NWO
Netherlands Organisation for Scientific Research
Earth and Life Sciences

Open Programme
Proposal form

The maximum length of a proposal is 11 pages.

1a. Details of proposal

Title: Assessing bioerosion drivers in the Caribbean region.

Area: x Geo and Biosphere O from Molecule to Organism

Summary (scientific summary in English, max. 250 words):
Bioerosion is a natural process that degrades carbonate structures of a coral reef. When erosion rates are exceeding calcium carbonate accretion it causes a net loss of the reef CaCO3 and 3D structure (i.e. habitat loss for reef-associated organism). Several studies have showed that bioerosion increases with enhanced nutrient loads; however the opposite has been demonstrated as well.

Research on bioerosion mainly has been located on the Great Barrier Reef and other locations within the Pacific. The main focus of prior research lies on the effect of enhanced nutrient loads on bioerosion. This study however aims to asses other drivers of bierosion as well. The different drivers assed in this study will be: physical environment, landmass, population density, threat index, fish abundance and reef health.

To increase the understanding of bioerosion processes and its effects on coral reefs, we herewith propose to investigate bioerosion within the entire Caribbean region by combining two different bio-erosion sampling techniques. Coral rubble will be collected at all locations to examine life macro bioeroders inside. Experimental blocks will be deployed to include bioersion by grazers and micro borers in the analyses. The main objective is to find the key drivers of bio-erosion in the Caribbean region.

1b. Details of applicant

Name: Selma Ubels
Gender: O Male X Female
Date of birth: 14-11-1984
Institution: NIOZ
Position: O Professor O Associate professor (UHD) O Assistant professor (UD) x Other:
Permanent position: O Yes x No, end date contract: n.a.
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Research School: University of Utrecht
Name and address of the responsible person at your institution (e.g. scientific director of the institute or dean of the faculty): Henk Brinkhuis (h.brinkhuis@uu.nl)

1c. Alternative contact

Name: Fleur van Duyl
Email: fleur.van.duyl@NIOZ.nl

1d. Renewed application? O Yes X No
In case of a renewed application please indicate the file number of the previous application and summarize the main changes

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1e. Applying for: x PhD student O Post Doc O Ship time

1f. Composition of the research group
List all staff members involved in the proposed research: provide name, initials, titles and type of involvement, e.g. daily guidance, technician, thesis supervisor, advisor.

Name and title	Specialization	Institution	Involvement
Dr. Fleur van Duyl		NIOZ	Daily guidance
Dr. Mark Vermeij		CARMABI	Thesis supervisor
Dr. Johan Stapel		knowledge centre St. Eustatius	Advisor

2. Summary for the general public
(please provide in 100 words a title and summary for the general public, preferably in Dutch)

Bio-erosie is een natuurlijk proces dat kan lijden tot afbraak van koraalrif wanneer het de opbouw van calciumcarbonaat overstijgt. Verscheidene studies hebben aangetoond dat een toevoeging van nutriënten kan leiden tot een toename van bio-erosie processen. Echter veel verschillende methoden voor het meten van bioerosie worden gehanteerd. Daarnaast is het voornamelijk gedaan op het Great Barrier Reef in Australië. Dit onderzoek heeft als doel de factoren die bio-erosie versterken in kaart te brengen in het gehele Caribisch gebied. Waarbij naast nutriënten hoeveelheden ook andere omgevingsfactoren (zoals bevolkingsdichtheden en status van het rif) in acht worden genomen. Hiervoor zullen twee verschillende onderzoeksmethoden worden gecombineerd.

3. Description of the proposed research

INTRODUCTION

The world's coral reefs are in various stages of decline, due to multiple anthropogenic threats including coastal development, overfishing, increased sedimentation and eutrophication. Currently 20% of the world’s reefs are effectively declined (Wilkinson, 2004) and there are no pristine reefs left (Jackson et al., 2001; Pandolfi et al., 2003).

A positive calcium carbonate deposition budget is necessary for reef building and maintenance. Bio-erosion, in addition to chemical and physical erosion, can degrade calcium carbonate structures (Neumann, 1966; Rose & Risk, 1985). When erosion exceeds carbonate accretion of calcifying organisms it causes net loss of the reef (Stearn et al. 1977; Goreau & Hartman 1963).

Bio-erosion is facilitated by external and internal bioeroders that respectively scrape and weaken the reefs 3D structure. External bioeroders are generally grazers and include fishes, echinoderms and crustaceans. Internal bioeroders are subdivided into macro and micro bioeroders. Micro bioeroders such as fungi, bacteria and algae are typically the early infesters of the substrate and make it more suitable for macro bioeroders such as molluscs, sponges and polychaetes (Tribollet & Golubic, 2005).

