Sliced Ecosystem: Modelling Transects of Vulnerable Marine Landscapes

Joerg Rekittke[1], Yazid Ninsalam[1]

[1]National University of Singapore, Singapore · rekittke@email.de

Abstract: In this paper we discuss our digital work and design research on a vulnerable ecosystem, constituted by a landscape that is largely invisible for the unequipped visitor. Within the Bunaken Marine National Park of North-Sulawesi in Indonesia the landscape above the water's surface – mainland and islands – is deemed to be a minor matter. Contrastingly the main actor, relating to tourism, is the vast underwater world that is visible only for snorkelers and divers. This part of the National Park is most endangered by increasing visitor numbers and related environmental stress – above- and underwater –, affecting the mangrove belts, seagrass meadows, reef flats, reef crests and the vertical reef walls. We argue that it is a necessity to make these sensitive biotopes visible in the form of demonstrative models. We realise that the negative effects of mass tourism are so simultaneously numerous and subtle, that they can only be approached by detailed three-dimensional analysis and design. An understanding of the set of problems faced underwater is key for the design of necessary infrastructure and new forms of management on both water and land. Precise visualisation and modelling not only make sense in this context, they are requisite. While aerial imaging provides the ability to gather spatial data over large areas in short time, which is used to complement more detailed field-based sampling methods. The environmental as well as technological limitations of related underwater reconnaissance in such areas prevail. We centre on two aspects of the described above- and underwater challenge: 1) the experimental assembly of aerial, close-range terrestrial and underwater imageries to create a demonstrative model of the marine landscape, and 2) the corresponding generation of landscape design variants, using the demonstrative model as a baseline. We discuss the limitations and challenges of obtaining a transect model of the marine environment, which includes the complex mangrove structures. These mangroves epitomise the ever-changing conditions in an intertidal ecosystem, illustrating the temporary visibility and invisibility of marine landscape elements over water. Our field-based samples were embedded into a larger digital surface model acquired through aerial photogrammetry to obtain a spatially accurate demonstrative model for our design work. With a comprehensive baseline model, we are able to generate future scenarios and visualise design options.

Keywords: Landscape visualization, photogrammetry, modelling of underwater landscapes

1 Overview Machines

Digital approaches in landscape design have undergone a breakthrough since the application of terrestrial laser scanners; and the use of unmanned aerial vehicles (UAV) equipped with digital camera technology became quasi standards. The possibility to generate three-dimensional representations of reality in the form of dense point clouds catalyses a new generation of digital tools and methods. Erstwhile gadgets transformed into serious machines can thus be used to procure complex digital models. When tackling large-sized landscape projects, the contemporary landscape designer is well advised to carry an 'overview machine' – a UAV equipped with a powerful camera – in the field. It provides an unrivalled overall view, sometimes eye-opening insights, and emancipates the designer from any frustrating territorial myopia. The transformation of the visual material into point clouds leads to terrain models of significant precision – quick, effective and rather simple to generate. In order to advance our research on the in situ acquisition of digital elevation models for design tasks,

Journal of Digital Landscape Architecture, 1-2016, pp. 36-45. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-612-3, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537612005.

we look for challenging landscapes and timeless problem statements rather than the next short-lived digital product in an ephemeral market. The Bunaken Marine National Park, North Sulawesi, where a growing stream of dive tourists put the most species-rich coral reefs of the world at risk, represents such challenge. Only a fraction of its landscape is above water, meanwhile the better part lies underwater (Figure 1).

