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RIVER REEF IMPACT STUDIES I (RRIS I): REEF RESPONSES TO CHANGING WATER TEMPERATURES

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Abstract: Vietnam coastal waters host a wide range of marine ecosystems. Of these, coral reefs continue to be stressed by a variety of threats, particularly in areas of dense human populations, such as in Nha Trang Bay NTB. So far there are no studies available that try to establish direct causal links between natural or anthropogenic factors. This study attempts to do so by asking: what are average, max/min temperatures in NTB and how profound are seasonal changes?; can we identify major changes/ trends from year to year?; and, are there differences in coral cover and species composition and can these be related to temperature? For long term temperature measurements, 10 Hobo (USA) loggers were deployed at depths of six to 20m at selected locations directly in the coral reefs. Coral transects were performed according to the Lifeform standards and by using a video cam for permanent transects.

Within few weeks two record lows and highs (in June 2012) and covering 10° temperature differences (in September 2011) in a depth of 12m, were recorded. In comparison to 2007 through 2009 not only were more extremes found, but a much higher intra-day variation, which can easily cover 5° difference, in exceptional cases even 8°C, was found.

On coral species level only low to moderate coral cover was found in general. This is reflected in a clear gradient of coral cover and diversity from West to East. On a community level coral reefs are well developed in the southern area of Nha Trang Bay. The most immediate impact to reefs and the main driver of environmental degradation in NTB is thought to be from pollution and nutrient sources. As shown here, the temperature regime is providing a sub-optimal environment for coral growth. The overall situation is more complex than previously assumed and a number of stressors are important. For reefs in the south we predict an „increased resilience“.

Key words: *Temperature records, Long-term deployment, Coral reefs, Resilience, Nha Trang Bay.*

I. INTRODUCTION

Vietnam coastal waters host a wide range of marine ecosystems.The condition of 60% of Vietnam's reefs can be described as fair, 20% as poor, 17% as good, and only 3% as excellent (Chou et al. 2002). These coral reefs continue to be stressed by a variety of threats, particularly in areas of dense human populations. For protection and conservation of coral reef ecosystems in Vietnam, their distribution and status should be investigated and monitored (Vo 2001). Recently, the

Vietnamese government supported a number of monitoring studies, with the aim of establishing tourist sites and marine protected areas (e.g. Cat Ba - Ha Long, Nha Trang Bay, Con Dao Archipelago and Phu Quoc Islands; Vo et al. 2005; Vo et al. 2008). However, these studies only assessed coral species identification, reef status, and stress levels at a limited number of specific reefs. Because information on coral cover and status is important for coastal management programs, but, our knowledge about coral reefs is still limited, an interesting new approach involving satellite imagery was applied by Tran et al. (2012).

Nha Trang Bay (NTB) is under the seasonal influence of the SW and NW monsoons. They have effects on the oceanography, particularly water temperatures, circulation patterns and plankton concentrations. Large ocean swells (> 3 m height) generated by the NW monsoon and typhoons in the South China Sea (SCS) impact on the sub-littoral communities most years. Wave energy during SW monsoon is usually more moderate (< 1 m high). Ocean currents of low/moderate velocity (< 1 knot) flow between the islands driven by coastal winds, tides and regional oceanography. Sea surface temperatures usually peak at ca. 30°C (SW), falling to 24°C during NW monsoon (Vo et al. 2002). Upwelling off Vietnam occurs during SW monsoon when a cyclonic circulation cell in the northern and an anti-cyclonic gyre in the southern SCS are initiated by spatial asymmetry in the wind field (Wu et al. 1998).

NTB covers c. 13.000 hectares and contains nine islands, which are located about 1 km to 15 km offshore. They provide the topographic basis for a wide range of coastal and marine habitats, including coral reefs, sea grass beds, mangrove areas, sandy beaches and rocky shores (Nga et al. 2002). The Bay houses the highest coral reef diversity of any surveyed location in Vietnam. Coral reef communities occur around most of the islands, their structure varying relating to the degree of physical exposure, with coral species having strong wave-tolerant growths forms predominating in the more exposed areas (e.g acroporids) and more sediment tolerant species in the sheltered bays (e.g. poritids, fungiids). Most extensive reef building has occurred on the north coast of the islands. The rocky shores support mostly sparse benthic cover. In the most sheltered areas of the large bay of Hon Tre Island, the coral communities merge into sandy, silty areas, some of which support sea grass beds. Adjacent to the sea grass beds at the inner margins of the deeply incised bays of Hon Tre, small patches of mangroves exist (Vo et al. 2002).

It is assumed that there is a strong correlation between nutrients, sedimentation and land based pollutants with declining coral cover and degradation of coral reefs (Pavlov et al. 2004). Therefore it is of vital importance to better understand coastal processes within the Nha Trang Bay and identify not only whether sediment and accompanying land based pollutant sources are potentially harmful to coastal coral reefs, but, also the sometimes rapid fluctuation of physical stressors such as temperature, oxygen or salinity.

So far there are no studies available that try to establish a direct causal link with these physical stressors. Many studies focus on sediments, nutrients, potential pollution, etc., but in their conclusions, all refer to multi-factorial influences and the lack of detailed information. In the present research we singled out temperature and look in more detail in to its effects. The areas examined are:

What are average, max/min temperatures in NTB?
How profound are seasonal changes?
Can major changes/trends from year to year be identified?
Are there differences in coral cover and species composition and can these be related to temperature?
Are the corals of Nha Trang Bay more depending on terrestrial or oceanic water mass influences?
Are there significant changes between months; is this related to temperature gradients or temperature changes?
Are there any differences between coral reefs in relation to the distance from the coast with regard to the above questions?

The major aim is to identify primary drivers for changes in coral reefs. While research is well aware of the significant impacts of the major rivers and their load of materials, and the increasing background data about the temperature regime for successful management of NTB, which also includes science-based justifications for law enforcement within the Marine Protected Areas.

