1. Title of the program

Resilience of the Richest Reefs:
Defining the safe operating space for tourism in Marine Protected Areas

2. Applicants

WU Graduate Schools
Wageningen Institute for Environment and Climate Research (WIMEK),
Droevendaalsesteeg 3a, Building 100, 6708 PB Wageningen
Wageningen School of Social Sciences (WASS), Hollandseweg 1, Building 201, 6706 KN Wageningen
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WU program leader
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3. Program description

a. Problem statement

Coral reefs are under severe threat worldwide[1]. Some of the most biodiverse reefs in Indonesia and the Dutch Caribbean are currently a focal point for **marine conservation** by governments and organizations. At the same time these reefs are actively promoted as a key attraction for **marine tourism**[2,3]. Tourism is predicted to grow rapidly in the coming decades (UNWTO, 2019), while the current COVID-19 crisis has shown that it can also suddenly come to a complete standstill. The key question we address is how tourism, in combination with other drivers such as climate change, fishing and pollution, will affect the ecological integrity, local livelihoods and social cohesion of these marine tourism hotspots.

Marine protected areas (MPAs) are commonly used to protect coral reefs and to serve as a reservoir of biodiversity for a larger region, as well as to sustain livelihoods, e.g. through marine tourism. An MPA consists of an ecosystem, a social system and a governance arrangement to restrict access and distribute benefits. In other words, an MPA is a multidimensional entity requiring an interdisciplinary approach to understand and **adaptively manage its resilience**. The resilience of MPAs refers to the capacity of the social and ecological system to respond to environmental and societal changes and absorb perturbations without losing the functions and composition[4–7]. Marine tourism may support the resilience of MPAs, e.g. by financing marine conservation measures, but may also reduce the resilience by putting stress on the ecosystem and affiliated societies[8]. A key challenge remains to understand the dynamics of the MPA as a whole: how are social and ecological factors interlinked and how do they affect resilience? In the proposed project, we set out to identify and develop the conceptual and hands-on methodological tools for analyzing how resilience can be (i) measured, (ii) monitored, and (iii) governed to safeguard the marine protected areas in a future of fluctuating tourism and climate change.

Through **onsite interviews and digital workshops** between January-September 2020, diverse stakeholders from Indonesia and the Dutch Caribbean have identified the following needs where maximal impact can be made: (a) filling key gaps in knowledge on biodiversity dynamics, hydrodynamics, nutrient flows, financial flows and governance structures;(b) understanding the ecological, economic, and social effects of tourism;(c) building awareness among tourists and locals about their direct and indirect impact on the system;(d) enriching higher education and academic development of faculty at local universities;(e) training staff of NGOs and local government in advanced monitoring techniques;(f) low-tech solutions for sanitation;(g) tool for adaptive management of tourism and other drivers of change in the MPAs. In order to address the stated issues, we propose a **social-ecological-systems approach** to sustaining the resilience of Marine Protected Areas in the face of growing tourism and climate change[4,5,9]. This approach explicitly links the resilience of ecosystems to governance structures, economies and society. Central to this endeavor is an improved understanding of the state of the social-ecological system of the MPAs in different levels of tourism development.

b. *Objectives (short and long-term objectives)*

While Wageningen University (WUR) has a strong research profile on marine science, social-ecological systems and resilience, those efforts remain somewhat fragmented. In this INREF proposal some of the most visible, productive, and promising **mid-career scientists** will join forces to make **Wageningen one of the global hotspots** of social-ecological systems research and coral reef research in particular. Our actions are guided by short and long-term objectives that have been co-developed with our network of **academic partners,** the **private sector** (branch organizations and representatives from the tourism sector), as well as **conservation NGOs** that play a central role in the creation and management of the MPAs, and the **public sector,** where we have the support from regional and national level of governance. The variety of **academic organizations** in Indonesia, Dutch Caribbean and the Netherlands match and bring in diverse expertise in conservation, sanitation, governance, hydrodynamics, economics, governance and tourism. The proposal has been co-written by all members in Table 2 (at end of proposal), underscoring the strong **ownership among all partners,** including end-users and stakeholders.

General aim: Build resilience of MPAs in an age of tourism and climate change

Short term objectives (within timeframe of the project)

- Build human and institutional capacity at universities, institutes and NGOs in Indonesia and the Dutch Caribbean through joint sandwich PhDs, technical workshops and scholarships.
- Develop an interdisciplinary online education program on MPAs and social-ecological-systems within WUR, and among Indonesian and Dutch Caribbean institutions.
- Develop, assess, and implement scalable solutions to manage drivers and stressors in small island ecosystems (e.g. develop sound sanitation practices).
- Co-Develop and assess a dynamic Resilience Dashboard to monitor and track resilience indicators that (i) can be adapted as needs, stressors and available data evolve and (ii) is scalable and can be used for other social-ecological-systems.

