilized food resources" in the sense that they have been exploited for a very long time by many indigenous peoples, but have rarely been the subject of systematic studies.

- They are a 'cultural keystone species'. A resource is defined as such when the society in question elaborates a system of tales, beliefs and practices around it, the study of which would make it possible to approach the cultural identity of the society through its relations with its natural environment. Cultural keystone species also play a role in the transmission of knowledge and the proper accomplishment of founding rituals. There is continual resurgence of the evocation of a cultural keystone species in common speech (linguistic profusion and large lexical field). Cultural keystone species contribute to the development of a more holistic perspective of ecosystems and provide us with one more avenue through which to emphasize the importance of species and habitats to particular peoples (Dounias & Mesnil 2007).

- These organisms are bio-indicators whose study will help addressing the impact of changes on the ecotones to which these organisms rely upon: they offer a broad spectrum of differentiation in terms of mobility (sessile *versus* vagile) and area of distribution (endemic *versus* regional distribution); they act as ecotone natural engineers as recyclers, absorbers and natural accumulators; finally, they are sensitive to changes in the physico-chemical conditions of the environment.

When these resources are further recognized as bio-indicator species by ecologists, they provide fertile ground for closer collaboration between scientists and traditional knowledge holders because they consider exactly the same object, yet through distinct cultural prisms.

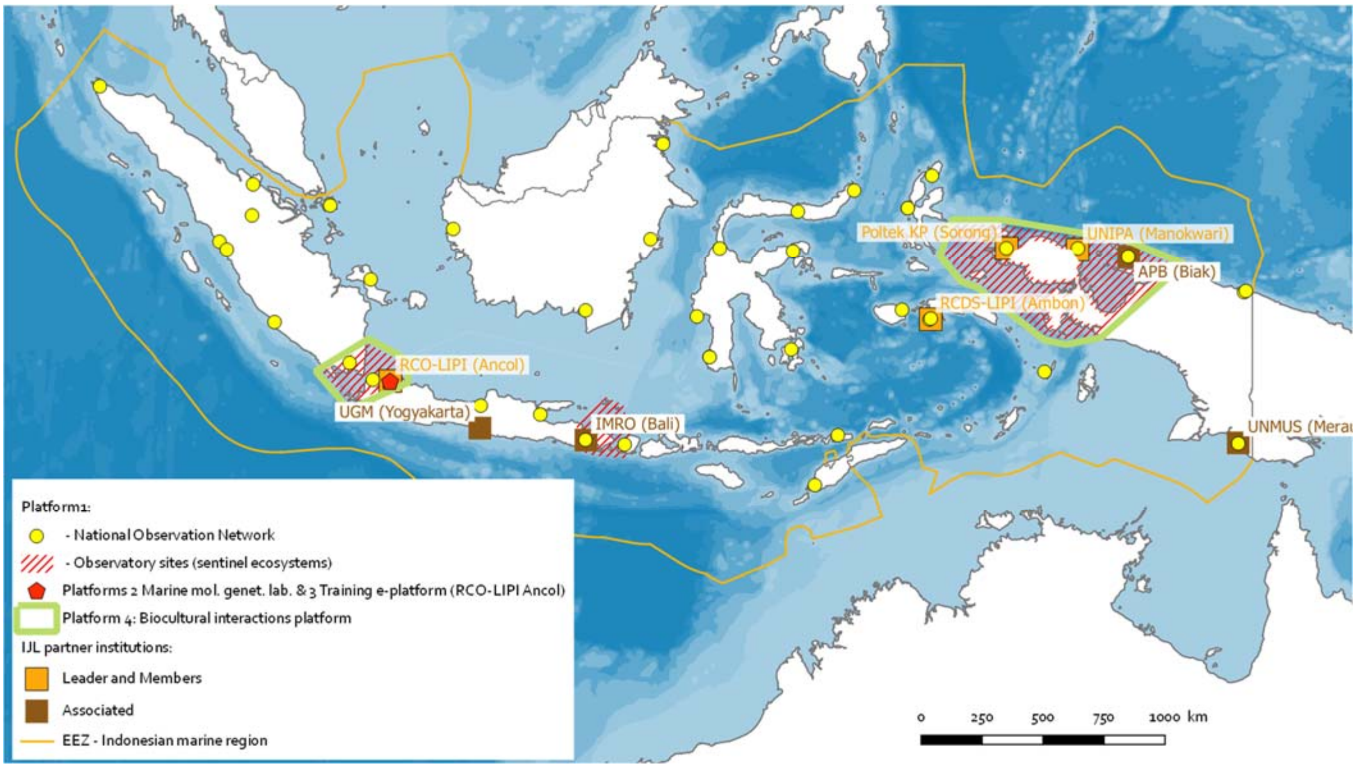

Figure 2 : Map of the Indonesian archipelago, with location of the Selamat IJL platforms and of the observatory sites [See full view in appendix 14].

2.3. Strengthening capacities and skills in scientific diving

Studying marine ecosystems and marine biodiversity often requires diving interventions (for observation, sampling of specimens or substrates, installation of sensors, installation of videos, etc.). Several members of the IJL SELAMAT are SCUBA divers qualified for scientific diving (see Appendix 2). The team's skills and experience in scientific diving and in the organization and supervision of underwater operations is strong. The IJL possesses the capabilities to conducting the field work necessary to study the sentinel ecosystems -in the framework of projects supported by external funds-, including the mesophotic coral ecosystems (MCE) or the twilight zone (Hinderstein et al 2010) with closed-circuit rebreathers (Hocdé et al 2017). As during the Lengguru 2014 and 2017 expeditions, partners who already possess diving skills will be trained in scientific diving techniques and methods.

2.4. Organization, functioning and governance of the project

The Selamat IJL is led by representatives from member laboratories and scientific departments.

The two coordinators will be guided by the steering committee in terms of strategy and main orientations. They will also ensure compliance with the regulations derived from the Nagoya protocol on access and benefit-sharing/ABS and with the terms of the Indonesian-French collaboration.

The scientific committee has a dual advisory and coordinating role : it has a think-tank role and will help to prioritise scientific issues, to ensure cohesion and the scientific quality of actions, and will help communicate and disseminate knowledge and results. It will assist the two coordinators in the production of information and reports, in arbitrations, in problem solving.

Each platform will be animated by two members of the IJL.

The associate laboratories and departments are invited to participate in the IJL's actions: long-term observation and data acquisition, biomolecular analyses and data processing (genetic, remote sensing or environmental data, training, production of knowledge ...).