Sponges have been found to be the main bioeroder agents in several studies (Tribollet, Decherf, Hutchings, & Peyrot-Clausade, 2002) (Schönberg, Wilkinson, & Hoppe, 1996) (Rose & Risk, 1985). Erosion rates of sponges may be relatively high, a six month experiment revealed that potential erosion rate of burrowing sponges (*Cliona lampa*) can be estimated at 256g $CaCO_3$ per m^2 substrate per year (Rutzler, 1975). Sponges, as well as other internal bioeroders are mainly filter feeders. An increase of planktonic organisms (i.e. bacteria and phytoplankton) due to eutrophication has a positive effect on the abundance of internal bioeroders (Chaves-Fonnegra, Zea, & Gómez, 2007).

Numerous studies have recently focussed on the effects of eutrophication on bioerosion of coral reefs. These studies were exerted either on live corals (Carballo, Bautista-Guerrero, & Leyte-Morales, 2008; Holmes, Edingerà, Limmon, & Risk, 2000; Schönberg et al., 1996), coral rubble (Carballo et al., 2008; Holmes, 1997, 2000; Risk, Heikoop, Edinger, & Erdmann, 2001), experimental blocks (Carreiro-Silva, McClanahan, & Kiene, 2009; P. Hutchings, Peyrot-Clausade, & Osnorno, 2005; Tribollet et al., 2002; Tribollet & Golubic, 2005) or life 'in situ' counts (Le Grand & Fabricius, 2011). A recent review of >20 studies by Le Grand and Fabricius (2011) showed a positive correlation between internal macro bio-erosion and nutrient availability, independent on the kind of method used. Studies that questioned this relationship (Tribollet et al., 2002) were carried out on experimental blocks that were exposed for less than less than 3 years. Boring sponges and bivalves (both filter feeders) showed higher abundance with eutrophication. Polychaetes however displayed a more complex pattern; deposit feeders are more abundant at eutrophic sites while suspension feeders are more abundant at oligotrophic sites. Hence polychaetes vary in species composition rather than in total density.

In contrast to macro bioeroders ,micro bioeroders show higher abundance at oligotrophic sites than at eutrophic sites (P. Hutchings et al., 2005; Tribollet et al., 2002; Tribollet & Golubic, 2005). Micro borer communities are diverse and various nutrification components can have different effects on the micro-borer community. Enrichment with N and P led to an increases in autotrophic bioeroders and the total bio-erosion rates, while addition of OM led to an increase in only the heterotrophic bioeroders (Carreiro-Silva et al., 2009). Tribollett et al. (2002) and Tribollet & Golubic (2005) demonstrated micro bio-erosion to be the main agent of bio-erosion after one year. This is proving them to be important for total bio-erosion and possible preparation of the substrate for macro borers and grazers.

Studies at the Great Barrier Reef (GBR) Australia found grazers to be the main bioeroders. These studies compare inshore with offshore sites where offshore (pristine) sites experience higher grazing activity than inshore sites (P. Hutchings et al., 2005; Tribollet et al., 2002; Tribollet & Golubic, 2005). These patterns can be explained by the difference in abundance of grazers. Grazers however scrape the substrate from the surface while internal bioeroders weaken the reef framework from the inside. This can lead to increased vulnerability to storms and reduced coastal protection, hence a reduction of its 3-d complexity with habitat loss for reef-associated organism as a result.

OBJECTIVES

To increase the understanding of bio-erosion and its effects on coral reefs, we herewith propose to investigate bio-erosion within the entire Caribbean region by combining two different bio-erosion sampling techniques. The main objective is to find the key drivers of bio-erosion in the Caribbean region. To reach this objective we have the following specific aim:

> -To investigate the effects of habitat, with different environmental and anthropogenic conditions, on bio-erosion. Not only terrestrial runoff (i.e. nutrient loads) will be taken into account but difference in local physical, geographic and anthropogenic environment as well.

SCIENTIFIC APPROACH AND METHODOLOGY

To investigate the effects of the environmental conditions, seven locations in the Caribbean that represent different physical environment are chosen (Figure 2). The choice of locations is primarily derived from a study by Chollet et al. (2012) on the physical environments of the Caribbean Sea. Based on Sea Surface Temperature (SST), water clarity, salinity, wind-driven wave exposure, and hurricane incidence they categorised the Caribbean region into sixteen physicochemical provinces (Figure 1) divided over 6 broad groups (Table 1). The main oceanographic features of these groups are indicated in Table 1.