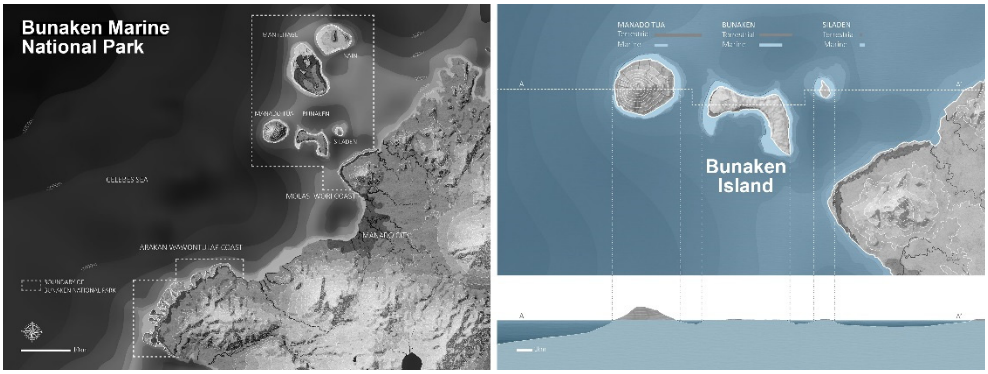

Fig. 1: Situated in the species-rich Malay Archipelago, the main landscape volume of the Bunaken Marine National Park extends underwater (Graphics: MLA Studio Rekittke, 2015)

We centred our efforts on both the under- and above-water areas of Bunaken Island, which is framed by the islands of Siladen, Manado Tua, and Mantehage. Within the immediate Bunaken ecosystem (Figure 2) we identified three main zones, namely: 1) the coastal secondary forest of the island, where a building boom for unsustainable resorts occurs; 2) the precious intertidal mangrove belt, which is increasingly perforated by the boat traffic to the resorts; and 3) the extraordinarily sensitive intertidal seagrass meadows that extend from the mangrove belt to the steep coral wall of the reef. These zones require instant design and management action to avoid further biotope loss and environmental damage. The uninterrupted tidal change influences the patterns of use of the described zones, and defines the accessibility of these areas concerning the selection of specific fieldwork tools and methods. While aerial and terrestrial digital photogrammetry produce synoptic representations of the visible landscape, the superficial invisibility of intertidal and underwater zones requires the landscape designer to submerge. Our aerial overview had been recovered by two DJI Inspire-1 UAV that are equipped with a Zenmuse X3-FC350 camera carrying a Sony EXMOR 1/2.3" sensor. The flight campaign covered an area of about one hectare. The central island road to the east, and the coral wall to the west bordered the area under investigation. 318 images were captured continuously at a frequency of one shot every five seconds – using the jpeg mode. Of these, 314 were calibrated with the help of the processing software Pix4D. The point cloud densification process produced approximately 13 million points at an average density of 21.03 per square metre. The UAV overview of the site provided us with a comprehensive georeferenced base model, which we could embed supplementary close-range terrestrial and underwater point cloud models within.