II. MATERIALS AND METHODS

Nha Trang Bay (NTB) is located between 109°18.5' E and 109°11.32.5' E and 12°12' N and 12°15' N at the western margin of the South China Sea (SCS) (Fig. 1). Nha Trang City is a huge city with more than one million inhabitants, flanked by two rivers, the Cái north and the Tac, (also called Be) in the south. Apart from the islands, which are located on the shelf in front of the bay, two large bays (Nha Phu and Van Phong) are found just north of NTB, and, a large lagoon is found just to the South (Cam Ranh Bay) with significant aquaculture and industrial activity.

For logistic and comparative reasons NTB was divided into three zones, with different distances from the coast (0-5, 5-10, 10-15 km). Regular measurements of physical and chemical properties of the seawater were performed and linked with data from other studies and historical data.

For measurement of T, S, DO and pH both a WTW (Germany) Multi 340i Sensor for spot measurements and a multi-parameter sensor from Ott (Germany) for serial records during scuba dives and on stations were used, whereas water samplers or plankton nets were operated from small vessels. For turbidity measurements a Secchi disk was deployed.

Water samples for nutrients (NH4+, NO3-, PO4), Chlorophyll and C/N and stable isotope signature were taken with water samplers from Hydrobios (Germany) or in plastic bottles during Scuba dives. For the completion of data sets from Schulz (2008) and Nebel (2009), Si, DOC and TDN samples were also taken.

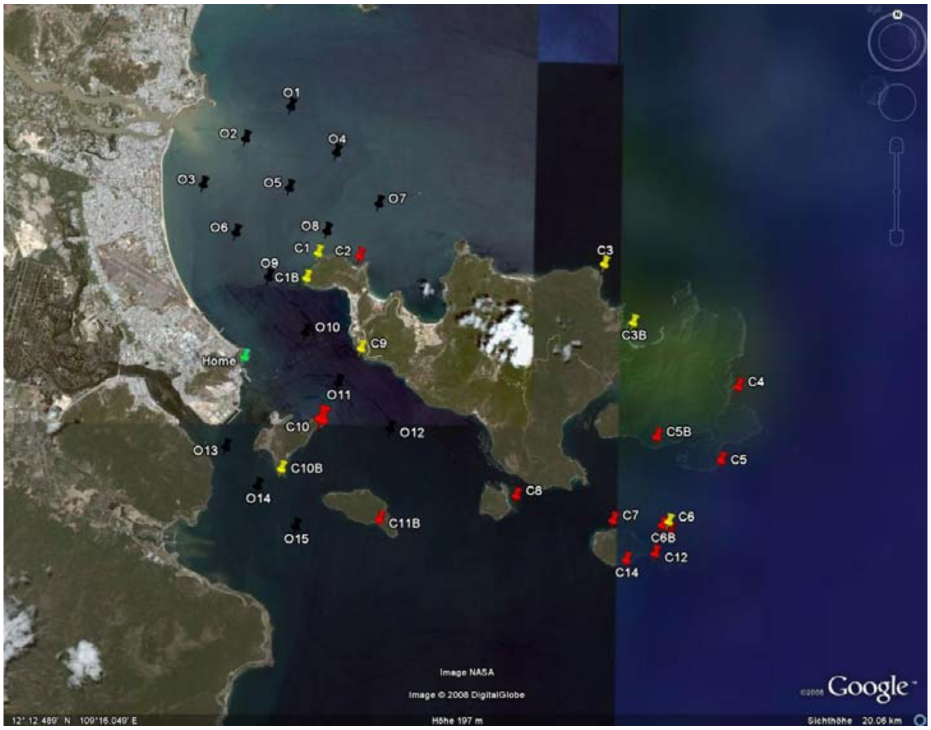

Figure 1. Map of Nha Trang Bay with sampling and monitoring stations. O = ocean station (water and sediment samples), C = coral station (logger and transects; C6b = C13)

For long term temperature measurements 10 loggers from Hobo (USA) were utilized at depths of six to 20m at selected locations directly on the coral reefs (see station grid, Fig. 1). Deployment and subsequent recovery was performed once each year (May 2009 and May 2011) yielding data sets of 365d and 400d. Two deployments in 2007 and 2008 had shorter measurement periods. The logging interval was 0.0167 Hz (1 x min-1).

Coral transects were performed according to Lifeform standards (UNEP/AIMS 1993 and English et al. 1994) and by using a video cam (Sony HRE90), recording a 50m permanent transect at a vertical distance of 1m using Scuba gear.

III. RESULTS

1. Physicochemical Data, surface measurements (from 2008 & 2009)

Temperature shows significant differences between sampling periods and stations. The temperature in the Tac River differs (with an average of 31.7°C) significantly from other sampling areas. Salinity and conductivity values decrease with decreasing distance in the river stations. The average surface temperature of coral stations in 2007 and 2008 was 29.2 °C. The water temperature of Nha Trang Bay showed a continuous decline from October 2008 till February 2009 (Fig. 2). Maximum temperature during the research period was 29.1°C (surface) and

28.9°C (bottom) in October 2008 and reached a minimum with 23.1°C for surface and bottom waters in January 2009. During the first sampling period the temperature was similar between the surface and bottom (paired Wilcoxon $p = 0.95$), whereas in the second sampling phase surface waters have been warmer than bottom waters (paired Wilcoxon $p < 0.0001$). During this period onshore waters (D1) were warmer in comparison to offshore waters (D3) (Kruskal-Wallis test, $p = 0.015$).

With respect to **oxygen** levels, the Cai River mouth is significantly different from other sampling areas (post-hoc tests). For the Tac River there was a significant drop in oxygen level between 2007 and 2008 from 7.3 mg/L to 4.0 mg/L. In the surface and bottom water of non-river stations (Fig. 2), the average was between 6.69 and 6.97 mg/L. Oxygen levels always remained slightly higher at the surface than at the bottom throughout the study (Period 1 2008: Wilcoxon, $p = 0.004$; Period 2 2009: $p < 0.0001$). The lowest DO content was 5.29 mg/L at station C8 in October 2008.