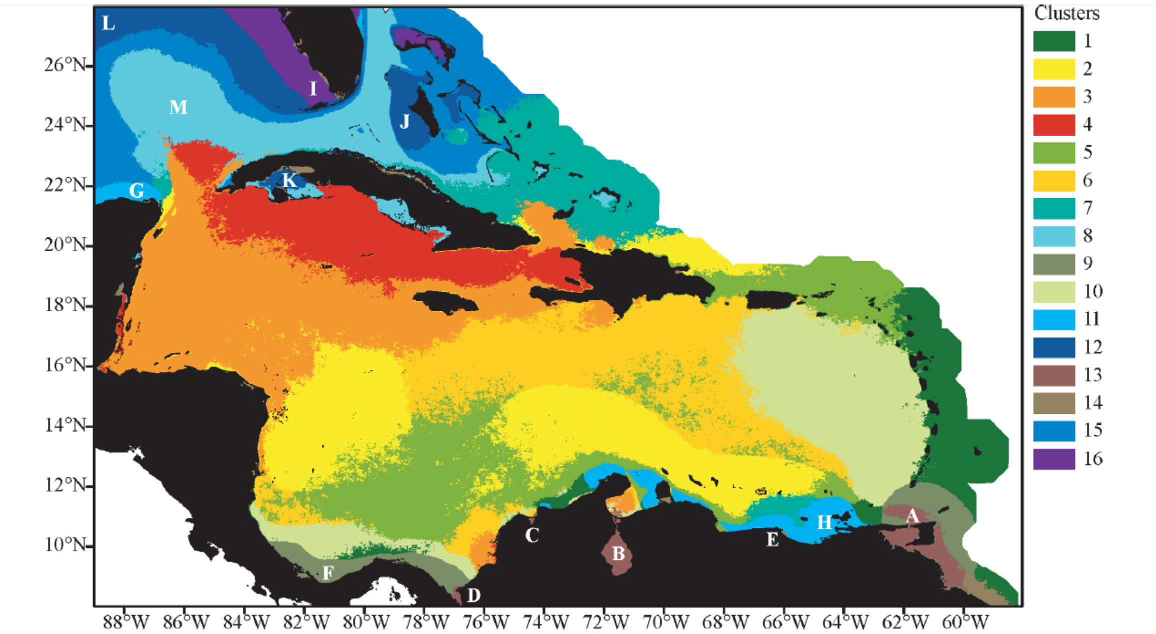

Figure 1. Spatial arrangement of the 16 physicochemical provinces in the Caribbean Sea, (Chollett, Mumby, Müller-Karger, & Hu, 2012)**. These can be divided over 6 groups (Table 1).**

Table 1. Mean oceanographic features of the 6 groups with assigned physicochemical provinces 1-16.

Group	Mean oceanographic features	Physicochemical province
1	Low water clarity, low salinity, average temperature	13
2	Low water clarity, average salinity, average temperature	14
3	Average water clarity, low salinity, average temperature	9
4	Upwelling	11
5	High latitude	12,15,16
6	Inner Caribbean	1-8,10

To ensure that the environment, and as a consequence the reef habitat, does not vary too much between locations, all our sites are located within the inner Caribbean (group 6). This group consists of 9 different physicochemical provinces. We excluded the two higher latitude provinces, 7 and 8. In every province we choose a location that consequently next to physical environment, differs in local climate, onshore population density, landmass and threat index (Table 2). The threat index is determined by Burke and Maidens (2004) by intergrading the four threats; coastal development, sedimentation, marine-based pollution, and overfishing (Burke & Maidens, 2004).