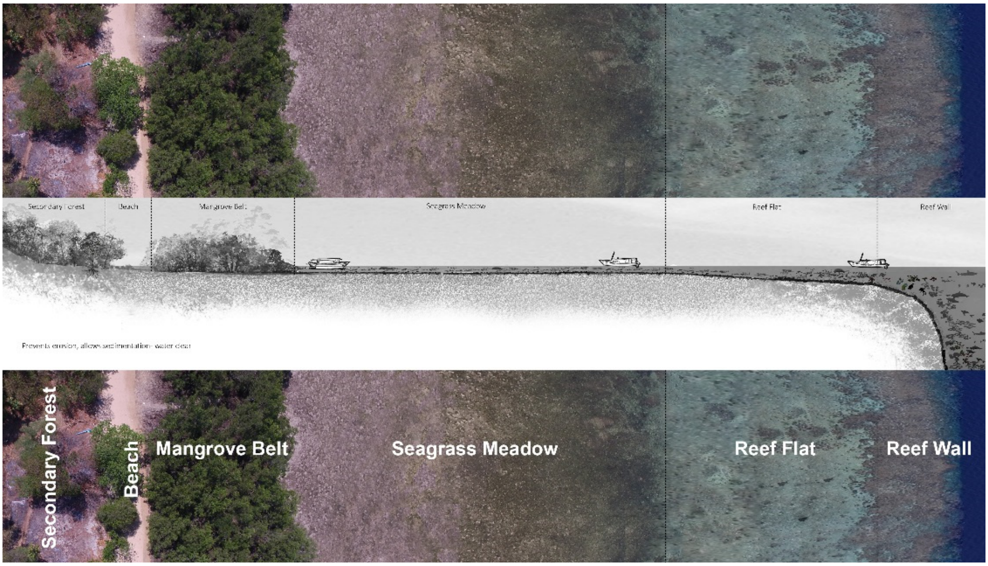

Fig. 2: Aerial image acquired by UAV and corresponding cross-section of the interconnected ecosystem, generated from the respective post-processed point cloud, overlaid with explanatory drawings by students. From left to right: secondary forest, beach, mangrove belt, seagrass meadow, reef flat, reef wall (Photo: Authors, Graphics: MLA Studio Rekittke, 2015).

2 Detail Generators

Our next step was to fill the gaps left uncovered by the UAV campaign. These gaps are found in areas under the vegetative canopy as well as in all underwater environments. In our campaigns, we have successfully produced samples of the species-rich coral reef that is permanently underwater (Figure 3). In this paper however, we focus on the modelling of the complex, exposed and vulnerable structures of the intertidal mangrove belt, located partly above and under the water's surface. In order to generate this segment of the model, we deployed two methods: 1) capturing the above water layer by foot or boat; 2) capturing the underwater layer by snorkeling. In order to contribute to the demonstrative model we chose a number of sites accessible by both methods. Above water, we deployed the well-tried GoPro Hero3+ Black Edition and a Canon EOS 550D DSLR by foot and boat respectively to capture overlapping images along the mangrove belt (Figure 4). The close-range terrestrial photogrammetry methods, applied previously for complex urban and vegetative environments (REKITTKE & NINSALAM 2014, NINSALAM & REKITTKE 2016), were adequate for locations accessible by foot and boat.

For the underwater photogrammetry campaign, we were equipped with an Olympus TG-4 camera, which houses a backside illumination (BSI) CMOS 1/2.3" sensor. We operated the camera while snorkeling, using a manouvre of turns (Figure 3), – outside the day-to-day routine of the urban landscape architect. Our task was not only impacted by the clarity of the water (up to 30 metre visibility) on the reef, and the operational capacity of our equipment

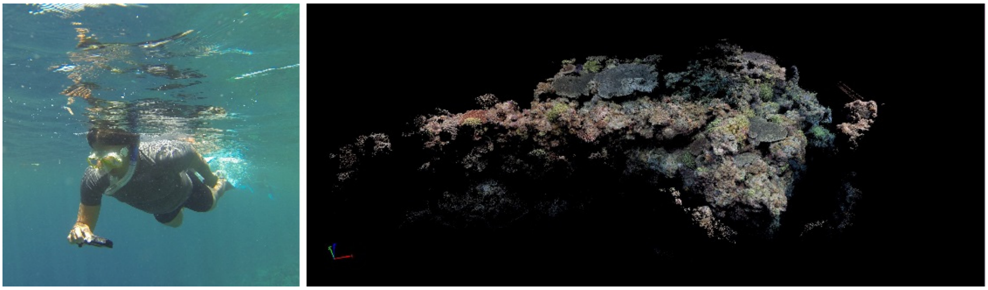

Fig. 3: Underwater photogrammetric image capture of the corals. Point cloud model sample of species-rich coral reef located at the steep reef wall (Photo: Rekittke, Model: Authors, 2015).