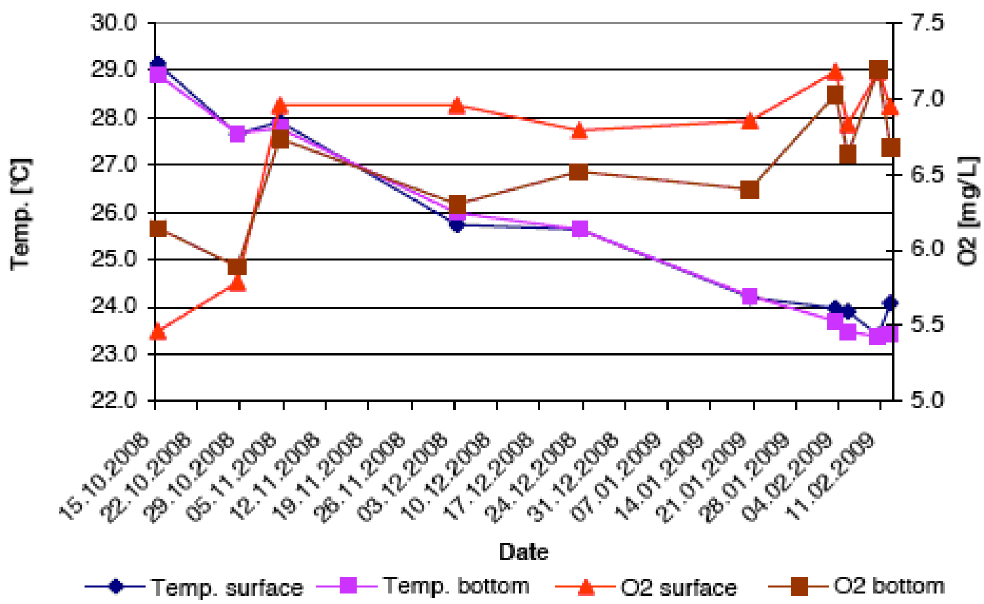

Fig. 2. Temperature (T) and dissolved oxygen (DO) from Oct 2008 to February 2009 at ocean stations from Fig. 1. Each dot is a mean of three measurements.

In Sept. 2007 and May 2008, Cai River had lowest **salinity** (0.8 psu) and conductivity (0.9 µS/cm) in the river mouth. The average salinity value of the eastern ocean stations was 32.3 in 2007 and 32.7 in 2008 (max values at coral stations were 34.3 and 32.3, respectively). Concerning salinity, the coral and eastern stations are significantly different from all other stations.

Salinity in 2008/9 displayed large variability through space and time. Extreme values were found in 2008 at station O5 with 21 PSU and for coral stations with 25 PSU at C1B. Two times bottom waters in coral reefs reached a salinity of 28 PSU (C2, C1B in 2008). However no significant differences were found between coral and ocean stations.

There is a general trend of lower **pH values** in 2008 (pH 7.9) than in 2007 (pH 8.2) for all stations. In 2008 and 2009 the pH remained relatively constant within a range of 0.46 (min. 7.72, max. 8.18)

The vertical **visibility** of the water column was homogeneous for stations and within periods, varying from 2 - 10 meter (in the North). Transparency onshore was lowest (D1 - average 4 m), followed by medium distance (D2 – 6 m) and highest transparency was observed offshore (D3 – 8 m). Particularly in the months May and June transparency at outer stations (C15) can also reach 15 m and more.

2. Temperature observations (long-term measurements in reefs 2007-2012)

Long-term temperate (T) observations at Station C2 (10m depth, 12°13.907N /109°14.573E, Fig. 3) from 30.08.07 to 13.07.09 show that Tmax was 30.3 °C in late Sept. 2007. T decreases continuously until beginning of March 2008 (min. 21.8). Starting from mid-March 2008 the temperature rises sharply and rapidly to 29.6 by end of April 2008. In 2008 the peak temperature was reached in October exceeding 30°C. The next minimum was reached again in mid-January 2009 with about 23°C.

This pattern with: a) high Ts in September, slowly decreasing over seven months with low Ts in March; and, b) a more or less sharply rising Ts from March to May is also visible at other stations.

Another long-term observation at Station C13 (12m depth, 12°10.226N/ 109°19.041E, Fig. 4) from 20.08.09 to 13.06.12 shows again that Tmax was reached in mid-September 2009 exceeding 30°C for several days. T decreased steadily to 22°C in mid-March 2010. Then rose steeply in only 2.5 months (19.05.2010) to a record high of 31.2 °C, lasting for several days. This was followed by an exceptional and first time recorded, extremely sharp drop to 21.8 in only 9 days (28.05.2010). Another exception in this year 2010 was a second high of 30.7 °C in October lasting until November. Thus, the long and steady decrease in this particular year was much shorter from November to February 2011. The rest of 2011 displayed a normal pattern, with peak again in September, exceeding 30°C, and a long decrease from September to Mar 2012. In the first half of 2012 another exceptional second low was recorded in late April of with 21°C, even lower than the March low, and the lowest temperature recorded so far. The high in 2012 was reached in June with a very high 30.7°C.