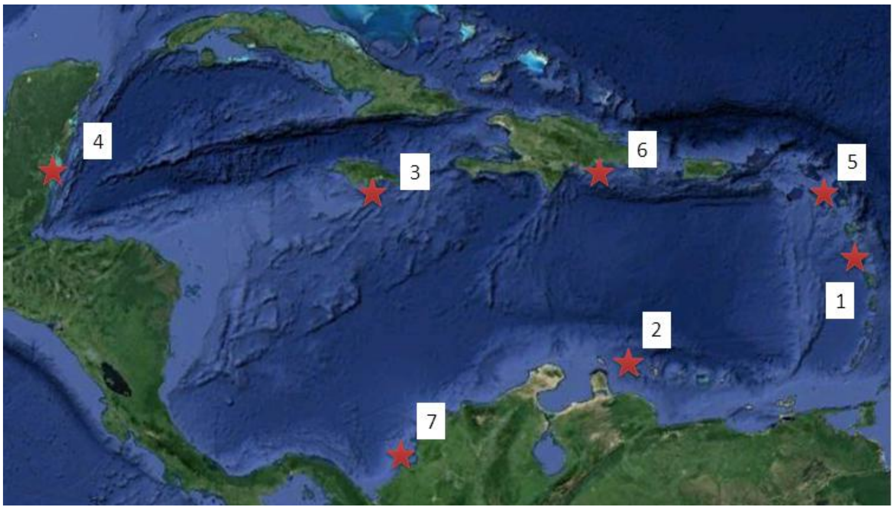

Figure 2. Proposed location for experiments and sampling. For physicochemical province, land and population properties and threat index see Table 2.

Table 2. Sample and experimental locations 1-7 with the associated physicochemical province, land and population properties and threat index.

Map nr.	Location	Physicochemical province	Land Properties	Pop density	p/km^2	Threat index
1	Dominica	1	Small island	Med	97	Very high
2	Bonaire	2	Small island	low	55	Low
3	Jamaica	3	Big Island	High	248	High
4	Belize	4	Continent	Low	14	Medium
5	St. Eustatius	5	Small island	Med	171	Low
6	Dominican republic	6	Big island	High	209	High
7	Colombia	10	Continent	Low	40	High

At all seven locations three sites will be visited. Experiments and sampling will be done between 3 and 6 meter depth. Bioersoion will be measured by using two different methods. Coral rubble will be collected to examine life macro bioeroders within the rubble according to the method by Holmes et al. (2000). At every location 15 pieces of coral rubble will be collected. To collect micro bioeroder and grazing data experimental blocks will be deployed for three years at all locations at 5 m depth (method derived from Tribollet et al. 2002). Data of both methods can be combined for creating a map of the bioerosion risks of a certain region.

Next to bio-erosion nutrient availability, reef health status and fish abundance will be examined per location. Reef health will be estimated by using transects to measure the percentage of coral cover, coral species diversity (Edinger, Jompa, Limmon, Widjatmoko, & Risk, 1998) and coral mortality index (Gomez, Alino, Yap, & Licuanan, 1994). With the aid of PRIMER™ v6 (Clark and Gorley, 2006) and PERMANOVA A+ for PRIMER (Anderson et al. 2008) PCO analyses will be performed to asses the importance of the different environmental factors that influence bio-erosion. Environmental factors used in this analyses will be physical environment, landmass, population density, treat index, fish abundance and reef health.

PREVIOUS RESEARCH AND INNOVATIVE ASPECTS

The aforementioned studies merely focussed on the effects of eutrophication on bio-erosion rates. When comparing for example inshore with offshore sites though (P. Hutchings et al., 2005; Tribollet et al., 2002; Tribollet & Golubic, 2005) many more components of the ecosystem may play a role in the composition and erosion rates of bio-eroding organisms. Overall grazing for example is dependent on the amount of grazers present at location, the same might account for other bioeroder agents such as bivalves and sponges. Variances in bioeroder agents can be caused by differences of larvae availability, larvae settlement, currents, food availability and substrate availability. In addition different stages of the reef might influence boring rates as well as across reef variances (Carballo et al., 2008). Destruction might begin from the outer areas and move towards the interior. Therefore in this study we aim to integrate different factors (physical environment, landmass, population density, treat index, fish abundance and reef health) that might influence the bioeroder community.

Bioerosion is a very complex process that is not fully understood yet. It becomes apparent that the various bioeroder agents (micro-, macroborers and grazers) have different effects on the total bio-erosion rates and on top of that react differently on eutrophication. This might be caused by the methods that have been used to determine bio-erosion. Examining life coral tissue is a good and accurate method for determining erosion rates within the life coral, however it is very destructive to the reef and therefore can only provide with limited material and information.

Measuring the eroded volume inside coral rubble can offer clues about erosion processes over a period of unknown length, but about the reef status of today's reef it provides with insufficient information. Unless a major killing event of a certain species occurred, the age of the rubble cannot be estimated. In addition it has to be kept in mind that boring rates are not constant over time (P. A. Hutchings, 1986), hence within a long period different stages of the reef are represent.

Holmes et al. (2000) counted life tissue still present in coral rubble after cutting. This method was compared to using life coral tissue and proved to be as effective to even more sensitive. Scoring life tissue in coral rubble is therefore a good alternative to the two afore mentioned methods.