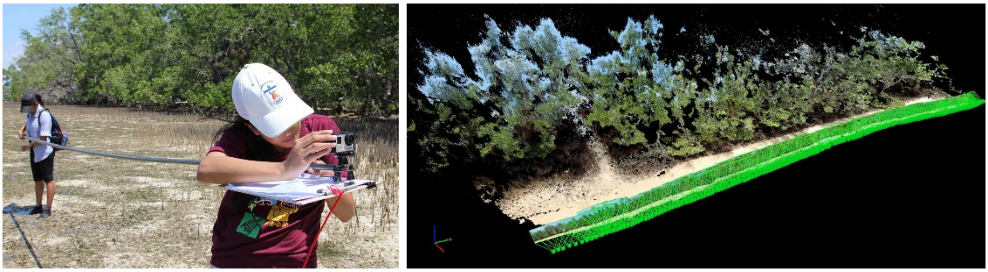

Fig. 4: Close-range photogrammetric image capture of the mangroves. Resultant point cloud, also showing the path of systematic capture of overlapping images (Photo: Ninsalam, Model: Authors, 2015).

(limited to depths of 15 metres). However, during our snorkeling campaigns in the turbid waters between the mangroves' roots our physical performance and mental capacity were challenged. We also faced difficulties managing the tidal change that induces strong currents. This predicament was compounded by the existence of the local Banded Sea Krait, one of the most venomous water snakes, whose visible presence had caused us uneasiness during the already trying underwater work. With regard to the selection of field equipment for underwater imaging, Massot-Campos and Oliver-Codina (2015) specify four factors: 1) the payload volume, weight and power available, in cases where the system is an on-board platform; 2) the measurement time; 3) the budget; and 4) the expected quality of the data gathered. The lightweight Olympus TG-4 camera and its long battery life enabled us to conduct one-hour long underwater campaigns. In spite of being a low-cost solution, the camera delivered satisfactory imagery to digitally reconstruct a demonstrative model (Figure 5 and Figure 6).

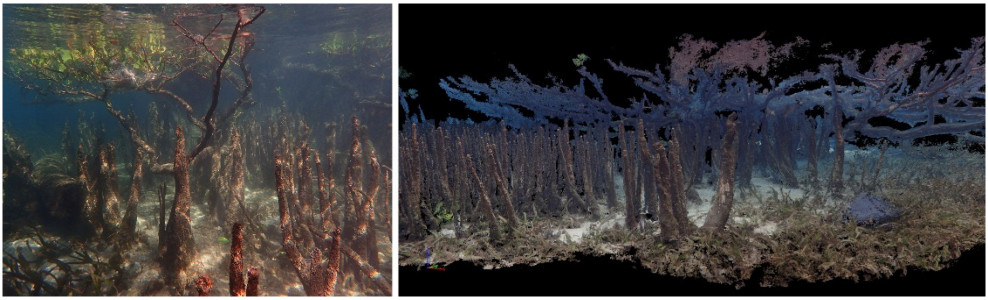

Fig. 5: Example of an underwater photo (left) and generated model (right) of an underwater mangrove sample (Photo and model: Authors, 2015)