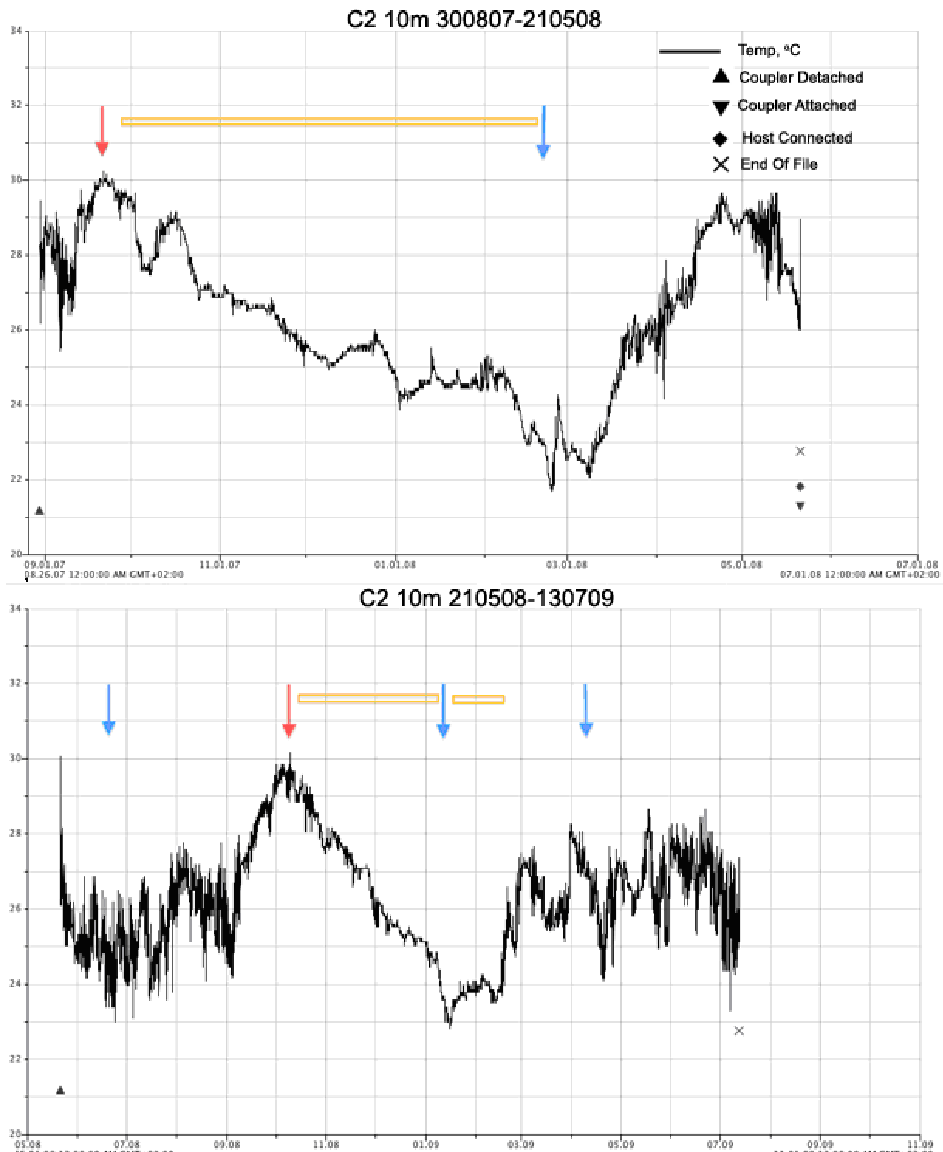

Figure 3. Temperature data (Hobo Logger) at Station C2 (10m depth) from 30.08.07 to 13.07.09.

This means two record record lows and highs occurred within five weeks in June 2012 and within 7 weeks (in September 2011) – covering 10° temperature difference **in a depth of 12m**. In comparison to the years 2007 through 2009 there were not only more extremes, but also a much higher intra-day variation, which covered 5°, and, in exceptional cases even 8°C.

In general the temperature data correspond with the seasonal change of currents, which is also supported by DO data from the years 2007 through 2009.

Lower T and higher DO was observed in rainy season. Min and max SST values were 20°C in March and 31°C in October.

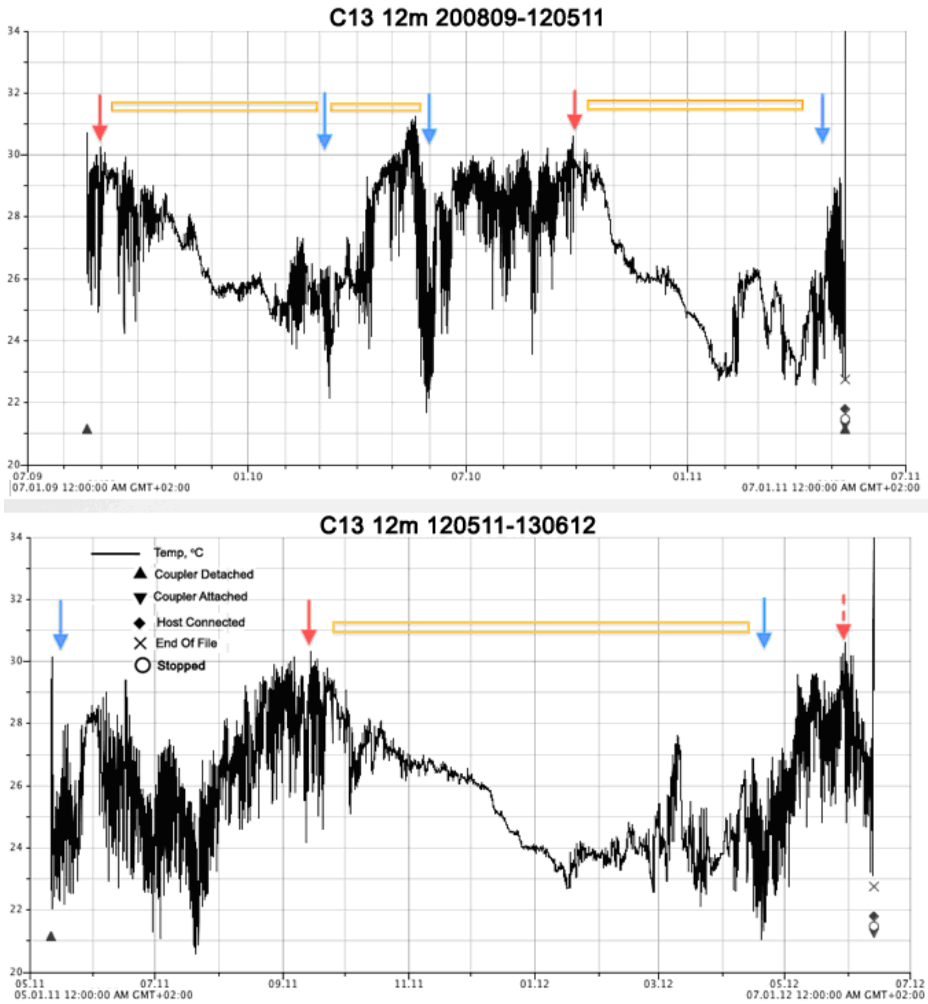

Figure 4. Temperature data (Hobo Logger) at Station C13 (12m depth) from 20.08.09 to 13.06.12.