Long term objectives (beyond timeframe of project)

- Lead and advance excellence in interdisciplinary research and education in social-ecological systems at WUR and partner institutions
- Craft a strong network and strategic international and transdisciplinary partnership of knowledge institutions, MPA authorities and management bodies, and private sector in Dutch Caribbean and Indonesia that can contribute to Research for Development and Education (RfDE) and compete for international grants on Sustainable Development Goals (SDGs)
- Contribute to healthy life below water and a sustainable use of related marine resources (SDG14), resilient coastal ecosystems to combat impacts of climate change (SDG13), methods for integration of SDGs (SDG17) though SES approach and dashboard.

c. Conceptual framework & contribution to multidisciplinary research

We will analyze the social-ecological system of selected MPAs in Indonesia and the Dutch Caribbean, by focusing on drivers of change (such as climate change), the mediating factors (such as institutional capacity or social capital) and inherent feedbacks and interactions to understand how local and global stressors can be effectively managed[6,10]. The current exposure to an interplay of stressors and external drivers gives rise to complex dynamics with potentially catastrophic effects that tend to come as surprises[4,5,11]. Interestingly, increasing evidence shows that the critical level of climate change beyond which a system will lose its function may be altered by conditions that can be managed locally[4]. In other words, global shocks may be cushioned by local management strategies. Safeguarding the sustainability of coral reefs requires an understanding of the **flows above and below the sea surface** that determine the dynamics (see Fig.1). For example, the attractiveness of a coral reef may have a positive impact on tourist numbers and activities, which could partially finance MPAs, but may also put additional pressure (e.g. via sewage) on the ecosystem, potentially eroding resilience of the reef against disturbances (e.g. climate change). An MPA is a protected zone of sheltered habitat, but it is physically, ecologically, economically, and socially connected to a world outside the MPA. For example, the currents and bathymetry will determine how pollution from nearby villages or resorts affect the coral reefs inside the MPA. Also, the opportunities and profits to be made in the tourism industry, may trigger migration and investment from outside the MPA, which again has effects on the resilience of the reef. Finally, MPAs are exposed to larger national or global external drivers, such as climate change, population growth, technological change, socio-

economic change that affect the resilience of the system. Those external drivers may lead to gradual changes (e.g. sea level rise) or unexpected events (a complete halt of international mobility because of Covid-19). Together, the combination of small-scale and large-scale flows determines the multidimensional resilience of the system. Ultimately, the goal of conservation and management efforts is to preserve or achieve a stable state, in which the coral reef can sustain human well-being (defined by the SDGs) at levels deemed acceptable**.**

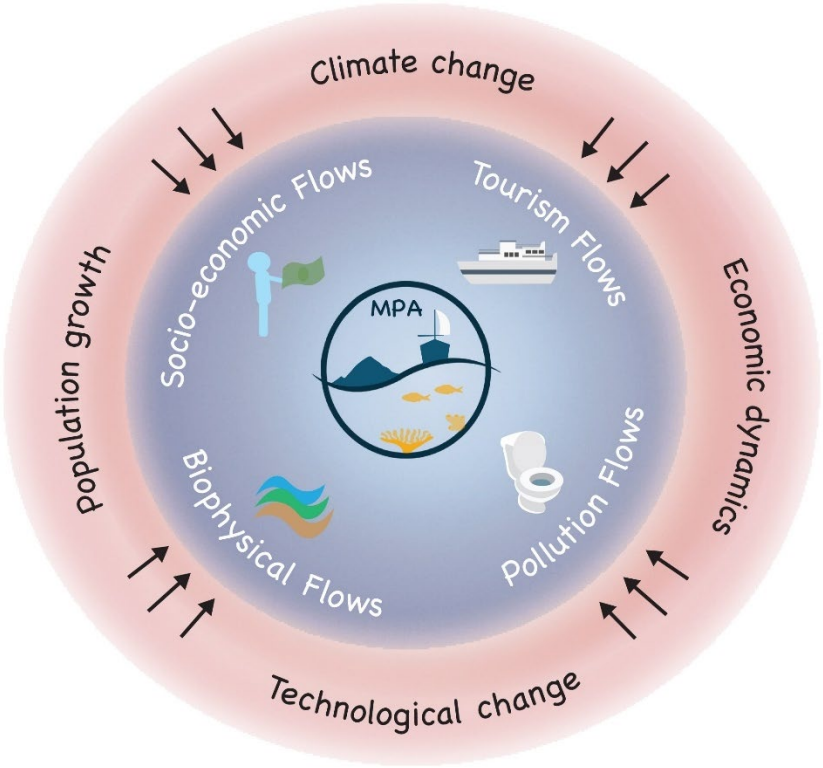

Figure 1: Conceptual framework of the project. Coral reefs are governed as marine protected areas (MPA), where (i) biophysical, (ii) pollution, (iii) socioeconomic and tourism flows within and from outside the MPA affect resilience. Key drivers, such as climate change, population growth and migration, and economic and technological dynamics trigger gradual changes and unexpected events. The interaction of drivers and flows determine the safe operating space of the MPA (the blue area). A dashboard can visualize how close the current state is to threshold values that are considered outside the safe operating space.