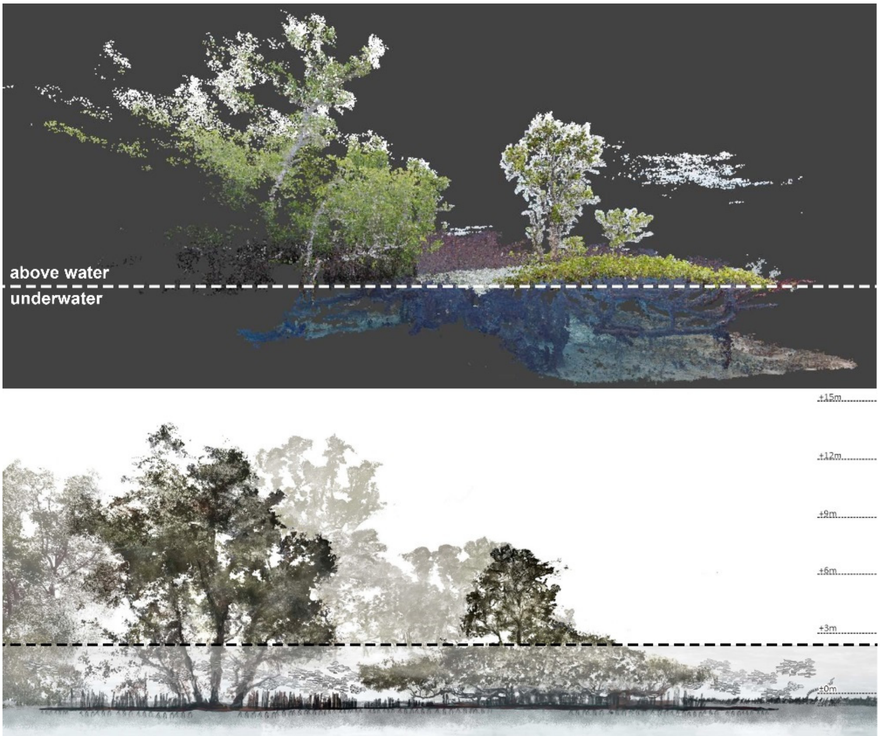

Fig. 6: To reconstruct the mangrove above water, 168 out of 232 images produced 4.5 million points with an average point density of 122/m^3. To reconstruct the mangrove underwater, 495 out of 552 images produced 23 million points with an average point density of 1113/m^3. The separate field-samples were subsequently integrated into the larger marine landscape transects acquired by the UAV (Model: Authors, Graphics: MLA Studio Rekittke, 2015).

The underwater material and the above-water results – recorded in succession – have been manually assembled in the 3D modeler, Rhino 5. The detailed point clouds of mangroves acquired in the snorkeling and foot campaign have been embedded within the georeferenced mangrove overview model, which was acquired in the aerial campaign described earlier (Figure 2 and 9). In so doing, the scaleless detail samples could be accurately resized. The relatively small size of these allowed a swift post-processing of the field material.

3 Design Work with an Ecosystem Transect Model

Based on our ability to operate in the air, on land, and finally in the water – as well as by incorporating field-sampled marine landscape elements into a larger site model – we were able to generate a precise and geo-referenced landscape transect. These cross-sectional slices that typify the intertidal ecosystem of the Bunaken Marine National Park, are detailed enough for all aspects of our landscape architectural design work and related proposals for park management improvement. In the studio environment we displayed our work using an eight meter wide overhead projection. This enabled us to describe the tidal change, all types of boats and their different draft, tourists and their behaviour, sea animal species, plants, corals etc. in such a way that overcame the visual limitations of the printed form (Figure 7).

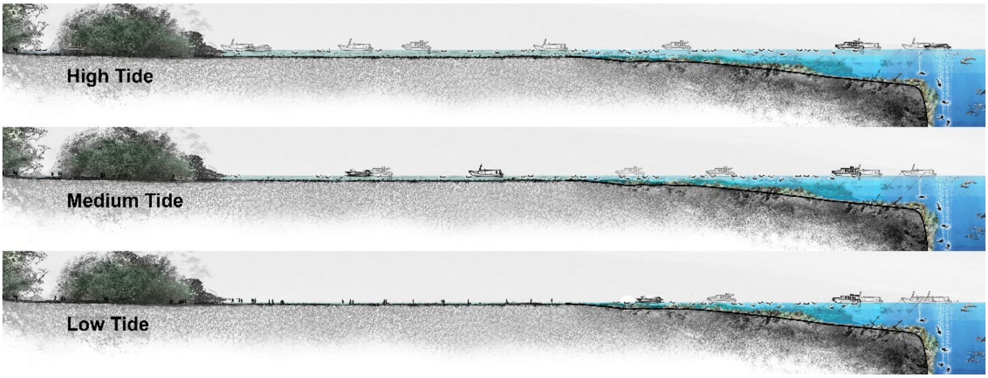

Fig. 7: Cross section produced from the field-acquired spatial data (Graphics: MLA Studio Rekittke, 2015)