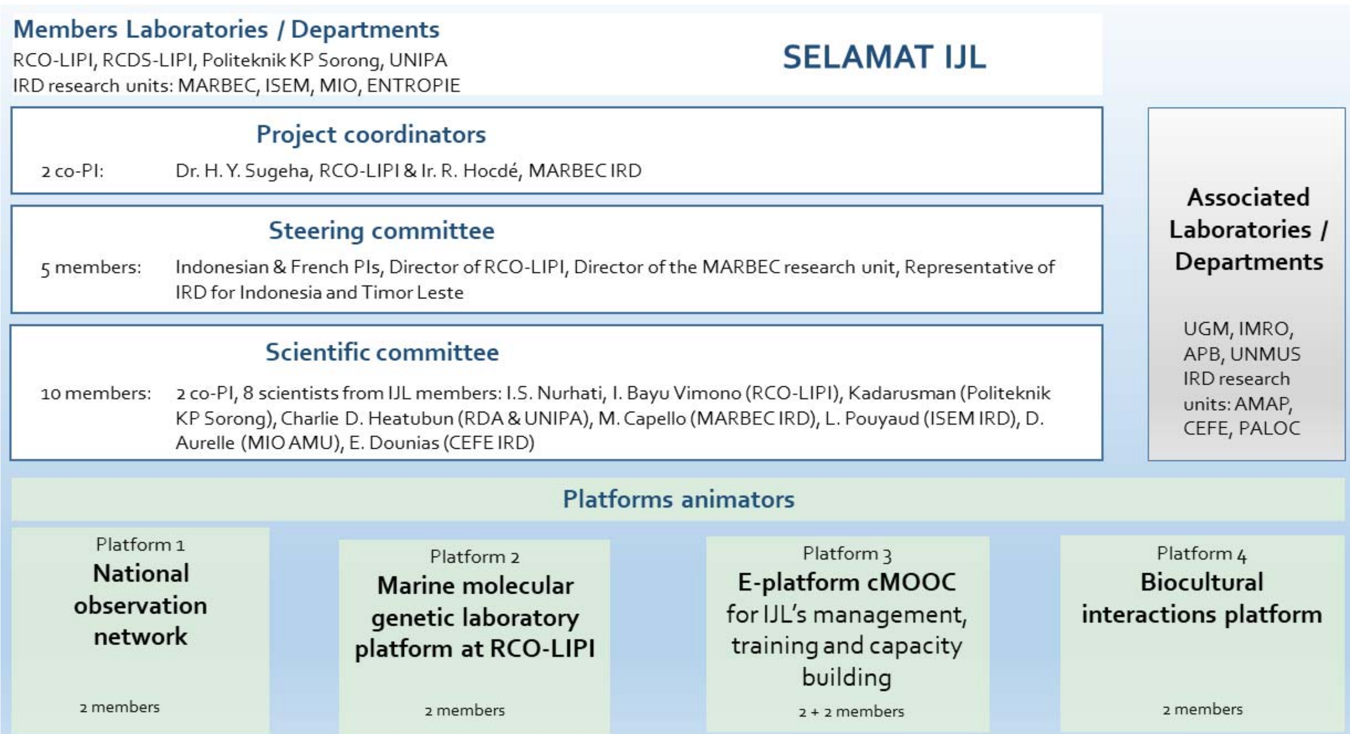

Figure 3 : Governance of the Selamat IJL

3. Project Description (15 pages max.)

3.1. Context and general issues addressed by the project

3.1.1. World's richest marine biodiversity hotspot

Indonesia is the world's largest archipelago, comprising thousands of islands. It lies at the interface of two oceans, bordered to the West by Indian Ocean waters and to the North and East by Pacific Ocean waters. Encompassing the heart of the world's richest biodiversity hotspot (the Coral Triangle), Indonesia hosts nearly 20% of the world's coral reefs, 5% of the world's seagrass meadows and around 20% of the world's mangrove forests (Gray 1997; Kuriandewa et al. 2003; Choong et al. 1990). The Coral Triangle at the core of the Indo-Malay-Papua archipelago hosts the world's richest marine biodiversity (Allen & Erdmann 2009, 2012; Veron et al. 2009; Mangubhai et al 2012), as in the case of Scleractinian corals (Fig. 4). This exceptional level of diversity and endemism is due to a combination of factors: the complex marine currents and history of sea level changes (Mora et al 2003), vicariance and dispersal at various spatio-temporal scales (Hubert et al. 2017), diversity of habitats from karsts to many types of coral reefs (Mangubhai et al 2012), plate tectonics (Leprieur et al 2016), and stable climate conditions during the Quaternary (Pelissier et al 2014; Sarr et al. 2019). As a result, Indonesia is endowed with an exceptional marine diversity, but still poorly known and already threatened (Ainsworth et al 2008). Documenting and monitoring the marine biodiversity of Indonesia is therefore crucial to sustainable fisheries management, ecosystem service management, and conservation. This is also crucial to our understanding of marine speciation, given the complex histories of vicariance and secondary contact that have contributed to the diversity of species in this area (Drew & Barber 2009; Hubert et al. 2017; Matias & Riginos 2018; Chen & Borsa 2020).

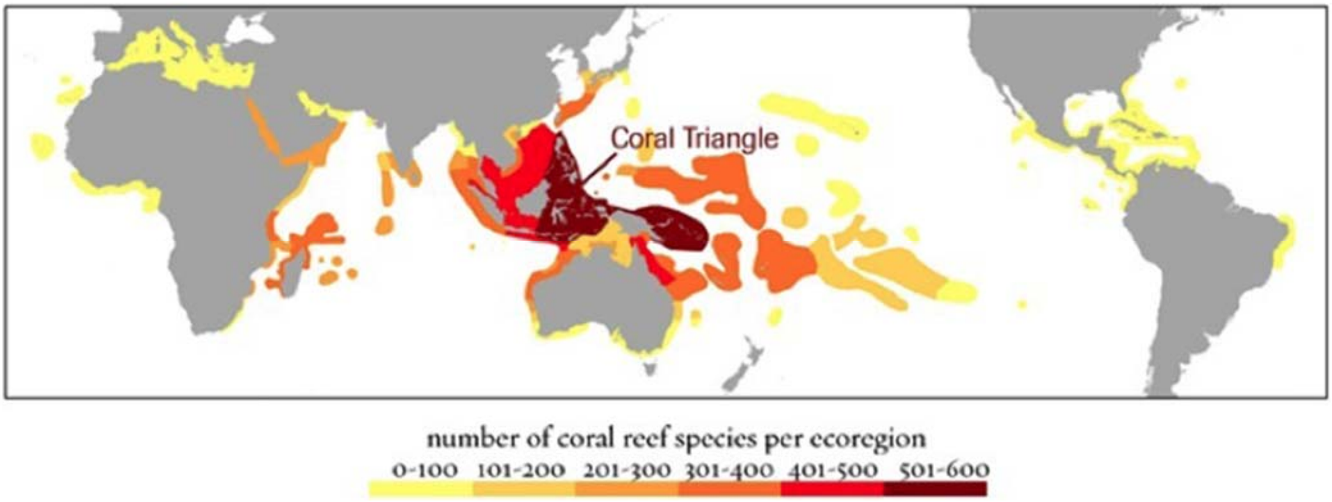

Fig 4. Global distribution of photosymbiotic Scleractinian species and delimitation of the Coral Triangle (Veron et al. 2007).

The Indonesian Throughflow (ITF) is a strong transfer of water from the Pacific to the Indian ocean through the eastern part of the Indonesian archipelago (Castruccio et al 2013, Feng et al. 2018). This region of the world is characterized by a complex system of strong oceanic currents (Mayer et al. 2010, Wijeratne et al. 2018, Liang et al. 2019). The strong flow favours the passive dispersal of larvae (Antoro et al. 2006) but combined with other factors (physico-chemical characteristics of water masses, geological or bathymetric) it also favours the occurrence of gyres that enhance retention (Condie et al. 2016) and may be associated to oceanic fronts that may act as physical barriers (Kadarusman et al. 2020). The present patterns of genetic diversity are shaped by the interaction of historical processes and current oceanography.

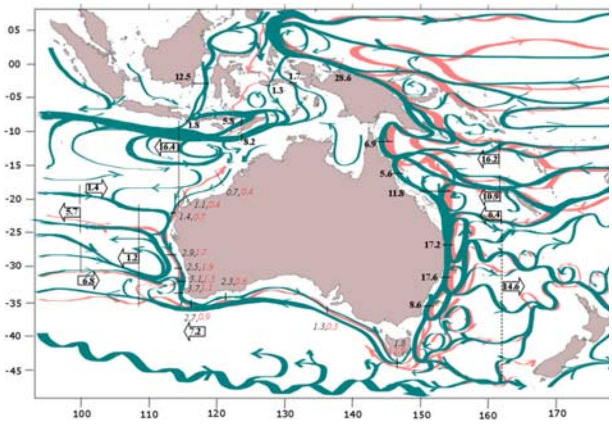

Fig 5. Schematic of major currents and mean transport estimates (in sverdrups) based on the long-term ozROMS simulation. Surface and subsurface currents/transports are represented in green and red, respectively. Transports across major cross-sections are provided with surface and subsurface transport in black and red, respectively. Values inside arrows indicate meridional transport averaged over the dashed line associated with the arrow (Wijeratne et al. 2018). Current-based dispersal models provide a means of investigating potential genetic connectivity between populations from coral-reef or mangrove habitats at the regional scale (Kool et al. 2011).