Our partners in the field identified the need for adaptive management of MPAs, yet they miss the knowledge and tools to implement this adequately with appropriate indicators. Besides local differences, there are interdependencies within reefs as well. A safe level for one stressor depends on the level of other stressors. We need to understand these synergies, to define a multidimensional space of safe values, the so-called **safe operating space**[4,9]. We will develop a dashboard to visualize the safe operating space for each MPA. Each indicator on the dashboard will have a range of safe values, including signal-values identifying the need for action/caution. End-users can use the dashboard to identify how close current stressors are to threshold values that are considered outside the safe operating space, and can use the model behind the dashboard to simulate management strategies. Most coral reef studies focus on pathways of degradation. We aim to use our gained knowledge of interactions and dynamics of the local social-ecological system to identify pathways to build resilience against current threats, such as those related to climate change and tourism.

d. ***Activities (including number of PhD and MSc students)***

In total 12 sandwich PhDs, 2 Postdocs, at least 20 MSc in six workpackages:

- WP1 Biophysical flows: biodiversity and hydrodynamics
- WP2 Pollution flows: nutrients, sedimentation and plastic
- WP3 Socio-economic flows and governance arrangements
- WP4 Social-Ecological-System: integration of all flows
- WP5 Resilience Dashboard: tool to visualize and manage all flows and indicators
- WP6 Education, Consultation & Dissemination: integration of knowledge

All WPs are seen in relation to resilience to tourism and climate change. Another common focus will be the ecological, social-economic and governance focus on target species that are commercially important for the local communities (giant clams, conch, lobster, sea cucumber, snapper, grouper, sharkfins) as well as ecologically important indicator species (coral, algae).

Most PhDs will be sandwich candidates, i.e. they will have a faculty or staff position in one of the collaborating research institutes. After graduation they will return to their formal position. Where this is not the case, we will ensure traineeships. *Please see section 4 for methods and tasks.*

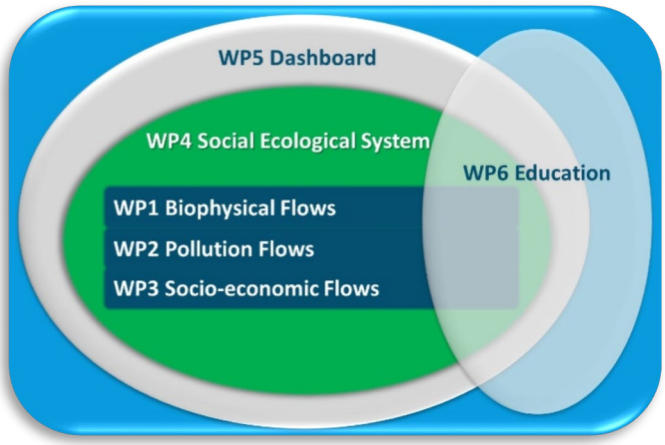

Figure 2. Workpackages showing interdisciplinary research. Our project consists of six workpackages (WPs) in total: three interconnected WPs focused on the dynamics underlying the flows of biodiversity, hydrodynamics, pollution, socio-economics and governance (WP1-3), embedded in a WP for integration by developing the social ecological system (WP4), while all these WPs are the backbone for the WPs on the Resilience Dashboard (WP5) and Education, Consultation & Dissemination (WP6) which in their turn weave throughout all WPs.

e. Expected outputs and follow-up activities

This program will result in a range of outputs and follow-up activities important for realizing multiple SDGs in marine conservation and tourism settings worldwide

1. Increased scientific knowledge: at least **50 publications,** 12 **PhD theses and 20 Master theses** completed and defended.
2. **New, interdisciplinary and innovative research approaches and methods** to understand biophysical and socioeconomic flows, marine social-ecological systems, coral reef conservation, tourism and governance.
3. **Resilience Dashboard**, a knowledge platform, that enables MPA decision-makers to monitor levels of critical indicators within a Safe Operating Space (Fig. 3). The aim of the dashboard is threefold: 1. Informing the public, 2. A policy tool to identify governance strategies and instruments to build necessary infrastructure and steer tourism developments and activities within these limits, 3. An education tool.
4. A **Citizen science application**, connected to the Resilience Dashboard, for both locals and tourists to contribute to monitoring critical indicators in the context of marine conservation and tourism (indicator species, trash, and experience levels) and for raising awareness.
5. **Educational program** that builds the necessary expertise and capacity for MPA authorities in Indonesia and the Dutch Caribbean to monitor and steer tourism developments within the safe-operating-space. We aim to build this capacity by academically training professionals in the two case regions, by strengthening academic and vocational curricula in educational institutions in the two case regions, and by developing online training materials (knowledge clips) to be used worldwide. Moreover, the program will result in an international **PhD training course**, organized at Wageningen University & Research on with the tentative title "Building social-ecological resilience of MPAs".
6. **Training workshops** developed and executed to train local partners to use the Dashboard, monitoring techniques, survey methods.
7. An **international final conference** of academics and practitioners from the fields of marine conservation, tourism, social social-ecological-systems analysis
8. **Travel Fellowships** for prospective MSc students from the two case regions to be trained within the network of academic partners of the program.
9. **Plan for attracting additional funding** beyond INREF, for expanding the approach developed within this program to other exemplary regions and for scaling up this approach to international, regional and global levels.
10. The program will result in a **new generation of research leaders at WUR** and build a strong international research network capable of developing strategic international RfDE partnerships in the area of tourism, marine conservation, and resilience in small island development states.

f. Targeted SDG and the relevance of the program for these SDGs

Tourism is considered an important sector relevant to reaching several SDGs in small island developing states (SIDS) and archipelagic states (UNDP-UNWTO 2017), for example through decent work, economic growth (SDG8) and responsible consumption and production (SDG12).