Due to increasing visitor numbers, the vulnerable landscape of the National Park suffers increasing environmental stress – affecting the islands, the mangrove belt, the seagrass meadows, the reef flats, reef crests and the vertical reef walls. The main attraction for the visitors is the unique underwater fauna and flora, featuring one of the highest coral species varieties in the world (MEHTA 1999). The marine paradise can only survive if the ecosystem becomes well managed and protected in a sustainable way. Currently, this is not at all the case. On Bunaken Island, the number of dive resorts has been estimated to double every ten years since 1995. This reality is contrary to the National Park status that ought to theoretically forbid any further construction activity. For the past twenty years, despite having collected entrance fees contributed by the tourists to the National Park, various local stakeholders are thus far unable to name a single project financed by the proceeds. We observe that one of the most problematic and damaging current practices is the individual boat transport to the many resorts from the sea. Each visitor tramples repeatedly through the sensitive intertidal zone constituted by the seagrass meadows, reef flats, and mangrove belt. This occurs on arrival and departure, in addition to the several times a day they partake in water activities like snorkeling and diving. All luggage and dive equipment, air tank by air tank, are carried to the island in the same manner. The collective traffic causes massive biotope stress, which we visualised with the help of our fieldtrip findings (Figure 8).

Fig. 8: Left: Individual dive tourist clumping through the precious seagrass meadow at low tide, followed by a local dive guide, carrying the air tanks and equipment. Right: Visualisation of the collective movement pattern around Bunaken Island in one week (Photo and Graphics: MLA Studio Rekittke, 2015).

While the reef flats and seagrass meadows are degraded by low tide traffic, the mangrove belts become increasingly perforated by boat landings at the resort beaches during high tide. The mangroves serve as indispensable nursery grounds for fish and other aquatic organisms. Without these mangroves, the continuation of the perpetuation of the fish stock is not possible. Without fish stock, the dive tourism will migrate to places with better protection concepts. The mangroves not only epitomise the beautiful multi-dimensionality of an intertidal zone, they also exemplify the interconnectedness of all elements in an ecosystem. Given this powerful correlation, one of our central design proposals was to diametrically oppose the organization of the current transportation system, from a sea-access to a land-access based system. Instead of transporting visitors and goods through the reef flats, seagrass meadows, and mangroves, a low number of reef-compatible but large jetties must serve as a contact point. Linking a centralized sea-based access and an individual land-based distribution system, which provides transportation to and from the tourist resorts and local villages. This proposed 180-degree turnaround – from a sea-access to a land-access based system – will not be quick and easy, and involves numerous related design measures, examples are mentioned below. The necessary infrastructure would have to be financed and built by local stakeholders. In light of this turnaround, the mangroves will be of utmost importance. Over time all traffic-induced gaps would have to be closed via mangrove restoration projects. Based on our spatial data the students visualized this process (Figure 9) for the plot of our local host – an environmentally aware resort operator.

Fig. 9: Iterative mangrove restoration project visualization for a resort-induced mangrove gap on Bunaken Island, based on our own ecosystem transect (Models: Authors, Graphics: MLA Studio Rekittke, 2015)

The studio group produced a comprehensive catalogue of land- and water-related design and management measures that allows a sustainable continuation of the tourism industry. At the same time, this catalogue marks and protects those sensitive areas of the National Park, which are essential for its future (Figure 10). Offshore, strategically placed mooring buoys will reduce destructive reef anchoring of diving boats, while boat marker buoys will indicate un-navigable and protected reef zones. Snorkel marker buoys – by all means comparable to established swimming lane demarcation – will stop snorkelers from endangering accessible reef areas with their fins and hands. Preservation zones will encourage the flora and fauna of the reef to thrive. In tourism zones comparatively intensive use will be tolerated, and core zones will represent exclusion areas for any form of use or access – to name a few. All new rules and limitations would in fact only be enforceable by a well-equipped park ranger squad, which would have to be established from scratch.