3.1.2. Need for sustainable exploitation of Indonesia's marine resources

The Indonesian population, over 260 million, highly depends on marine ecosystems and resources for food and income. Indonesia's marine economy is worth 180 billion US$ annually, more than one quarter of the national economy (Rodrigues de Aquino & Kaczan 2019). Freshwater and marine fishes represent more than 70% of the country's protein source. About 20% of Indonesia's GDP comes from fisheries and related activities.

Reconciling economic and social development with the sustainable use and conservation of natural resources is both challenging and timely for Indonesia, particularly under the ongoing global change. Experts point to the Papua and Halmahera ecoregions of the Indonesian archipelago as top priority areas for implementing conservation efforts, based on their high levels of endemism, the diversity of natural habitats and species, and the relatively preserved state of their terrestrial and coastal ecosystems (Huffard et al. 2012). In 2015, West Papua was declared by the Indonesian government a 'Sustainable Development' province.

3.1.3. Toxic dinoflagellates in the Indonesian archipelago: a likely underestimated hazard

Among dinoflagellates, a few genera (*Gambierdiscus*, *Fukuyoa*, *Ostreopsis* and *Prorocentrum*) produce ciguatoxins. The ciguatera fish poisoning syndrome (CFP; Roué et al. 2018; Friedman et al. 2017) is caused by the consumption of fish contaminated with potent neurotoxins from benthic harmful algae (B-HABs). The ciguatoxins accumulate in fish, molluscs or echinoderms like sea urchins (De Fouw et al. 2001, Darius et al. 2018, Roué et al. 2018). *Gambierdiscus* has been recorded in Indonesian waters (Praseno and Wiadnyana 1996; Sidabutar et al. 2001, Sidharta 2005), with toxic strains of *G. yasumotoi* being linked to coral habitats damaged by dynamite fishing in the Komodo National Park. New species have also been identified in Indonesia such as *Gambierdiscus Balechii* in the Celebes Sea (Bravo et al. 2014, Fraga et al. 2016). Increasing reliance on marine fish as a source of proteins together with increasing habitat degradation leads to an increasing risk of fish poisoning. Even though officially, the presence and risk maps mention Indonesia as a 'white zone' (Chan 2015), several cases of fish poisoning have been reported (D.F. Putra, pers. comm., 2018) and some imported tropical fish from Indonesia caused one CFP outbreak in Germany (Friedemann 2019). However, only limited information about ciguatoxins (CTX) has been reported (Skinner et al. 2011; Razi et al. 2014, Skinner 2015; Widiarti et al. 2015, Thoha et al. 2020). Local populations live on seafood including fish most often implicated in ciguatera fish poisoning elsewhere in the Indo-West Pacific: dogtooth tuna, barracudas, large groupers, large carangid fishes, etc. and are therefore potentially exposed to fish poisoning. Moreover, in the last decade seven new *Gambierdiscus* and one new *Fukuyoa* species have been described from various areas in the world demonstrating the unexpected species diversity in these dinoflagellates (Tester et al. 2019, Tester et al. 2020) (See *appendix 16. Global occurrence of Gambierdiscus and Fukuyoa species from published records from 2009 to 2018 (Tester et al. 2019)*). Indonesia, where such studies are still scarce, possesses a likely underestimated biological and toxic diversity within CFP species. Climate and environmental change effects Dinoflagellate abundance and community composition and triggers harmful algal blooms (HABs) (Anderson 2012).

3.1.4. Capacity-building needs

Scientific capacity building has been identified as a high priority by the Indonesian Ministry of Research and Technology (RISTEKDIKTI-BRIN). Indonesia has over 3,226 universities scattered all over the archipelago. Efficient educational and research exchanges are indeed serious challenges (Logli 2016).

Compared to other countries in the ASEAN or in the world, Indonesia can still largely improve its investment in research and development. Improving capacity building and scientific production could be a first attempt as expected in this IJL proposal.

Beside the upgrading of molecular capacities on Platform 2, the implementation of a national observatory network (Platform 1), and the animation of research training through an innovative e-learning platform (Platform 3), the IJL will prioritize M.Sc. and Ph.D. student supervision with the involvement of the French doctoral programs (ED) from Aix-Marseille University (ED 251 Sciences de l'Environnement) and Montpellier University (ED GAIA) (See appendix 5).

Upgrading the scientific and academic skills of young Indonesian researchers who participate in the IJL is an advantage regarding Indonesia's sustainable development goals of achieving a sustainable future in the face of increasing global change.

Table 1 : Indonesia's world rank as expressed by the World Bank's science and technology indicators (source: World Bank data.worldbank.org/topic/science-and-technology - details: Researchers in R&D (per million people), Research and development expenditure (% of GDP) and the Scimago Journal & Country Rank: citable documents (1996-2018) and H index by country)

	Researchers in R&D (per million people)	Research and development expenditure (% of GDP)	Citable documents (1996-2018)	H index (1996-2018)
Israel	8 250 (2012)	4,25 % (2016)	344 498 (n°25)	665 (n°16)
US	4 313 (2015)	2,74 % (2016)	10 701 848 (n°1)	2 222 (n°1)
Germany	4 893 (2016)	2,94 % (2016)	2 787 096 (n°4)	1 203 (n°3)
UK	4 430 (2016)	1,69% (2016)	2 935 537 (n°3)	1 373 (n°2)
France	**4 450 (2017)**	**2,25 % (2016)**	**1 969 558 (n°6)**	**1 094 (n°5)**
Brazil	881 (2014)	1,27% (2017)	888 530 (n°14)	530 (n°24)
Thailand	1 210 (2016)	0,78 % (2017)	168 248 (n°44)	311 (n°39)
Vietnam	672 (2015)	0,44 (2015)	48 863 (n°59)	198 (n°62)
Burkina Faso	48 (2010)	0,22% (2014)	6 429 (n°108)	102 (n°104)
Indonesia	**216 (2018)** / 89 (2009)	**0,08% (2013)**	**106 501 (n°48)**	**214 (n°57)**
Democratic Republic of Congo	11 (2015)	0,08% (2009)	4 464 (n°117)	97 (n°109)
Madagascar	31 (2017)	0,01 % (2017)	4 199 (n°120)	91 (n°120)

3.1.5. A long-term French-Indonesian collaboration with common research projects

The IJL will formalize a long-term partnership with our Indonesian counterparts. This partnership was initiated in 2010 through several research projects including the Lengguru (www.lengguru.org), PARI, BARCORE, and Harmful Algal Bloom programs (See Table xx). The objectives are to develop interdisciplinary research, capacity building and student training (MSc and PhD) in respect with UN Sustainable Development Goals 14, 15 & 17. Our partnership with Indonesia has already included several PhD projects (already 8 PhD theses and 1 in progress; see Appendix 13) and the upgrading of RCO-LIPI's marine molecular genetic laboratory platform. Our partnership with Indonesian institutions has already produced over 50 joint conferences and publications in scientific journals. Four joint field expeditions, dozens field work campaigns and several training workshops have been yearly co-organized and involving more than half of IJL's participants. Both Indonesian and French Institutions have participated in the funding of these research and training activities, including the joint PHC Nusantara (RISTEKDIKTI, MEAE, MESRI) and the Institut Français Indonesia supporting programs (IFI Jakarta).