But how this should take shape is still up for academic and societal debate. This project will tackle the relation between tourism, marine conservation and livelihood by focusing on a selection of SDGs. We will analyze tourism development in relation to hygienic standards and health facilities (SDG3). For example, many emerging coastal destinations will continue to dispose sewage in the marine environment, releasing increased nutrient levels in the marine environments with detrimental effects (SDG14). We will analyze the limited governance capacities in SIDS and their dependence on partnerships between state and non-state organizations, such as the enforcement, monitoring and financing of tourism development and marine conservation, including nature conservation organizations, foundations and philanthropic networks, and international academic organizations (SDG10,17). The envisaged research stimulates climate action by advancing the resilience of ecosystems that ameliorate impacts of climate change (SDG13). Enhanced understanding of the resilience of the richest reefs allows for the implementation of guidelines and regulations to allow for a sustainable use of the related marine resources (e.g. tourist experiences, fish stocks, water quality)(SDG14).

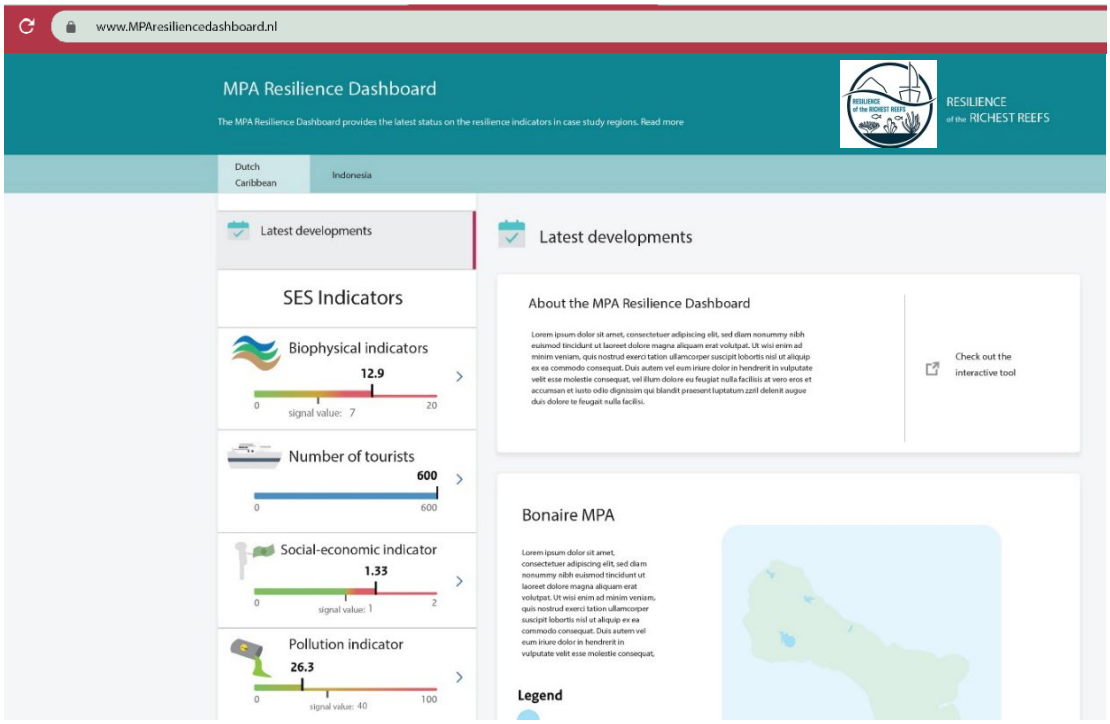

Figure 3. Illustration of online Resilience Dashboard and policy tool, inspired by the CoronaDashboard. Now only example indicators are given, in the project multiple indicators will be developed per flow within the social-ecological-system. Indicator values and signal values will be identified in the project in WP1-4. This Dashboard will function as a decision support tool, as well as an education tool. Once baseline information on underlying dynamics is established the dashboard can be updated with monthly (automated) measures. The 'maximal acceptable levels' or the red zones will be variable, as the thresholds of safe operating space are dependent on the interconnected dynamics, e.g. the 'acceptable' number of tourists may increase, if proper sanitation systems are installed.

g. Location of the program activities

Current studies on social-ecological-systems and resilience of coral reefs are either on a broad conceptual level or, alternatively, are constrained by their disciplinary focus, site-specific nature and limited spatial replication. Studying replicate MPAs under different degrees of tourism development in Indonesia and the Dutch Caribbean allows the formulation of general conclusions, while in depth studies allow specification of drivers of change, threshold values and interactions. This allows intra- and interregional comparison and testing of concepts and simulations which will greatly enhance the field. In **Indonesia** we will study three regions: 1. Bali (Nusa Penida: mass tourism development with cruiseships), 2. Eastern Moluccas (Banda & Lease Islands: moderate tourism), 3. Raja Ampat (with low, but rapidly increasing tourism and access). In the **Dutch Caribbean** we will study three regions: 1. Aruba and Bonaire (mass tourism with cruiseships), 2. Saba (moderate tourism), 3. St. Eustatius (low tourism). The selection of the MPAs has been made based on longstanding expertise and in close collaboration with the network of the consortium. Each of the MPAs involved provide a specific and contrasting set of challenges within the Social-Ecological-Systems framework, providing a rich environment for learning and experimentation.