3. Coral data (entire bay grid 2009)

The coral reefs at Nha Trang Bay are located in shallow waters around the islands (max. distribution depth 15 m) and are fringing reefs. At exposed sites such as open bights and headlands they are unstructured, whereas in bays and sheltered areas structured reefs can be found. Most frequent are Acroporids (wave tolerant) at exposed sites and Poritids/Fungiids (more sediment tolerant) at sheltered sites.

29 coral life forms were pooled into six categories to enlarge the data set for statistical analysis. These were dead coral, *Acropora*, non-*Acropora*, algae, other

fauna/flora, and abiotic cover. Coverage of 100% with life corals was never reached at any station (although we know of several spots, which have a PC of 100%). Degraded reefs, with high percentages for dead corals, were observed throughout the whole Bay, both at 6 m and 10 m depth (see also Nebel 2009, Tab. 4, Appendix). The highest number of dead coral was found at the stations C11B (35.9 %) and C4 (at 6 m: 36.7 % and at 10 m: 38.8 %).

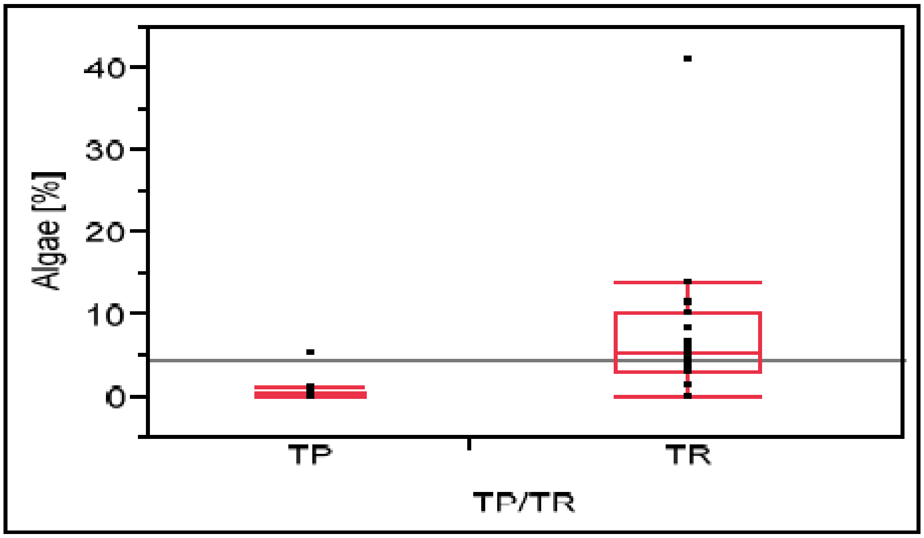

Fig. 5. Differences in algae cover in between permanent (TP) and random (TR) transects. Mean TP = 0.61 %, n = 14; TR = 7.42 %, n = 19.

Algae coverage was highest at station C8 in 2007 with 41 %. In average algae cover was less than 5% in permanent transects and c. 10-15% in random transects (Fig. 5). A comparison of the coral stations revealed an increase of *Acropora* coverage with increasing distance from the coast. Mean (0.48 %) *Acropora* coverage at D1 was much lower than at D3 (6.25 %) (Tukey Kramer HSD p = 0.047) (Fig. 6). All other categories revealed no significant differences regarding the distance.

4. Coral data (long-term, selected stations 2007-2012)

Additional information comes from long-term data from three selected locations (C7, C6b and C14), where a comparison from 2007 to 2012 is possible. In permanent 50m-transects the overall live cover (LC) and the hard coral cover (HC) remain fairly stable over those years. C7 displayed 66% LC and 50% HC in 2007 and 79% and 57% in 2012. The LC rose in the first period and remained at 80% for the last three years (Fig. 7). A similar trend was observed at station C6b, where HC was 36% in 2008 and rose to c. 50% in 2011 and 2012 and at C14, with 69% HC in 2008 and 76% in 2011 and 2012 (Fig. 8).

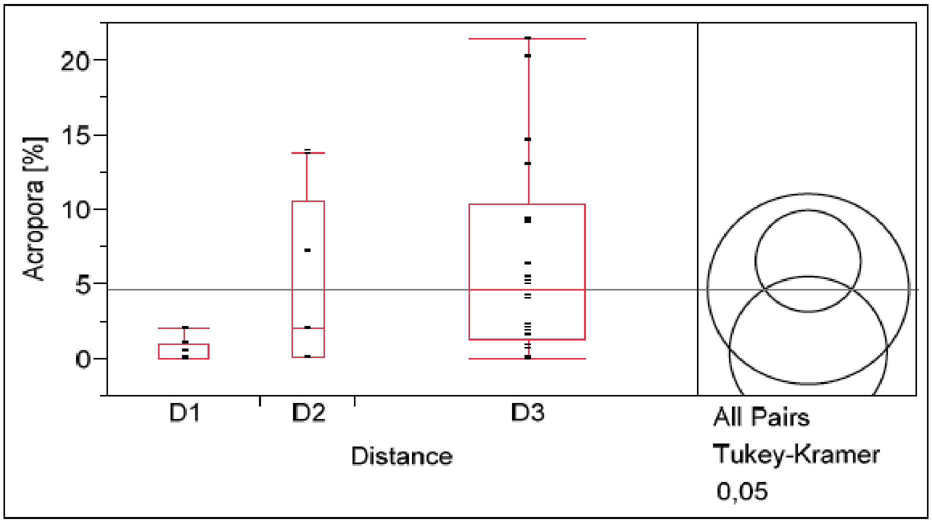

Fig. 6. *Acropora* coral cover as a function from distance (5, 10, 15 km) to the coast.Mean D1 = 0.47 %, n = 8; D2 = 6.43, n = 6; D3 = 6.25, n = 19.