The existing sustainable collaboration coupled with new research dynamics will ensure the future success of the SELAMAT IJL. The long-term collaborative dynamics established through the Lengguru expeditions (P.I. L. Pouyaud & R. Hocdé) has created a trusted environment and has become a model of international collaboration as acknowledged by the Indonesian Ministry of Research. Compliance with Access and Benefit Sharing (ABS) procedures is also our concern and the IJL framework will be helpful in achieving compliance with ABS requirements. We are aware that this will necessarily impact the collection of samples and data and their management. The SELAMAT IJL will continue the equitable scientific partnership we have built in Indonesia over the years (see table 1 of Appendix 15: Previous joint French-Indonesian research project in the fields of marine biodiversity, fisheries, and fish aquaculture).

Several ongoing and future projects will rely on one or another of the four platforms and the research dynamics of the Selamat IJL. Fundraising is also in progress, to start new projects and to continue others. The IJL members have already demonstrated their ability to raise private or public funds (see table 2 of Appendix 15: Ongoing research projects and fundraising for new projects).

3.1.6. A positive context

Aware of the environmental and societal challenges that stem from demographics and economic growth coupled with global change, the Indonesian president made sustainable management of marine resources one the top priorities for the country. Meanwhile, Indonesia having been declared one of France's geostrategic priorities[1], the Agence française de développement (AFD) supports the Indonesian government in the implementation of its development policy, particularly in the maritime sector through the construction of an oceanographic vessel and the funding of ambitious projects in applied oceanography. Year 2020 also marks the 70th anniversary of French-Indonesian scientific cooperation.

3.2. **Scientific objectives and related capacity-building**

Capacity building will essentially be reached through realistic scientific objectives. In this section, we detail these. Making full use of its four platforms, the IJL SELAMAT will support research activities and research capacities to address the resilience of Indonesian marine socio-ecosystems to global change.

The IJL research objectives are dedicated to ecological sentinels to study the interaction between human societies, environmental changes and marine biodiversity. Ecological sentinels are species or groups of species that translate as directly and as clearly as possible qualitative or quantitative changes in the properties of the ecosystems of which they are part (Hazen et al. 2019). Sentinel species and sentinel ecosystems are chosen according to already available knowledge and to the possibility of sustained observations to act as early warning of the impact of local and global pressures (Christian and Mazzilli 2007). Sentinel species warn us about the effective impacts of global change on marine and coastal ecosystems. A variety of species such as microalgae (including toxic algae), invertebrates (including Scleractinian corals), mangrove trees and large marine vertebrates (including large predators) can be viewed as “sentinels” as defined above. These species are sensitive to local or global environmental stressors that may affect their life histories, their population dynamics, and their genetic diversity. Such disturbances in turn may affect communities, ecosystem stability, ecosystem services, and human health.

The two main research axes of our ‘sentinel laboratory’ are ‘sentinel species’ and ‘sentinel ecosystems’.

3.2.1. Sentinel species structure and dynamics throughout the Indonesian archipelago

We will implement the monitoring of a diverse set of sentinel or key species at different spatial scales, from local to regional: sharks (2 species) and rays (2 species), Scleractinian corals (with a focus on *Pocillopora* species), mangrove

[1] AFD and Indonesia, 2019 ; F. Hollande President's statement on maritime cooperation in 2017 www.elysee.fr/francois-hollande/2017/03/29/declaration-de-m-francois-hollande-president-de-la-republique-sur-la-cooperation-maritime-entre-la-france-et-lindonesie-a-jakarta-le-29-mars-2017 ; list of agreements signed by President F. Holland on this event id.ambafrance.org/Visite-d-Etat-de-M-Francois-Hollande-en-Indonesie-La-liste-des-accords-signes ; E. Macron President 's speech at the ‘Assises de l'économie maritime’ in Montpellier in December 2019

trees (3 species) and toxic dinoflagellates responsible for ciguatera food poisoning CFP (3 genera). We will examine for five consecutive years the genetic diversity of the species, their population connectivity, their population dynamics and evolution, with the use of genomics or metagenomics and modelling approaches (Platform 2). These activities will be enforced by a set of transversal and complementary approaches i.e. field interviews; fine scale remote sensing-based mapping of mangrove and coral reef habitats, terrestrial and underwater visual census surveys, and long-term abiotic parameters acquisition. The support of the DIVA network (Platform 1) and the expertise of local communities (Platform 4) will guarantee a yearly overview across the archipelago.

Justification of the choice of sentinel species :

- **Sharks and rays** are large marine vertebrates now functionally or entirely extinct in many coastal ecosystems (Jackson et al. 2001). Indonesia is currently the world's top harvester of sharks and rays (Dulvy et al. 2017). Over one quarter of the tropical species in elasmobranchs are threatened with extinction (Dulvy et al. 2014). The high extinction risk in sharks and rays is a consequence of their K-type life-history characteristics under heavy fishing pressure (e.g. tuna fisheries with FAD and long-lines), and the degradation of coastal ecosystems including mangroves and reefs in the Indonesian archipelago. Most elasmobranch species are large-size mesopredators or top-predators: they are thus sentinel species of marine ecosystems *par excellence*. A DNA barcoding initiative based on traditional fish markets and shark-fin exporters across Indonesia has revealed an alarming situation, where threatened and near threatened elasmobranch species represent up to 93% of captures in contrast of "least concern" reef sharks (7%) (Sembiring et al. 2015). The IUCN-rated Vulnerable silky shark and the Critically endangered scalloped hammerhead shark are the two most common shark species caught as bycatch in tuna fisheries in Indonesia, comprising nearly 30% of the total catch (Sembiring et al. 2015). These circumtropically distributed species show strong phylogeographic partitioning among oceans and exhibit significant population structure in the Indo-West Pacific as well (Duncan et al. 2006; Clarke et al. 2015). Despite the high levels of exploitation and related population viability concerns, data on the genetic diversity and population structure of these species in the Indo-Pacific are still scarce. We propose to develop a genomic approach for testing the impact of fisheries on the spatio-temporal genetic diversity of these two sentinel species across the Indonesian archipelago. Two stingray species complexes are of particular interest in the context of the present IJL. One is the undulate whipray *Himantura undulata* species complex, an IUCN-rated Vulnerable species which is sensitive to the conversion of mangrove habitats for aquaculture (Manjaji & White 2009). The other one is the blue-spotted maskray *Neotrygon kuhlii* species complex, the most abundant in the catches throughout the Indonesian archipelago (White & Dharmadi 2007). The blue-spotted maskray occurs in shallow coastal waters associated with coral reefs; it shows an unusually strong phylogeographic structure, where lineages have narrow geographic range (Borsa et al. 2016). The blue spotted markray's preference for coral reefs and lagoons means it is also threatened by extensive reef habitat degradation. We therefore see this species complex as an appropriate model for studying the degradation of reef habitats at a narrow local scale.