4. Methods and approaches

	Workpackage 1	Biophysical flows
Tasks	T1.1 (PhD1-2) Map regional and local hydrodynamic flows and bathymetry in Indonesian and Caribbean MPAs and develop hydrodynamic numerical models to identify hotspots for monitoring biophysical & pollution flows (in **WP2**) using flow monitoring, Multibeam mapping, Hydrodynamic modelling, Tracer simulation[12] T1.2 (PhD3-4) Map biodiversity and distribution of economically and ecologically important indicator-species (input interviews **WP3**) using genomic techniques, underwater drones, deep learning techniques of photo-analyses T1.3 (PhD1-4) Quantify population connectivity and spill-over of fish between MPAs and surrounding regions (input interviews **WP3**) T1.4 (PhD1-4) Identify indicators of biophysical flows and Reef Health Index for Inter-regional comparisons and for Dashboard (**WP5**)	

	Workpackage 2	Pollution flows
Tasks	T2.1 (PhD5-6) Map nutrient runoff from islands and ships and quantify regional and local pollution flows through tracer studies with hydrodynamic models[13] (targets for monitoring in **WP1**) using nutrient flow modelling T2.2 (PhD5-6) Construct island elevation maps to simulate flows of sediments, nutrients, plastics and solid waste across the land-sea interface and identify their sources and sinks (informed by models from **WP1**) using aerial imagery analysis, drone surveys, automated catchment detection T2.3 (PhD5-6) Assess the impact of sedimentation, nutrients, plastics, and solid waste on coastal coral, seagrass and mangrove ecosystems (biodiversity indicators from **WP1**, input interviews **WP3** and citizen science **WP4**) T2.4 (PhD5-6, commercial party) Interregional comparison of impacts of different sanitation practices on the resilience of MPAs with a reef health status (Dashboard indicators **WP5**) T2.5 (commercial party) Develop and implement sanitation solutions and guidelines for local implementation, improving ecosystem and human health (knowledge transfer **WP6**)	

	Workpackage 3	Socio-economic flows and governance
Tasks	T3.1 (PhD7-8) Map discourses of tourism development and marine conservation using discourse analysis, focus group sessions, and interviews. T3.2 (PhD9-10) Assess socio-economic flows in relation to tourism and alternative economic opportunities and evaluation of benefits and external cost distribution. T3.3 (PhD9-10) Assess the motivation and steering capacity of various actors, networks, and their instruments in governing key flows, such as tourism or fishing using behavioral economics and randomized control trials. T3.4 (PhD9-10) Identify and test effectiveness and efficiency of strategies and instruments that can govern these flows towards safe levels (leverage points for citizen science **WP4**) T3.5 (PhD7-8) Identify strategies to make conservation funding and livelihoods more resilient and less dependent on mass tourism (governance toolbox **WP5**) T3.6 (PhD7-10) Assess the window of opportunity for transformation: How can an undesirable state be transformed to a desirable, sustainable state (input **WP6**)	

	Workpackage 4	Social-Ecological Systems integration
Tasks	T4.1 (PhD11-12) Map the social-ecological system: identify interactions, drivers of change, mediating factors, feedbacks and potential for tipping points (**WP1-3**) T4.2 (PhD11-12) Develop social-ecological systems models, using participatory approach (interviews, fuzzy cognitive webs), social media/big data (nr. tourists, attractiveness area), satellite data (coastal development, erosion), citizen science, monitoring data (input **WP1-3**). Evaluate policy options and simulate future scenarios for Indonesian and Caribbean MPAs. T4.3 (PhD11-12 & commercial party) Develop code for 'Tourist as monitoring device' using image and text analysis from social media. T4.4 (PhD1-12) Identify indicators of resilience for Dashboard (**WP5**), available data sources and range of sustainable and unsustainable values for each indicator (input **WP1-3**) T4.5 (PhD11-12) Identify, analyze and explain relationships between Dashboard indicators and reef resilience using the SES-model (input **WP6**)	

	Workpackage 5	Dashboard
Tasks	T5.1 (PD1, external party) Develop an interactive Dashboard of the resilience of the MPAs, with signal values, assess, test and validate the Dashboard with different end-users T5.2 (PD1) Identify means of automatic data feed of selected indicators into the dashboard (e.g. #tourists permits sold, number of boat trackers, dataloggers)and a framework for data collections T5.3 (PD1, whole team) Combining monitoring protocols of Dashboard indicators and determine monitoring frequency for each indicator (based on **WP1-3**) with local end-users T5.4 Identify what kind of information would trigger and inform policy makers or nature park managers	

	Workpackage 6	Consultation, Education, Outreach
Tasks	T6.1 (PD2, whole team) Develop a joint online MSC course between academic partners integrating knowledge clips of **WP1-5** T6.2 (PD2, whole team) Website with key knowledge clips for lay public in English, Indonesian, Papiamento and Dutch for general public T6.3 (PD2, commercial party) Develop citizen science app to monitor reef health and pollution T6.4 (PD2, whole team) Local training in monitoring skills, e.g. genetic techniques, monitoring, waterquality. Develop education links with SISSTEMS program of Aruba University and Traineeship program of DCNA. Develop scholarship program for Dutch Caribbean MSc students aligned with Traineeship program of DCNA T6.5 (whole team) Develop outreach and advocacy strategy	

The results from WP1-2 will inform the questions asked in WP3, and results of WP3 will inform locations and targets in WP1-2. Results from WP1-3 will inform the locations for monitoring and provide the data and material for WP4-6.