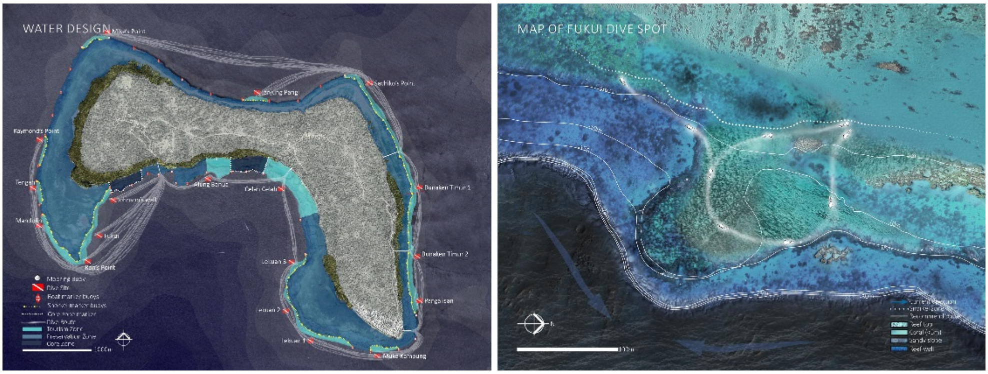

Fig. 10: Left: Map of all water-related design and management measures for Bunaken Island. Right: Detailed map of a dive spot, showing the dive routes and proposed snorkel zone limits (Graphics: MLA Studio Rekittke, 2015).

4 Lessons Learned and Next Steps

Our hypothesis – not new and necessarily long-term – is that environmental design work can only exercise adequate persuasive power when it is based on in situ gathered data of maximum precision and extent. This is why we constantly push to improve our technology-based fieldwork workflow – an infinite process without prospect of a final solution. If we, the designers who come from outside, don't familiarise ourselves with our study sites and their conditions almost better than the local stakeholders, we will not succeed in the initiation of positive change. A Marine National Park is home to numerous insiders, like nature lovers, dive guides with excellent local expertise, and others. Thus, any form of design proposal or suggestion of improvement must be verified by incontrovertible facts, exact to the centimetre, instead of by well-meant universality. The positive jury reactions to our studio results – which are soon to be presented in a stakeholder workshop in the Bunaken National Park – demonstrate our progress. We are looking forward to our next steps now that we have begun to work both in- and underwater. The Bunaken studio was just the prelude to a long-time academic relationship concerning the future development and management of the Bunaken Marine National Park. We currently prepare to return with the next generation of fieldwork equipment. This includes a state-of-the-art high-precision handheld scanner (FARO Freestyle3D), which can document even the most detailed structures and objects in 3D, creating high-definition point clouds. This is fairly relevant for the work in intertidal seagrass meadows and reef flats, where every square metre may feature hundreds of vulnerable creature and plant specimens.

5 Acknowledgements

Our thanks to our local hosts Sarah and Sasha Westropp, and indeed to the NUS MLA students *("MLA Studio Rekittke")*: Qiying Poh, Yibei Tao, Yunzi Sun, Anzhou Chen, Deepika N. Amonkar, Anushree Agarwal, Li Xuan Lim Cherlyn, Li Wen Tan Ashley, and Zhi Ning Cheok. The presented studio work was embedded into the NUS research project WBS No R295000108112 Under-the-Urban-Canopy 3D (PI: J. Rekittke).

References

MASSOT-CAMPOS, M. & OLIVER-CODINA, G. (2015), Optical sensors and methods for underwater 3D reconstruction. Sensors, 15 (12), 31525-31557.

MEHTA, A. (1999), Bunaken National Park: Natural History Book (English Version). National Research Management Program USAID, 271 pp.

NINSALAM, Y. & REKITTKE, J. (2016), Landscape Architectural Foot Soldier Operations. Sustainable Cities and Society, 20 (1/2016), 158-167.

REKITTKE, J. & NINSALAM, Y. (2014), Head in the Point Clouds – Feet on the Ground. In: WISSEN HAYEK, U., FRICKER, P. & BUHMANN, E. (Eds.), Peer Reviewed Proceedings of Digital Landscape Architecture 2014 at ETH Zurich. Wichmann, Berlin/Offenbach, 198-207.