- **Scleractinian** corals should also be considered as sentinel species, as this group of highly emblematic reef organisms is vulnerable to various human-mediated threats including reef limestone and reef sand mining, urban and infrastructure development, hyper-sedimentation, pollution by nutriment-laden runoff waters, plastic pollution, oil pollution, over-exploitation of reef resources, and ocean warming (Fabricius 2005; Dalton et al. 2020). Coral bleaching has already been observed in Indonesian waters, where *Pocillopora* spp. corals were among the most impacted species (Guest et al., 2012; Yusuf and Jompa, 2012). This IJL will focus on the ecology and genetics of *Pocillopora* species. This genus is already well studied (including in the Lengguru project in collaboration with RCO-LIPI) with genetic markers, allowing species delimitation (Gélin et al., 2017). Some results obtained with microsatellite loci suggest an important genetic structure of *Pocillopora* populations in the Bird's Head Seascape (Starger et al., 2013). Nevertheless this should be studied by taking into account the diversity of cryptic lineages we already observed in this area (article in prep.). The integration of different ecological conditions in genetic sampling would also be useful for a proof-of-concept study of the role of *Pocillopora* as sentinel species. In the framework of the LMI we will then explore the diversity of *Pocillopora* corals at different levels. First we will investigate the diversity of *Pocillopora* species in the Indonesian archipelago with the help of the DIVA network. Species identification will be performed through mitochondrial lineages. This geographic mapping of *Pocillopora* lineages and species will be the basis for understanding their evolution in Indonesia, including speciation, connectivity, and responses to local pressures (Gélin et al. 2018). We will then focus on the lowly and highly impacted study sites (see 3.2.2). Here we will analyse the diversity of *Pocillopora* species (as previously), along with the genetic diversity of the most frequent species. We will thus be able to study the impact of human pressures on these two levels of biodiversity which can have important consequences on ecosystem functioning, and the monitoring of genetic diversity should be a target in biological conservation (Laikre et al., 2020). The analysis of intra-specific genetic diversity can be done with microsatellite markers (Gélin et al., 2017) and will consider different estimates, including clonal richness whenever relevant. The results will be analysed in light of demographic and ecological parameters such as coral cover, turbidity, pollution… The development of these studies will pave the way for deeper genomic studies of the evolution of *Pocillopora* species in this area (which will require dedicated funding outside the IJL). Genomic approaches such as RAD-Sequencing will be useful to study adaptation, hybridization and diversity at the genome level (e.g. Manel et al. 2016; Nunziata and Weisrock 2018). The data will be useful for management and conservation purposes.

- **Dinoflagellates**: Toxic algae are a bioindicator of anthropogenic pressure, characterized by their presence, phenology (blooms) and specific diversity (Faure et al. 2015). Indeed, the arrival of a new species on a site can sign the degradation of the environment (e.g. *Alexandrium* in harbours; Bravo et al. 2008). Three ways are being explored : 1) large scale field interviews through Diva network from Platform 1 and expertise of IJL's HSS for evaluating local knowledge on CFP and mapping putative outbreaks on local communities, 2) the detection of algae in selected 'observation sites' to know the specific diversity of toxic algae and 3) the detection of ciguatoxins (CTX) in fish flesh through the indonesian archipelago.

Data about ciguatera food poisoning (CFP) in Indonesia are scarce but there is evidence that such disease is known by local communities in several areas in Indonesia. Our first objective will be to evaluate through field interviews the importance of local knowledge about this human disease and to try to reconstitute an historical scheme of outbreaks' frequencies and magnitude. This work will be endorsed by HSS partners with the help of DIVA network participants and will consist of a questionnaire in bahasa Indonesia submitted to local communities involved in artisanal fisheries. The results will enable to select specific areas (observation sites) with CFP occurrence which will drive further research axis developed below.

The presence of ciguateric dinoflagellates living on macrophytes will be investigated during field works in the targeted marine ecosystems of the IJL (Java sea and Sunda strait, Bali sea, West Papua). Firstly, the observation by light microscopy will characterize the phytoplankton species for ecological purposes or for monitoring harmful species. Nevertheless, the technological progress in molecular analysis now makes it possible to identify these organisms more quickly and more accurately. After extraction and isolation of environmental DNA (eDNA), a sensitive and quantitative qPCR method will be developed in the Platform 2 'marine molecular genetic laboratory' to quantify abundance of Gambierdiscus and Fukuyoa species. Finally a metabarcoding (NGS) approach will be used to evaluate the diversity of CFP species in the environment.

The detection of CTX in fish flesh will be organized throughout Indonesia involving the Platform 1 'Indonesian national observation network' and will involve especially the lecturers-researchers of the DIVA networks. Some organs (liver, muscle) will be sampled from target species during the visit of fish landing places or fish markets. This strategy has a double advantage: an easier access in terms of sampling and an assessment of level of contamination of the fish consumed by the inhabitants (food safety). The target species will be herbivorous or carnivorous species known to potentially have a high concentration of toxins and also displaying a commercial interest for human consumption. The narrow-barred spanish mackerel *Scomberomorus commerson* ('Tenggiri' in Bahasa Indonesia or 'tazard' in French) is a good candidate (Lewis and Endean, 1983; Gillespie et al. 1986; Farrel et al. 2016, 2017; Soliña et al. 2020). Parrotfishes are also easily sampled on a large scale (Chungue et al. 1977; Satake et al. 1996; Soliña et al. 2020), and the grey mullet *Mugil* sp. (Ledreux et al. 2014, Soliña et al. 2020). The samples will be sent to the RCO-LIPI laboratory in Ancol. Toxicity tests will be performed on cell cultures to detect the presence and intensity of toxins. These toxic tests do not enable the identification of the molecules involved but provide a first level of information, which does not exist today. The chemical analysis allowing to perform the toxic spectra and thus to characterize the molecules are expensive and require specific infrastructures (which exist in Europe only in a few laboratories: Nantes/France, Barcelona/Spain...). Some toxin analyses will be performed as part of related research projects and will involve the training of Indonesian partners. These actions will be strengthened with the new "Ciguatoxins: Biological, Ecological, Economic and Health Impacts (CIBSEEA)" project funded by MUSE/University of Montpellier.

- **Mangrove trees:** Despite an increasing consensus on the leading role of oceanic circulation in shaping and maintaining genetic structures of mangrove tree populations (Van der Stocken et al. 2018), Arnaud-Haond (2006) and DO et al. (2019) have shown that two neighboring mangrove tree populations may strongly differ in terms of genetic structure because of contrasted life histories of mangrove species including contrasted propagule dispersal capacities. The propagules may float over a few days or weeks to a number of months before sinking. We still know little about the oceanic pathways followed by buoyant mangroves propagules. This information is, however, pivotal for a satisfactory dimension of conservation plans in either isolated or connected regions. With the SELAMAT platforms, a unique opportunity is offered to explore the connectivity of mangrove regions in Indonesia, the centre of mangrove diversity. The first results obtained in the framework of the INDESO and MANGCOC projects suggest that, within a few months, the Bird's Head Papua mangroves can deliver propagules to a large part of Southeast Indonesia. The result must be confronted with the analysis of mangrove species genetic diversity within and across regions. In the IJL, three mangrove species will be chosen as sentinels species: *Avicennia marina* which is found in arid and salty environments (or *Avicennia alba*), *Rhizophora apiculata* common on the seafronts of most of the Indonesian coasts, and *Bruguiera gymnorhiza* which occupies upstream positions often on raised remnants of coral reefs. Demonstrating that mangrove vegetation samples can be collected by Platform 1 and analysed by Platform 2 constitutes a major objective of SELAMAT that should raise a number of ground-breaking research projects. The genetics results interpretation will be strengthened with the remote-sensing and the numerical modeling of indo-pacific oceanic currents dynamics.

Table 2: The sentinel species monitored by the IJL, throughout the indonesian archipelago or in specific regions

Sentinel species	Geographic scope of study				Sampling methods	Operators		
	Indonesian archipelago (including observatory sites)	Specific region / observatory site				Platform 1 Observ.. network		Platform 4
		Java sea and Sunda strait	Bali sea	West Papua		DIVA network	Related research programs	Biocul. interactions
Sharks (2 species) *Carcharhinus falciformis*, *Sphyrna lewini*	X				Fish markets, shark-fin exporters,fish landing places	X		
Stingrays (2 species) *Himantura undulata*, *Neotrygon kuhlii*	X				Fish markets,,fish landing places, skin tanneries	X		Observations /testimonials
Scleractinian corals (1 genus) *Pocillopora* spp.		X	X	X	Scuba diving		X	
Mangrove trees (3 species) *Avicennia marina*, *Rhizophora apiculata*, *Bruguiera gymnorhiza*	X				Field sampling	X	X	Observations /testimonials
Dinoflagellates responsible for ciguatera (3 genera) *Gambierdiscus*, *Ostreopsis*, *Prorocentrum*		X	X	X	(algae sampling) Freediving and scuba diving		X	
	X				(fish tissues sampling - fish landing places	X		Observations /testimonials

3.2.2. Sentinel ecosystem interactions and dynamics in three observatory sites

The "sentinel ecosystems" correspond to long-term "observatory sites" where the SELAMAT IJL members will focus their research projects, in link with the IJL laboratory to analyse specimens (Platform 2) and train partners in specific techniques or methods (Platform 3). Fieldwork and research project activities will be funded by external funds to be raised by IJL members. Local communities (Platform 4) will be fully involved in these observatory sites.