Activities to ensure integration

The project is specifically designed to ensure that results will be used by the target groups. Marine Protected Areas are social-ecological systems that can neither be understood, nor governed when looking into each sub-system separately. Hence, an integrative approach is key to generate the knowledge that safeguard the resilience of coral reefs around the globe. We set out to break academic silos and harvest synergies between the different PhD projects. As is well known, despite good intentions and hopes, interdisciplinary work rarely emerges spontaneously, but requires careful nurturing, fostering, and hard work. Therefore, our INREF proposal is deeply integrated across disciplines. To **safeguard feasibility**, all PhD projects are firmly anchored in one discipline **with a supervision team composed of different natural and/or social sciences researchers.** In addition, the **WPs are cross-regional**, making sure that all PhD students in each WP will work together. A **data officer** will help to document and share all data, and also archive all data. An important mechanisms to achieve integration are joint **workshops and field campaigns, u**sing a past expedition format as example. Every six months we will conduct a 3- day virtual workshop following a format that we developed during the consortium building with INREF Seed Funding, where we include a **discussion moderator** to keep us on track and towards tangible outcomes. Furthermore, integration will be achieved through **joint publications**. While several multi-author, multi-disciplinary papers are envisioned, those will be carefully planned with the PhD candidates and the supervisory teams.

Education is an important WP which is instrumental for integration, where PhDs will act as learners, as well as teachers. While all PhDs will follow the PhD courses offered by the Wageningen graduate schools, we will also set up an **international PhD course** with the tentative title "Building social-ecological resilience of MPAs". Each WP will develop at least 3 educational videos that will be combined in an online course.

A key component to achieve integration is the **Dashboard WP**. The developed software and education, should not only function well and provide reliable results, but also be user friendly. Therefore, software will be developed in collaboration with stakeholders, to ensure that it produces output that is clear and relevant. Our **commercial partner for web design** has extensive experience producing software for different target groups. Equally important is a deep understanding and motivation of tourists, locals, conservation groups, and civil servants to actually use the information. Therefore, software will be developed in close collaboration with stakeholders. Importantly, end-users are already part of the consortium.

5. Time frame

PhD/PD	2021				2022				2023				2024				2025				2026			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
PhD1 - hydrodynamic flows Indonesia																								
PhD2 - hydrodynamic flows Caribbean																								
PhD3 - biodiversity flows Indonesia																								
PhD4 - biodiversity flows Caribbean																								
PhD5 - pollution flows Indonesia																								
PhD6 - pollution flows Indonesia																								
PhD7 - governance flows Indonesia																								
PhD8 - governance flows Caribbean																								
PhD9 - socio-economic flows Indonesia																								
PhD10 - socio-economic flows Caribbean																								
PhD11 - SES Indonesia																								
PhD12 - SES Caribbean																								
PD1 - dashboard development																								
PD2 - education																								
ALL - consultation, education, outreach																								
		M1 - project launch with stakeholders	M2 - start PhD students		M3 - joint field campaign Indonesia 1	M4 - joint field campaign Caribbean 1			M5 - joint field campaign Indonesia 2	M6 - joint field campaign Caribbean 2			M7 - stakeholder workshops Dashboard	M8 - launch sanitation solutions & guidelines		M9 - stakeholder workshops Education	M10 - final symposium PhD2 1-10			M12 - stakeholder workshops Dashboard	M11 - final symposium PhD11-12 & PD1			M13 - launch Dashboard & training program

Table 1. Planning of the proposed program, including Postdocs (PD), PhDs and program milestones (M1-M13). PhDs 11-12 will start later, as they require input from PhDs 1-10; they will join the 2nd field campaign to ensure integration and cohort development.

6&7. Partnerships, Organization and Management of the program

The core team consists of mid-career Assistant & Associate Professors, who form the **backbones of our university** and are on a promising path towards full Professorship. Hence, the proposed ideas come from the noisy engine rooms of our university, but they also represent the future of our university. We team up with educators, conservationists, policymakers, and researchers from universities as well as research institutes, NGOs and regional governmental agencies from Indonesia, the Dutch Caribbean and the Netherlands; **see picture and list of committed team members and organizations in Table 2 at end of proposal**. The framework of the social-ecological system binds us, by focusing on drivers, feedbacks and interactions within and between our respective fields. The team is open-minded and has experience in interdisciplinary collaborations, as well as proven abilities in funding acquisition, PhD supervision and leading projects to successful completion. The PI has worked in Indonesia since 2007, and the Dutch Caribbean since 2012, fostering long-term collaborations and a lively network of professionals who are now actively involved in the proposal. The proposal **builds upon and strengthens** existing initiatives. The proposed research also strengthens collaboration with our 4TU partner University of Twente (UT) through the involvement of Erik Horstman (Assistant Prof from UT), and contributes to the **4TU strategic research program** 'Designing Systems for Informed Resilience Engineering' (DeSIRE).