Another well-developed method is the use of experimental blocks of calcium carbonate to examine the extent of macro and micro erosion over a certain period of time. This method can ameliorate micro bio-erosion examination. The disadvantage of experimental blocks is that the succession of the ecological community infesting the substrate is not completed after one year. The species composition between one and three years of experiment is still changing. Three years of exposure however might be sufficient but cannot be supported by literature so far.

Although there does not seem to be an effect of the used method on the results of the study (Carballo et al., 2008; Le Grand & Fabricius, 2011) the limitations of the various methods might have played a role in the different research outcomes observed. By integrating two different sampling and experimental methods we hope to obtain sufficient information on the effects of the chosen environmental factors on bioerosion. We therefore propose to use the rubble collecting method derived from Holmes at el (2000) and the experimental substrate deployment method as applied by Tribollet et al. (2002).

On top of this hardly any studies on bio-erosion are performed in the Caribbean region (Le Grand & Fabricius, 2011). The Caribbean region encompasses an entire different reef system than the Pacific region, with lower species diversity and different species composition. In addition bio-erosion never has been assessed on such a large scale. Performing bioerosion experiments and sampling throughout the entire Caribbean region will gather valuable new knowledge on destructive processes going on within a coral reef.

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4. Timetable of the project

Year 1
- Preparation of sample and experiment techniques
- Five month field trip
  - Deploying experimental blocks
  - Sampling rubble and collecting environmental data at 3 locations
- Processing collected data

Year 2
- Four month field trip
  - Sampling rubble and collecting environmental data at at 2 locations
- First publication

Year 3
- Three month field trip
  - Sampling rubble and collecting environmental data at 2 locations
  - Presentation at international conference
- Second publication

Year 4
- One month field trip
  - Collection of experimental blocks
  - Analyse in laboratory on experimental blocks
- Finishing data analyses and writing papers and thesis

5. Scientific embedding of the proposed research
Affiliation with national and international research programmes, national and international collaborations

The PhD position will be mainly stationed at the NIOZ, supervised by Fleur van Duyl who has years of experience with coral research in the Caribbean region. We will also collaborate with IMARES and receive support from the Wageningen interdisciplinary research programme Triple P @ Sea Caribbean Netherlands.

International collaboration will be provided by CARMABI institute (Dr. Mark Vermeij) on Curacao and the new knowledge centre for Caribbean research at St. Eustatius (Dr. Johan Stapel).

6. Societal significance

Coral reefs provide with economical services in the sense of fisheries and tourism as well as social and leisure services e.g. diving and snorkelling activities. Coral reefs in addition supply with natural coast protection. Bio-erosion is an important process for reef building and maintenance. In recent years there has been an increased interest in reef degradation processes on top of reef growth studies that have been the focus already for many years. Still not much is known about the destructive processes going on inside the coral reef. By investigating bioersion processes Caribbean wide we hope to fill in these caps in knowledge. This is important for management strategies and decisions making in a world where natural environments needs protection against the increasing human development.

7. Budget

		Year 1	Year 2	Year 3	Year 4
Personnel (mm)		12	12	12	12
Research costs (k€)					
	Equipment	3			
	Consumables*				2
	Fieldwork/Travel*	10	10	10	7

* The sums requested for consumables and fieldwork/travel expenses combined should not exceed 50,000 euro for the entire grant period.

Specification of the requested funds:
Equipment: Will include dive gear, little diamond saw device, other field equipment for collecting data, performing transect studies and deploying experimental blocks.
Consumables: Nitric acid and Formaldehyde for fixing experimental blocks after collection.
Fieldwork/Travel: Travel to location for collecting samples and set up of experiment is required every year during the PhD period. 10.000 should cover flights and all other travel expenses (car rental, boat rental, accommodation) per year.

8. Financial assistance from other sources

NIOZ will contribute ca. 10k€/yr. lab facilities, library facilities, office facilities and overhead costs.

9. Statements by the applicant

YES I endorse and follow the Code Openness Animal Experiments (if applicable)

YES I endorse and follow the Code Biosecurity (if applicable)

YES I have completed this form truthfully

Name: Selma Ubels
Place: Den Hoorn, Texel
Date: 12-07-2012

Please submit the application to NWO in electronic form (pdf format is required!) using the Iris system, which can be accessed via the NWO website (www.iris.nwo.nl). The application must be submitted from the account of the main applicant. For any technical questions regarding submission, please contact the IRIS helpdesk (iris@nwo.nl).