Three 'observatory sites' were selected according to contrasted levels of anthropic pressure and to the contiguity of both coral reefs and mangrove sentinel ecosystems. The proximity of partner marine stations was also a criterion as this will facilitate logistics and training. Indeed, the partner institutions (RCO-LIPI, RCDS-LIPI, RITF-MMAF, Politeknik KP Sorong-MMAF, RCPMR-UNIPA,...) possess several marine stations throughout the Indonesian archipelago. Six of these stations (Ambon, Ancol, Bali, Lampung, Manokwari, Sorong) will support the implementation of these integrated studies (multiple-taxon approach, remote sensing *versus* fieldwork, key environmental indicators) (See Fig. 2) :

- **the relatively preserved coral reef – mangrove sentinel ecosystems of (1) West Papua**: West Papua, at the heart of the Coral Triangle, harbours the world's most extensive and diverse mangroves and coral reefs. These two ecosystems rely on complex symbiotic relationships and support the highest diversity of the Indo-West Pacific ensemble. Although still in good condition and benefitting from conservation initiatives such as the establishment of multiple marine protected areas (MPAs; Map….) whose total area represents 25% of the Indonesian total, the Bird's Head (West Papuan) seascape (BHS) is facing critical challenges such as rapidly increasing population size, all-out tourism development, terrigenous pollution from logging and coastal development (Starger et al., 2013 and references therein) . Deforestation, especially that induced by the current low productivity of shrimp aquaculture in Indonesia, may have devastating effects on coastal ecosystems in West Papua over the next two decades (Ilman et al. 2016). Indirect effects are: hyper-sedimentation, deregulation of freshwater input, increasing pollution associated with increased runoff and intensive agriculture. These are the causes identified for the current degradation of the Australian Great Barrier Reef in interaction with climate change (Fabricius 2005; Fabricius et al. 2016; Bainbridge et al. 2018). The observatory site of West Papua encompasses the field work localities of Cenderawasih bay, Raja Ampat and Lengguru.

- **the anthropized sentinel ecosystems of (2) Java sea and Sunda strait regions, and of (3) Bali Sea area:** these areas are exposed since a few decades to important ecological disturbances in relation with human activities and neighboring highly populated areas. This situation creates key challenges for marine biodiversity and ecosystem functioning, with consequences on ecosystem services. We plan to make an evaluation of the present state of these selected sentinel ecosystems and to reconstitute their historical status scenario from a review of the huge corpus of ecological data already available in the litterature. The comparison with anterior status on these 'observatory sites' can reveal some shifts in communities composition and structure (i.e. herbivorous vs. corallivorous species, HAB and CFP dynamics), and will allow us to predict possible tendencies in more studied preserved sentinel ecosystems. This approach will also enable to test putative MPA effects for these areas and to propose eventually new conservation strategies. The observatory site of 'Java sea and Sunda strait' encompasses the field work localities of Seribu Islands archipelago (north of Jakarta megapole), and the Sunda strait (along a gradient from Ujung Kulon National Park to Lampung Bay). The observatory site of Bali Sea area includes coastal ecosystems of Bali Island and the Bali strait between Bali and Lombok islands (known to be one of the major channel exchanges between Indian and Pacific Oceans).

In the 'observatory sites', we aim at developing an integrative approach based on innovative methods (multispectral mapping, modelling and forecasting, metabarcoding, genomics and metagenomics) for understanding the structure and the dynamics (specific and genetic diversity, connectivity and adaptive potential) of the complex coral reef and associated ecosystems, with the aim to examine their possible resilience to local and global pressures. For both areas, we will emphasize the interactions of local human communities with these vulnerable ecosystems, to inform future management and conservation initiatives.

The multiple-taxon approach will include several bioindicators in addition to the IJL sentinel species, like the echinoderm *Acanthaster planci* known to be a major cause of coral mortality in Indonesia (Baird et al., 2013), macrophyte indicators of reef degradation (Littler & Littler 1980, 2013, Sangil & Guzman 2020), and mollusc, crustacean and annelid richness in the intertidal zone harvested by local communities. These taxa will not be genetically analysed but their occurrence, measured by opportunistic observations or via visual census surveys, will provide important data and knowledge to feed coral reef and mangrove habitats quality indicators. These multi-taxa approaches will be implemented or continued where they have been initiated as part of research projects (e.g.: Lengguru program in West Papua). Monitoring of alpha and beta diversity, including reef fishes, scleractinians corals, gorgonians, echinoderms, molluscs, macroalgae and seagrass will provide data on the state of ecosystem health: ecosystem resilience, community imbalance, and presence of opportunistic or habitat-damaging species (Baird et al. 2013; Leroy et al. 2017).

Moreover, the environmental DNA approach initiated by some of our programs in Indonesia (Juhel et al. 2020a, Juhel et al. 2020b) and abroad (Polanco et al. *under review* a, Polanco et al. *under review* b) is relevant to asses the state of an ecosystem through the composition of the living communities and to monitor its temporal evolution in an observatory perspective (Valentini et al., 2016; Taberlet et al., 2018, West et al., 2020, Juhel et al. 2020b, Polanco et al. *under review* a, Polanco et al. *under review* b). Despite the costs (which will be covered by related research projects), training in the early stages of marine sampling and laboratory extraction, with conditions appropriate to the requirements of DNA to avoid contamination, will be proposed under Platform 3 'e-platform cMOOC (IJL animation & capacity building)'. Our previous analyses of eDNA allowed us to set up the protocols for such sampling in remote areas (Juhel et al. 2020a, Juhel et al. 2020b).

For these "sentinel ecosystems - observatory sites", fieldwork and sampling will be funded by related research projects. However, molecular analysis will be performed on Platform 2 'marine molecular genetic laboratory'.

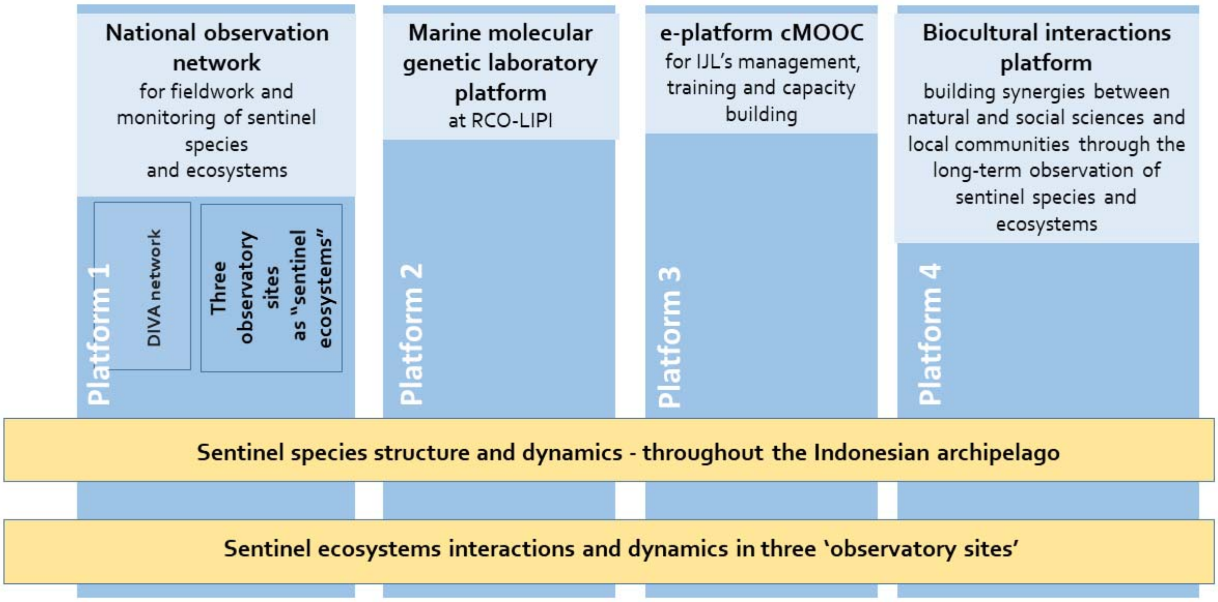

Fig. 6: "SEntinel LAboratory of the indonesian MArine biodiversiTy - SELAMAT" IJL architecture: four scientific platforms and two main research axes.