The Management Team consists of Dr. Becking as project chair with Dr. Lamers and Dr. van de Leemput as Co-chairs from WUR, Dr. Tapilatu (Papua University), Dr. H. Maduppa (Bogor University), W. Mangile (The Nature Conservancy Indonesia) from Indonesia, and T. Bervoets (Dutch Caribbean Nature Alliance), E. Meijts (Aruba University) C. Eckert (STINAPA) as from the Dutch Caribbean; Dr. Vermeulen and Dr. Strokal as Technical manager and Dr. Richter as Dissemination manager.

The Utilization Panel consists of the funding partners and other non-funding stakeholders, such as Prof. O. Karna Radjasa (Indonesian Institute of Sciences (LIPI), Indonesian Ministry of Research & Technology), Dr. Augy (Director Research Centre for OceanographyLIPI), Purwanto (Coral Triangle Centre), P. Shyafri (Director Raja Ampat Regency), K. Wulff (director Saba Conservation), Dr. A. de Groene (WWF Coordinator Dutch Caribbean) M. Ammer (Papua Diving), Team of Indonesian and Dutch Caribbean students & alumni of WUR (see full list in Table 2 at end of proposal). For the full proposal additional end-users will be approached. The Utilization Panel will advise on all matters concerning societal impact and implementation of the results.

The Advisory Board comprises experts in the field.The Advisory board will advise on scientific progress, integration in WUR and will ensure the best possible scientific results.

8. Budget

Budget per calendar year (in k€)	2021	2022	2023	2024	2025	2026	Total
Sandwich PhDs	145	290	290	290	145		1,160
Postdocs	-	-	-	200	200		400
Assistants	2	2	2	2	2		10
MSc travel fellowships	8	8	8	8	-	-	32
Research costs (durable, non-durable goods, travel costs) for PhDs & PDs	-	80	80	40	-	-	200
Staff time for coordination, integration, and learning activities	3	3	3	3	3	3	18
Travel, accommodation expenses non-PhD& PD	15	15	15	15	15	15	90
Cost for workshops & exchange	10	-	10	-	10		30
Costs for external communication	2	2	2	2	2	2	12
Hiring external parties							
Sanitation solutions & guidelines	-	-	-	25	25	-	50
Dashboard development & operation	-	-	-	-	50	50	100
						Total :	**2,102**
						Total INREF:	**1,200**
						Total External funding (42%):	**902**

Strategy to raise additional funding
Since receiving the INREF Seed funding, we have applied for and received the *NWO – Science Diplomacy Fund (20K for education materials and workshop in Indonesia)* and the NIAS interdisciplinary workshop fellowship *(10K for kickoff workshop in NL).*

Bogor University, Papua University and Technological University of Bandung have committed to support at least 6 sandwich PhDs, where two years will be supported by these Indonesian universities. To ensure the financial support Indonesian Education Scholarships (LPDP) will be applied to as a 'top up' or as full PhD scholarships. Together with Aruba University, Curacao University, WWF, DCNA, STINAPA, STENAPA will seek means to support 6 sandwich PhDs though local grants, Dutch Ministry of OCW, Dutch Ministry of BZK, commercial parties, and Charity Funds. Conservation International, The Nature Conservancy and Coral Triangle Center are partners and will provide in kind support for field logistics, e.g. boats and logistics, in Indonesia. Discussions with WWF and the Ministry of Landbouw Natuur en Voedselkwaliteit will be started to obtain financial cover for developing the Dashboard. Hours of Wageningen Marine Research members (E. Meester and L. Becking) will be covered by BeleidsOndersteuned-project "Basisinventarisatie Koraal Caribisch NL". A TKI-KIA proposal "Veerkrachtherstel van natuur en maatschappij in CN" (PI: Erik Meesters) has been submitted, if this is granted will cover a portion of the research costs in Dutch Caribbean.

In order to build awareness and engage with possible charity funds, we have started a **PR campaign** on the project, through an interview in National Geographic Traveller (June 2020 edition), WUR advertisement in NRC newspaper (3 oct 2020), recording of public lecture for popular science via Universiteit van Nederland (4 Nov2020). Once our communication packet of website, videos and flyer is complete (end of Nov 2020) we will reach out to Charity Funds based on contacts of WUR and of our NGO partners.

9. Related Program(s) of Graduate School(s) involved

PhD education is a fundamental element of the project and will provide opportunities for three graduate schools. We will develop and contribute to PhD graduate courses.

Our project responds to the following WASS research themes:

- Natural Resources and the Environment: Conflicts, Competition and Collaboration; by analyzing the governance systems of marine tourism, conservation and fisheries in SIDS and archipelagic states.

- Disparities: Poverty, Wealth and Distribution: by analyzing livelihood contribution of tourism in SIDS and archipelagic destinations.
- Responsible Production and Consumption: Sustainability, Health and Quality: by focusing on sanitation challenges in tourism, as well as its contribution to nature conservation.