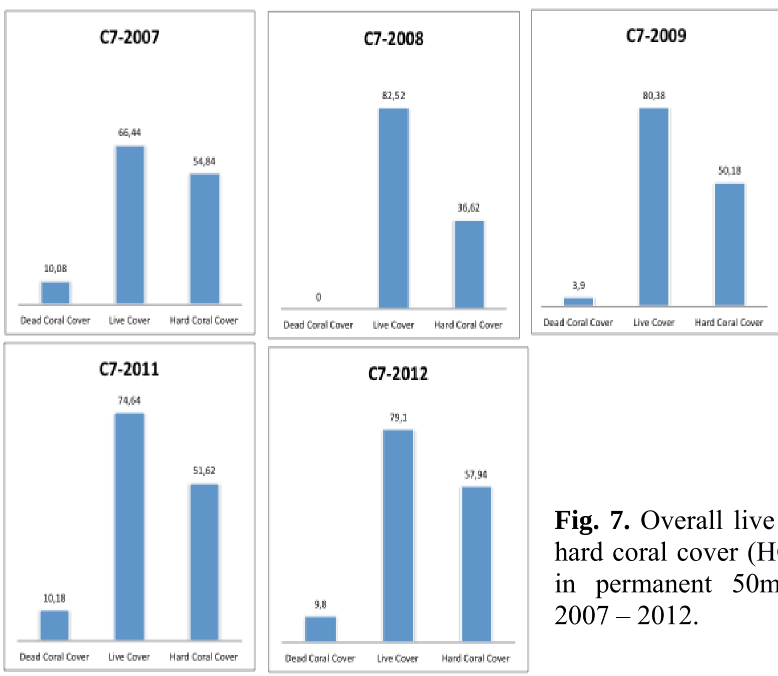

Fig. 7. Overall live cover (LC) and hard coral cover (HC) of station C7 in permanent 50m-transects from 2007 – 2012.

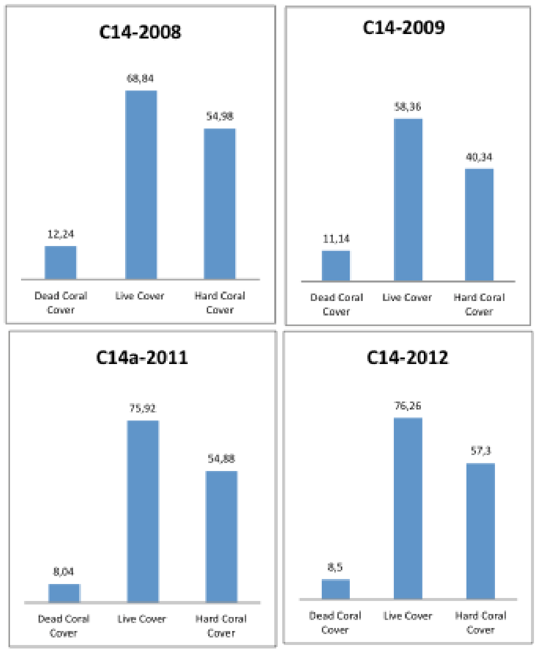

Figure 8. Overall live cover (LC) and hard coral cover (HC) of station C14 in permanent 50m-transects from 2008-2012.

In more detail in species groups (Fig. 9 to 11):

- At Station C7, the percentage of dead coral with algae (DCA) was stable at c. 10% while abiotic contribution was stable at c. 13%. An interesting cycle appears with Acropora and Millepora corals, when Acropora goes down, Millepora takes over and vice-versa (Fig. 9).
- Station C6b, an area covered by rocks is comparatively high (30%). Acropora percentage was always low at c. 2-3%, whereas the non-Acropora corals cover c. 30-45% of the area. The percentage of massive corals rose slowly from 12% to 20+% (Fig. 10).
- Station C14, is largely dominated by non-Acropora corals (45%). Also here the massive corals increased from 18% to about 25%. However, the Millepora corals seem to out-compete the Acropora corals rising from 8% in in 2008 to 18% in 2012, whereas the Acropora corals sank from 13% to 6% in the same period (Fig. 11).

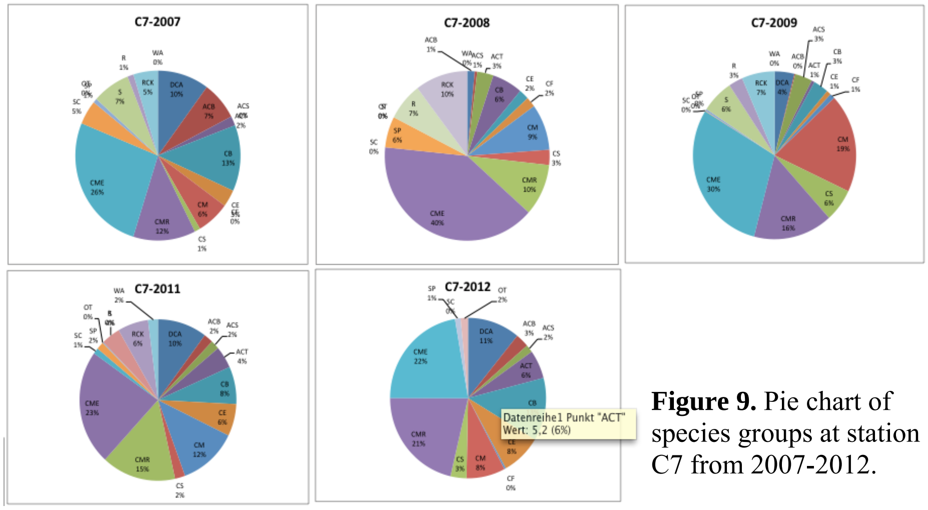

Figure 9. Pie chart of species groups at station C7 from 2007-2012.

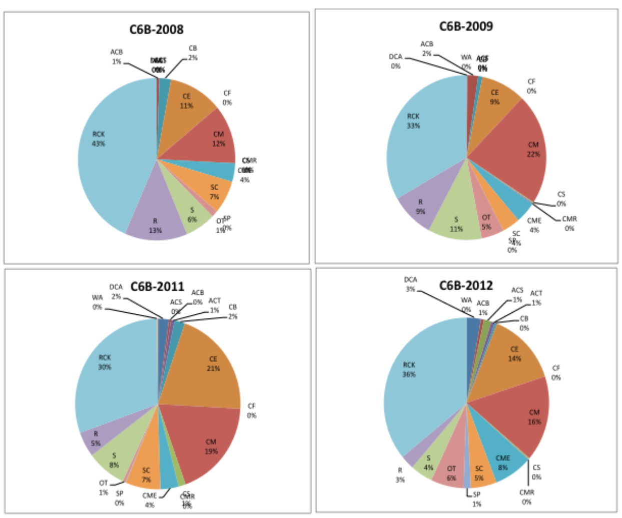

Figure 10. Pie chart of species groups at station C6b from 2008-2012.