Table 3. Animators of the four platforms

Platform	Indonesia	France
Indonesian observation network	Kadarusman	R. Hocdé
Molecular genetics	H.Y. Sugeha	L. Pouyaud
cMOOC / Scientific training	I.B. Vimono, Kadarusman	D. Aurelle, P. Borsa
Biocultural interactions	I.S. Nurhati. Local indigenous peoples and fisherfolks	E. Dounias

3.3. Training activities, social and economic added value

The cMOOC will be organized on a monthly to bimonthly basis for IJL animation and capacity building. A volume of forty to fifty sessions is scheduled over the duration of the IJL. Only the first six sessions are here defined to impulse the dynamics. The exact topics of the cMOOC are open, so they will be discussed and updated within the cMOOC. They will be opened to students and researchers of the IJL and associated partners. (See *appendix 17. Table: a) List of topics for the first six sessions of cMOOC. b) Ideas for subsequent sessions.*)

Training activities will also include seminars, workshops, as well as the supervision of M.Sc. and Ph.D. theses.

3.4. Chronogram of the planned activities

	2021		2022		2023		2024		2025	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Obtention of research permits and visas	X		X		X		X		X	
Platform 1: Observatory network										
1.1. Sampling of sentinel species in fish markets (DIVA Network)	X	X	X	X	X	X	X	X	X	X
1.2. Sampling of mangrove trees in the field (DIVA Netwok)			X		X		X		X	
1.3. Fieldwork in "observatory sites" (external funding)		X		X		X		X		X
Platform 2: Molecular genetic analyses										
2.1. Sentinel species barcoding		X		X		X		X		X
2.2. Sentinel species genomics			X				X			X
2.3. Multi taxa metabarcoding (eDNA)			X		X		X		X	
Platform 3 Capacity building										
3.1. e-platform cMooc	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
3.2. Scientific workshops		X		X		X		X		X
Platform 4. Biocultural interactions platform										
4.1 Approaching local communities	X		X							
4.2 Formalizing Free and Prior Informed Consent		X		X						
4.3 Joint research protocol building Designing Cyber Tracker interface and training		X		X						
4.4 Data collection by local experts			X	X	X	X	X	X		
4.5 Adjustment of research protocol during scientific workshops				X		X		X		
4.6 Local expertise advocacy based on research results						X		X	X	X
Animation of the IJL										
Steering committee	1		1		1		1		1	
Scientific committee	1	1	1	1	1	1	1	1	1	1
IJL coordination and animation	X	X	X	X	X	X	X	X	X	X
Yearly SELAMAT IJL day's		X		X		X		X		X

3.5. Consistency and added value of gathering the existing research teams, in terms of structuration / strengthening of the « North-South » and « South-South » partnership

The IJL aims to strengthen partnership in the field of Indo-Pacific marine biodiversity for contributing to the sustainable and inclusive development of coastal communities living at the heart of the Coral Triangle and more widely at the scale of Indonesia, the World's largest archipelagic country. Our initiative fits with the "inclusive development" concept developed by Pouw & Gupta (2017), which intends to bridge different disciplines for social wellbeing and ecosystem preservation through redefining political priorities in the context of Anthropocene.

France has the second largest marine exclusive economic zone (EEZ) in the world and makes a priority to develop international collaborations for the sustainable and inclusive development of marine resources especially in the Indo-Pacific region (French president Macron's statement, 2019). France is therefore an important development partner for strengthening Indonesia's blue economy through innovative programs supported among others by the French Development Agency group (AFD). In this context, the IJL will conduct its research and training activities in close consultation with the Indonesian office of AFD for ensuring innovative adapted research strategies and to face global change.

The example of the research network involved in Sasmito et al (2020) shows that Indonesian mangroves are the focus of international research effort. Studying the population connectivity and dynamics of mangroves will inform national plans for mangrove protection and the sustainable management of coastal ecosystems. Beyond the national scale, SELAMAT mangrove data will support the building of international research projects that will address ground-breaking questions on the adaptability of tree populations to a changing environment.

The IJL strategy based on the involvement of Indonesian institutional partners from various distant provinces (i.e. 3000 km between Java and West Papua) will be an important added value by strengthening partnership at the country scale through shared research projects or training activities. As an example, the gathering of Indonesian scientists during Lengguru Expeditions from RCO-LIPI and Papuan Universities fully demonstrated such fruitful partnership greeted by the Indonesian Research and Technology Minister.

The scientific backing of the Biocultural Interactions platform will include some originalities that may at first sight seem unusual in the context of an IJL, but which are inherent to the function of this platform and which should enhance its efficiency;

1. It is on purpose that the Indonesian partners of this platform will not be academic bodies but fishing communities. The latter will therefore intervene both as final beneficiaries of the study and as its main actors. Participatory sciences - first and foremost citizen science - fully justify this choice in the name of a different way of doing research. For obvious and practical reasons related to the Free Prior and Informed Consent, these platform partners can only be approached once the IJL has been validated: firstly, we need to avoid unnecessary frustrations in case the proposal would not be retained; secondly, negotiation with indigenous communities cannot be conducted remotely, but must on the contrary be carried out in direct contact.
2. The platform is designed to federate a network of experts covering a wide range of sensitivities within the social sciences rooted in participatory approaches: linguistics, history, geography, anthropology, ethnobiology, sociology, economics... are just some of the disciplines that should be mobilized in a qualitative and timely manner. This network will interact with experts from other disciplines in the IJL with exchanges between traditional and scientific knowledge on sentinel species and their ecological status.
3. The platform's activities will be supported by a GDRI-Sud (submission in 2020) dedicated to the valorization of indigenous knowledge as a means to achieve the Sustainable Development Goals (SDGs). Called "Sentinel VIPs" (for Vulnerable Indigenous Peoples), The vocation of this GDRI-Sud will be to provide transversal support to all IRD actions - including some IJLs - that mobilize indigenous knowledge through a participatory approach. Therefore, the experts who will intervene in this platform will not be members of the IJL, but members of the GDRI-Sud "Sentinel VIPs".
4. Ariadna Burgos, the IJL member who will dedicate a significant part of her ETP to the project, is currently a postdoc in the ANR POPEI Coll project, one of whose field sites is in Indonesia. Ariadna Burgos is an ethnomalacologist, an expert in coastal gleaning and participatory approaches. She is also a candidate for recruitment in 2020 at IRD for a CR position in the interdisciplinary section. If she is not recruited this year, she will structure her next recruitment application in relation to the SELAMAT IJL. It is therefore worthwhile mentioning here that the SELAMAT IJL will spearhead proposals in the recruitment of a young researcher.

All IJL activities will be conducted under the current IRD-LIPI MoU and IRD- AMFRHR-MMAF MoU. They will be compliant with the Convention on Biological Diversity, the Cartagena protocol, the Nagoya Protocol, as well as the UN-BBNJ regulation under UNCLOS.