Our projects responds to the following WIMEK research themes:

- Climate action: Towards fair and effective solutions for climate change mitigation and adaptation; by analyzing to what extend MPAs are resilient in dealing with both climate and tourism
- Managing our future biosphere: Developing strategies for the sustainable use of soil, water, atmosphere, biodiversity, ecosystems and landscapes: by identifying measures to conserve the last remaining rich coral reef systems
- Advancing circular systems: Inclusive innovation towards closed water, nutrient, and material flows: by analyzing ways to close the nutrient and waste cycle from tourism

Our project responds to the following WIAS research themes:

- Fundamental and strategic research socially relevant animals: focus will be the ecological, social and governance focus on target species that are commercially important for the local communities.
- Research cluster "Population dynamics and genomics' will be strengthened with 2 PhDs
- Resilience investment theme

10. References (consortium members in bold)

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Table 2 Team of Indonesia, Dutch Caribbean and Dutch members of who have developed the Resilience of the Richest Reefs Program and have guaranteed their commitment to the proposed project

Name	Institution	Specialization
The Netherlands		
Dr. L.E. Becking	Dept. Animal Sciences, **MAE**, Wageningen University & Research (WUR); Wageningen Marine Research Tropenteam (**WMR**)	Marine biology; population genomics
Dr. M. Lamers	Dept. Social Sciences, **ENP**, WUR	Environmental policy; conservation; tourism
Dr. I.A. van de Leemput	Dept. Environmental Sciences, **AEW**, WUR	Social-ecological framework; dynamic modelling
Dr. E. Horstman	Dept. Water Engineering & Management, **University of Twente** (UT)	Biophysical interactions
Dr. E. Meesters	**WMR**	Coral Reef Ecology and conservation
Dr. B. Vermeulen	Dept. Environmental sciences, **HWM**, WUR	Monitoring & modelling coastal hydrodynamics
Dr. A. Richter	Dept. Social Sciences, **ENR**, WUR	Economics of Social-Ecological-Systems
Dr. M. Strokal	Dept. Environmental Sciences, **WSG**, WUR	Nutrient flows; land-sea connections
Dr. Tiemen Nanninga	LeAF	Commercial party to develop low-tech sanitation solution
	HydroLogic	Commercial party to develop Dashboard and tourism social media tool
M. Mercera	Hogeschool van Amsterdam	Informatica Docent and coordinator of app developing projects for students
Indonesia		
Awaludinnoer Ahmad	The Nature Conservancy Indonesia (TNC)	Coordinator Monitoring Raja Ampat TNC; Conservation management; coral ecology & governance; TNC is active in Maluku, Bali, Raja Ampat

Prof. R. Tapilatu	Research Center for Pacific Marine Resources, Universitas Papua (UNIPA)	Marine conservation & ecology
Purwanto & Agustin Capriati	Coral Trangle Center (CTC)	Coordinator Reef Health monitoring CTC in Maluku, Bali, Raja Ampat; Head officer conservation education CTC Maluku, Bali, Raja Ampat
N.Ismu Hidayat	Conservation International Indonesia (CI)	Coordinator Reef Health monitoring in West Papua
Dr. F. Pakiding	Universitas Papua (UNIPA)	MPA Social Impact
Prof. Ocky Karna Radjasa	Deputy of Earth Science, Indonesian Institute of Sciences (LIPI) Ministry of Research Technology and Higher Education (RISTEK)	Director of Research & Community RISTEK
Dr. Augy	Research Center Oceanography, Indonesian Institute of Sciences (LIPI)	Director
L. P. Aji	LIPI	Coastal ecology
Prof. Luky	Dept. Marine Sciences, Institut Pertanian Bogor (IPB)	Chair; Social Ecological systems
Dr. Hawis Maduppa	Dept. Marine Sciences, Institut Pertanian Bogor (IPB)	Marine restoration, biodiversity, and genetics
Dr. Ayi Tarya	Institut Teknologi Bandung (ITB)	Hydrodynamic modelling of coral reef systems
P. Shafri	Raja Ampat Regency (BLUD)	Director
A. Miners	Misool Eco Resort	Resort
M. Ammer	Papua Diving	Resort
In conversation	Raja Ampat Homestay association	
In conversation	Raja Ampat Liveaboard association	
Dutch Caribbean		
C. Eckert & R. Francisca & Bertuol	STINAPA (Bonaire)	Park manager & ranger
Dr. Erik Boman	Park manager STENAPA (St. Eustatius)	Park manager
Dr. J. Stapel & Dr. K. Watson	Caribbean Netherlands Science Institute (CNSI)	Director and Data Officer
Eric Meijts	University of Aruba	Director SISTEMSS program; Social-Ecological-Systems
Dr. F. Marchena	University of Curacao	Sanitation
K. Wulf & A. Kuramae	Saba Conservation Foundation	Park manager & ranger
T. Bervoets & D. Hassell	Dutch Caribbean Nature Alliance (DCNA)	Director and coordinator projects
Dr. A. De Groene	WWF	Coordinator Dutch Caribbean
D. Kool, E. Semeleer, S. Martinez, T. Becker	Team of Caribbean WUR students and alumni	Unofficial group of motivated and engaged (former) students who have been involved in all meetings
In conversation	Arikok Park	
To be approached	*Tourism Board, Dive Bonaire, SeaSaba*	
Advisory board		
Prof. M.Scheffer	AEW	
Prof. S. Bush	ENP	
Prof. T.Hoitink	HWM	
Prof. F. Alpízar	ENR	
Prof. K.Wijnberg	UTwente	
Dr. R. Hille Ris Lambers	WUR Biodiverse Environment	Program leader