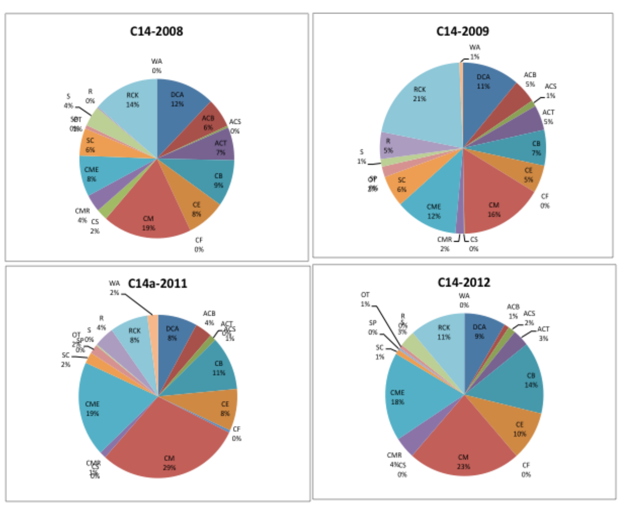

Figure 11. Pie chart of species groups at station C14 from 2008-2012.

IV. DISCUSSION

The Project River Reef Impact Studies tries to determine links between environmental and anthropogenic patterns, including terrestrial activities, with short-term and long-term responses from reef communities. In this paper the emphasis is on the impact of changing water temperature and attempts to analyse trends in coral community development.

There are a number of papers, which have reported about the impact of the **physical environment** on coral reef development (Dau 2002, Vo et al. 2008, Wu et al. 1998), however, very few cases of year-round-studies are available. Weather monitoring is available on a long-term scale and wind and rain data show lowest air temperatures in November (mean 17°C) coinciding with the highest rainfall data and highest air temperatures from May through August (mean 32-34) coinciding with lowest rainfall data. The prevailing wind direction during rain is from east with two similar peaks from ENE and ESE directions with the maximum number of windy days per month again in November/December (www.windfinder.com 2012).

From the literature, in combination with the present data it can be seen that temperature (T) and oxygen concentrations (DO) reflect changes of prevailing currents, well in line with the Northwest and Southeast Monsoon seasons. Lower T and higher DO values are found in rainy season. Minimum water temperatures of 20°C occur in March and maximum temperatures of 31°C in October. Intraday variations can easily reach 8°C, in exceptional cases also 10° and more (note that this is **not** SST, but water column T). These T signals are easier to detect in the south and east at greater distance to the coast, because here we find less "noise" from rain and river.

On the **coral species** level only low to moderate coral cover is found in general. This is reflected in a clear gradient of coral cover and diversity from west to east, and due to the fact that most islands are in the south, running from north to south). According to Vo et al. (2008), species composition for scleractinian corals mainly comprises 5 families (Acroporidae 110 species, Faviidae 38 species, Fungiidae 32 species, Poritidae 31 species, and Dendrophyllidae 25 species), making up 65% of the total species found. A number of authors have reported individual surveys, most of them performed as a consequence of the governmental plans around 2000 to establish a marine park in the Nha Trang Bay southern area (see below). Data from other areas are scarce.

On a **reef community** level the coral reefs are well developed in the southern area of Nha Trang Bay. This part was declared MPA and Hon Mun Island is the centre of the NTB-MPA. Three stations (C7, C6b/C13, C14) are in the MPA area. Within the MPA are areas with bleached corals, but no larger fields of rubble in the entire vicinity of Hon Mun. In contrast to the south, large fields of rubble and destroyed coral blocks are found on the northern locations of Hon Tre Island, a sign of illegal fishing activities with explosives. It is difficult to quantify the amount and frequency of such illegal operations, but two survey stations in the north of Hon Tre (C2, C3), had to be abandoned because of repeated theft of loggers and destruction of transect markers. Although extensive photographic and video documentation of those transects and the surroundings were made, it is not possible to recognize stations C2 and C3 anymore, due to massive landscape destruction. The northern reef areas are also locations with very high sedimentation loads. This is documented in the theses of Schulz (2008) and Nebel (2009) and is a part of on-going studies.

In front of the Cai river in the north, the highest deposition of sediment occurs at stations outside the estuary (Position O2: 36.13 g m^{-2} d^{-1} in the dry season and 19.35 g m^{-2} d^{-1} in the rainy season). Here strong seasonal changes occur, in contrast to the south. There the highest deposition rate occurs at the Tac/Be river mouth position, with 9.11 g m^{-2} d^{-1} (dry season) and 8.95 g m^{-2} d^{-1} (rainy season) (Du et al. 2012). As a result of sediment deposition, reefs close to the shore are generally not well developed.

Nha Trang is one of four major tourist regions of Vietnam. The current tourist trend suggests that this region will serve as a catalyst and further expansion of the tourism industry is predicted in the near future (Jansenverbeke & Go 1995). Nha Trang Bay with the Hon Mun Marine Protected Area (MPA) and its corresponding coral reef systems is one of the prime tourist attractions for the province.

Recent coral reef studies (Latypov 2006; Pavlov et al. 2004 and Vo et al. 2004) suggest there is growing concern that these economically important reefs are severely threatened. Disturbances exist on the local level (e.g. divers, fisherman), on the regional level (e.g. river flooding, improper land uses) and global level impacts, such as climate change and global warming leading to coral bleaching. According to Latypov (2006), the most immediate impact to reefs and main driver of environmental degradation in coastal areas is from pollution and nutrient sources directly affecting the Nha Trang Bay. However, as shown here, the temperature regime is providing a sub-optimal environment for coral growth.

Therefore, the overall situation is complex and a number of stressors are are evident, sometimes working simultaneously and sometimes over long periods. For some species this is challenging and their distribution is very limited. Other species seem to take profit or at least have slowly adjusted and their percentage cover appears to be increasing.