3.6. Innovative aspects of the project and expected results

The SELAMAT IJL aims to implement some innovative tools and methods for data acquisition and capacity building. The IJL will provide large scale and long-term data in the frame of the first national observatory network in the field of marine biodiversity.

> cMOOC: as the SELAMAT cMOOC will reach SELAMAT members, associates and student associates both in France and throughout the widespread Indonesian archipelago, the cMOOC will be an innovative vector of scientific knowledge, scientific debate, and also team cohesion to overcome geographical disparity. This is especially important in Indonesia, where libraries are scarce and most researchers cannot as easily access resources of scientific knowledge as in other countries. Our view is that the SELAMAT cMOOC is the original and adequate response to a strong need for a virtual campus that ideally would provide Indonesian partners' access to universal scientific knowledge.

> Biocultural interactions platform: the citizen science approach we suggest to build through this platform is referred to as 'extreme' in the sense that it refers to 1- the extent of the scientific engagement of the non-scientific participants, 2- environments for which the mobilization of local expertise is seen as particularly critical, 3- the collaboration with remote or isolated indigenous communities, which are rarely viewed as reliable research partners because of their low level of literacy and their relative marginality. Ultimately, 'extreme' refers to an ethical posture that may have considerable political impact on the way decision makers consider these marginalized people. Beyond collecting data and sharing and knowledge, this platform is aimed to empower local groups and support action. The implications of this close collaboration between academic science and folk science in the sphere of political ecology will be the subject of specific attention (Cambrezy et al 2015). An extreme citizen science approach focusing on coastal ecotones will finally help designing a more refined analysis of the historical evolution of these fragile ecosystems, where satellite imagery data are lacking to interpret changes over a greater diachronic depth. The study of ancient ethno-historical episodes informed by local communities is a good illustration of the value of combining sources of knowledge and thus refining the realism of models reconstructing the kinetics of these ecosystems over time.

> Two examples of innovative outcome for sentinel ecosystems: 1/ in the case of mangrove ecosystems, habitat mapping derived from remote sensing will be analysed together with particle dispersal simulations (using the ICHTYOP model; https://www.ichthyop.org/), genetic structure of three mangrove species, and extreme citizen science contribution. This approach will help for a better monitoring and management of Indonesian mangrove sentinel ecosystems in the context of global change; 2/ In keeping with Bourlat et al. (2013), genomics and metagenomics in marine monitoring are new opportunities for assessing marine health status in the framework of the IJL. The study of sentinel ecosystems combines several methods (visual census of presence and abundance, genomics on specimens, metagenomics with environmental DNA on sea water, etc.) that will be applied to several taxonomic groups. New ecosystem health indicators will be developed and will enable to quantify ecosystem resilience in the global change context. This innovative corpus of results will be accessible to stakeholders and will serve an efficient management and conservation of marine resources in the Coral Triangle.

3.7. Opportunities for creating an operational research and/or training in the partner country and its potential visibility at regional and international level

The operationality of SELAMAT comes from a consolidated partnership supported by interwoven platforms. Both characteristics underlie a know-how in marine biodiversity research to be shared and developed in a complex oceanic and multi-cultural region, hotspot for many marine species. SELAMAT will produce invaluable data and knowledge from reproducible methods, perennial infrastructures and a reinforcement of capacity building.

The implementation of a long-term national observatory, with joined operational research and training activities, will give an important visibility at the regional and international levels. SELAMAT will promote sustainability science with the ambition to contribute to the sustainable and inclusive development of coastal communities living at the heart of the Coral Triangle through the study of sentinel species and ecosystems strengthened by the involvement of local experts. The success of this original approach will undoubtedly echo at larger scale in South East Asia enabling possible research and training extension of the IJL activities during its possible renewal.

After the first few years, the involvement of indigenous 'observers' will allow them to contribute to IPBES initiative within the next calls for contributions on indigenous and local knowledge.

LIST OF APPENDICES

Appendix - 1 *Curricula vitae of the project leaders (3-4 pages), and list of the main publications in the scope of the project.*

- Hagi Yulia Sugeha | CV
- Régis Hocdé | CV

Appendix – 2 *Short description of the teams participating in the project : list of permanent and temporary staff, with estimated time dedicated to the project. Only staff dedicating more than 30% of their activity to the IJL shall be considered as member staff of the IJL. Other staff shall be considered as associate members.*

Appendix - 3 *List of publications affiliated to South institutions of future members of the IJL, in the country(ies) and the topic(s) of the project, for 2019.*

Appendix - 4 *Chronogram of human resources mobilities: expatriation and long-term missions (including South-North & South-South missions) of the IJL members planned over the duration of the project (5 years).*

Appendix - 5 *List of universities and doctoral schools involved in the training activities (master and doctorate).*

Appendix - 6 *Description of the infrastructures (premises) and equipment made available to the project by the partner institution(s).*

Appendix - 7 *Full provisional budget over 5 years for each activity component, specifying the contributions from each partner institution to the implementation of the project, and the estimated additional needs (equipments, infrastructures, training at master and doctorate levels, etc.), including funding opportunities from national / international donor institutions.*

Appendix - 8 *Only if not included in the letter of intent submitted for preselection:*

- *A supporting letter from the director of each laboratory (or similar structure) to which the colleagues members of the IJL project are affiliated.*

- 8.1.a	*RCO-LIPI*	*(IJL leader)*
- 8.1.b	*MARBEC*	*(IJL leader)*
- 8.1.c	*RCDS-LIPI*	*(IJL member)*
- 8.1.d	*Politeknik KP Sorong*	*(IJL member)*
- 8.1.e	*UNIPA*	*(IJL member)*
- 8.1.f	*ISEM*	*(IJL member)*
- 8.1.g	*ENTROPIE*	*(IJL member)*
- 8.1.h	*MIO*	*(IJL member)*
- 8.1.i	*AMAP*	*(IJL associated partner)*
- 8.1.j	*IMRO*	*(IJL associated partner)*
- 8.1.k	*UGM*	*(IJL associated partner)*
- 8.1.l	*PALOC*	*(IJL associated partner)*
- 8.1.m	*APK Biak*	*(IJL associated partner)*
- 8.1.n	*UNMUS*	*(IJL associated partner)*

- *8.1.o* *The Research and Development Agency (RDA) - Provincial Government of Papua Barat (IJL associated partner)*
- *8.1.p* *Ambassade de France en Indonésie et au Timor Oriental / Kedutaan Besar Prancis untuk Indonesia dan Timor Leste*
- *8.1.q* *MUSE i-Site " "Montpellier University of Excellence"*

- *A principal agreement signed by the CEO of each institution to which the project leaders are affiliated.*
  - *8.2* *Memorandum of Understanding LIPI - IRD concerning scientific and technology cooperation (5th April 2017)*

Appendix 9. *Literature cited*

Appendix 10. *What are the differences between a cMOOC and a xMOOC ?*

Appendix 11. *List of member universities of the 'DIVA Indonesia' network*

Appendix 12. *French-indonesian co-authored scientific publications of the IJL members in the framework of past and current research programs*

Appendix 13. *Academic training*

Appendix 14. *Map of the Indonesian archipelago, with location of the Selamat IJL platforms and of the observatory sites [full view]*

Appendix 15 *Table 1: Previous joint French-Indonesian research project in the fields of marine biodiversity, fisheries, and fish aquaculture, Table 2: Ongoing research projects & fundraising for new projects*

Appendix 16. *Global occurrence of Gambierdiscus and Fukuyoa species from published records from 2009 to 2018 (Tester et al. 2019).*

Appendix 17. *Table: a) List of topics for the first six sessions of cMOOC. b) Ideas for subsequent sessions.*

Appendix 18. *Training activities images in the marine molecular genetic laboratory at RCO-LIPI (within Lengguru capacity building program post expedition)*