With regard to low sediment load, low fishing activity, and regular exchange with fresh, oxygen rich and transparent water from further south, Hon Mun Island its surrounding are the area with optimum coral survival rates, high species richness and fast growth. The challenge of a number of different stress factors appears less severe. Temperature variation seems to be a main challenge. Here corals tolerate high temperature intra-day, and also high inter-annual variations, including some extreme anomalies.

In contrast to most references, which generally suggest a severe threat for all reefs in NTB alike, we restrict these observations to northern reefs. For reefs in the south we predict an *”increased resilience“*.

Future Work

- Preliminary data suggest that the general situation of coral cover and coral diversity follows a gradient, with increasing diversity and cover both from west to east and from north to south. The percentage cover with live hard corals is, with few exceptions, generally low to moderate. Depth distribution of corals does not exceed 15 m in most cases. This can partly be explained by the repeated and regular occurrence of cold upwelling water, coming from eastern directions and not always reaching the surface.
- However, some open questions remain. What about the so-called 15m mystery? The explanation of cold water coming from the deep has been confirmed for locations where loggers were deployed for a long-term study. But also at locations in the north, hardly any corals were found in depths of more than 15m. This could be due to less light availability as a consequence of sediment load from river Cai (Du et al. 2012). Another possibility, which needs further confirmation, is reports about organic pollutants, which have been deposited in river sediments in front of the coast, e.g. agent orange and similar chemicals from World War II (Pavlov et al. 2004), where heavy storms can lead to re-suspension and transport further offshore right into the reef area. Or continuous organic pollutant loads from agricultural activities such as DDT (Du unpublished).
- For the coming years more deployments are needed, in order to minimize noise signals from land influence and in order to cover more areas, which are important for larval recruitment (e.g. Nha Phu Bay and van Phong Bay, but also offshore islands and patch reefs such as Hon Bac, Hon Dung and Hon Cau Islands).

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REFERENCES

1. Chou, L.M., Vo, V.S., PhilReefs, Yeemin, T., Cabanban, A., Suharsono, Kessna, I. 2002. Status of Southeast Asia coral reefs. In C. Wilkinson (Ed.), Status of Coral Reefs of the World, 123-152
2. Dau, T.V. 2002. Background Information for Hon Mun Marine Protected Area. Hon Mun Marine Protected Area Pilot Project, Biodiv. Rep. No.10, 167 pp.
3. Du, HT.; Jennerjahn, T.; Kunzmann, A. 2012. The impact of land-river input on sedimentation and biogeochemical parameters on the bottom sediments of Nha Trang Bay. In: Proc. Int. Conf. "Bien Dong 2012", xxx-xxx

4. English, S.A.; Wilkinson, C.; Baker, V. 1994. Survey manual for tropical marine resources ASEAN-Australian Marine Science Project , AIMS, Townsville, 1-368 pp.
5. Jansen-Verbeke, M. and Go, F. 1995 Tourism development in Vietnam. Tourism Management; 16(4): 315-325 pp.
6. Latypov, Y.Y. 2006. Changes in the composition and structure of coral communities of Mju and Moon islands, Nha Trang Bay, South China Sea. Vol. 32(5): 269 – 275 pp.
7. Nebel, C. 2009. River Reef Impact in Nha Trang Bay, Vietnam: The potential use of δ15N/δ13C isotopes as tracer of anthropogenic input in a heterogenic environment. MSc Thesis in ISATEC, Faculty for Biology & Chemistry, University of Bremen, 1-69 pp.
8. Nga, T.M.N., Duyen, C.T.T., 2002. Rapid survey on skills and understanding of Aquaculture practice in Hon Mot. Aquaculture Report no.1, IUCN http://www.nhatrangbaympa.vnn.vn/index_en.htm).
9. Pavlov, D.S., Smurov, A.V.; Il'yash, L.V. Matorin, D.N., Kluyev, N.A.; Kotelevtsev, S.V., Rumak, V.S., Smurova, T.G. 2004. Present-Day State of Coral Reefs of Nha Trang Bay (Southern Vietnam) and Possible Reasons for the Disturbance of Habitats of Scleractinian Corals. Russian Journal of Marine Biology, 30(1), 43–50 pp.
10. Schulz, I.K. 2008. Biogeochemical studies of dissolved and particulate matter in the Tac River, Cai River and the Bay of Nha Trang, Vietnam. Diplom Thesis, University of Bremen, 1-61 pp.
11. UNEP; AIMS 1993. Monitoring coral reefs for global change. Regional Seas. Reference Methods for Marine Pollution Studies 61, 72 pp.
12. Tran, V.D.; Phinn, S.; Roelfsema, C. 2012. Coral Reef Mapping in Vietnam's Coastal Waters from Highspatial Resolution Satellite and Field Survey Data. Asian Journal of Geoinformatics, 12(2):1-11 pp.
13. Vo, S.T. 2001. Coral reef monitoring and reef status in Vietnam: Country report. In: *Proceedings of ICRI Meeting*
14. Vo, S.T., Van Long, N., Tuyen, H.T., Hoa N.X., Hoang, P.K., De Vantier, L., 2002.). Coral reefs, species composition, communitiy structure, status and management recommendations. Biodiv Rep. No. 1. IUCN. (http://www.nhatrangbaympa.vnn.vn/index_en.htm
15. Vo, S.T., Ben, H.X., Long, N.V., & Hoang, P.K. 2005. Status of coral reefs in Southeast Asia : Vietnam. In, Japan Wildlife 95-112 pp.
16. Vo, S.T., Long, N.V., Ben, H.X., Hoang, P.K., & Tuyen, H.T. 2008. Monitoring of Coral Reef in Coastal Waters of Vietnam: 1994-2007.
17. Tun, K., Chou, L.M., Cabanban, A., Vo, S. T., Philreefs, Yeemin, T., Suharsono, Sour, K., Lane, D. 2004. Status Of Coral Reefs, Coral Reef Monitoring and Management In Southeast Asia, 2004. Status of Coral Reefs of the World, 1: 235-275 pp..
18. Wu, G., Shaw, P.T., Chao S.Y. 1998. Seasonal and interannual variations in the velocity field of the South China Sea. Journal Oceanography, 54, 261-372.