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Interactive comment on "Reviews and syntheses: Marine biogenic aerosols and the ecophysiology of coral reefs" *by* Rebecca Jackson et al.

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General Comments (review prepared by Michela Lever and Michael Steinke)

Coral reefs are important sources of the climate-active trace gas dimethyl sulfide (DMS). This review summarises some of our knowledge on the impact of coral reefs on sulfur cycling and the potential role of DMS and its precursor DMSP in alleviating physiological stress in corals. The paper is generally well-written but suffers from poorly designed figures and a narrow focus on corals from the Great Barrier Reef (see below).

Specific Comments

A. The review is sometimes too narrow and focuses on Great Barrier Reef processes

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only. However, there is some information available at least on Caribbean and Hawaiian reefs. For example, I am aware of the following:

Andreae, M. O., Barnard, W. R. and Ammons, J. M. (1983) The Biological Production of Dimethylsulfide in the Ocean and its Role in the Global Atmospheric Sulfur Budget. In: Hallberg, R. (ed.) Environmental Biogeochemistry Ecol. Bull. Stockholm: Ecol. Bull.

Hill, R., Li, C., Jones, A., Gunn, J. and Frade, P. (2010) Abundant betaines in reef-building corals and ecological indicators of a photoprotective role. Coral Reefs, 29, 869-880. Hill, R. W., Dacey, J. W. H. and Edward, A. (2000) Dimethylsulfoniopropionate in giant clams (Tridacnidae). Biological Bulletin, 199, 108-115.

Hill, R. W., Dacey, J. W. H. and Krupp, D. A. (1995) Dimethylsulfoniopropionate in Reef Corals. Bulletin of Marine Science, 57, 489-494.

B. Some sections only weakly link to marine biogenic aerosols (see title). Sections 7 and 8 appear to mostly cover reef conservation efforts. Possibly, Section 7 could be enhanced by adding information on atmospheric monitoring and how this could be combined with existing efforts (long-term monitoring) that quantify coral health. For example, some classic VOC studies conducted at Mace Head Observatory might be useful here:

Broadgate, W. J., Malin, G., Kupper, F. C., Thompson, A. and Liss, P. S. (2004) Isoprene and other non-methane hydrocarbons from seaweeds: a source of reactive hydrocarbons to the atmosphere. Marine Chemistry, 88, 61-73.

Carpenter, L. J., Sturges, W. T., Penkett, S. A., Liss, P. S., Alicke, B., Hebestreit, K. and Platt, U. (1999) Short-lived alkyl iodides and bromides at Mace Head, Ireland: Links to biogenic sources and halogen oxide production. Journal of Geophysical Research-Atmospheres, 104, 1679-1689.

C. Many of the figures are not well designed and/or provide little information. Figure 1

and Figure 2 can likely be removed. The caption in Figure 4 should explain all abbreviations similar to Figure 3. There are many issues with this figure, including:

a. Confusing use of terms such as 'ventilation' to explain loss of DMS to atmosphere but this is not indicated for loss of methanethiol.

b. What is meant by 'catabolism'? Is the demethylation step not a catabolism as well?

c. Why are zooplankton and phytoplankton the only sources of DMSP? Why not the coral?

d. Why is DMSP not released from other grazers such as herbivorous fish?

e. How do DMS and acrylate feed into microbial demethylation?

It is unclear how Figure 6 was generated. Where is this figure from? Is this original research and should not be presented in a 'review'? Lat/Lon and scale info is missing from Figure 6a, and why does Figure 6b display odd Latitude info? Unclear how the arrow in 6a relates to info in 6b. Is there a unit for the colour scale along the right (say on figure what it shows)? The actual reef is poorly illustrated in Figure 7. It is unclear what the white dots in the inset show, how the arrow relates between the two figures, what the dark blue area in the insert displays, etc. There is a scale and Lat/Lon information missing.

D. Some reviews contain a glossary – this may be useful here, too? Could explain specific terminology, for example: - Radiative forcing - Aerosol optical depth - . . .

Technical Corrections

Page 2, Line 1: Restructure (?): '. . .Coral reefs are being threatened by global climate change, with ocean warming, acidification and declining water quality adversely affecting coral health and cover in many coastal systems. . .'

P2, L14: '. . .Gaining a better understanding of the role of coral reef DMS emissions is crucial to predicting the future climate of our planet. . .' Is this justified? Do DMS

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emissions from coral reefs really affect the climate of our planet? May be regional climate? Coastal zones? Statement here seems to fit poorly with statement on P11, L34!

P3, L6: May have to widen out to beyond the genus 'Symbiodinium' or refer to Symbiodiniaceae? See paper by LaJeunesse, T. C., Parkinson, J. E., Gabrielson, P. W., Jeong, H. J., Reimer, J. D., Voolstra, C. R. and Santos, S. R. (2018) Systematic Revision of Symbiodiniaceae Highlights the Antiquity and Diversity of Coral Endosymbionts. Current Biology, 28, 2570-2580.e6.

P3, L8: Check hyphenation: '. . .membrane-enclosed compartments...'

P4, L2: What is meant by '. . .natural sulfur . . .' – change to 'biogenic sulfur'?

P4, L7: Check hyphenation: '. . .DMS-derived aerosol . . .'

P4, L11: I think some information should be provided on conservation and management before making the statement in the final sentence of Section 1: '. . .In the face of rapid climate change, non-traditional means of conservation and management may be required. . .'

P4, L16: Reword to (?): '. . .above a coral reef exposed to air. . .'

P4, L17: Capitalisation of 'Octocorals' necessary? These are animals as in 'dogs'?

P4, L18: What are the concentrations for dinoflagellate cells and benthic algae?

P4, L21: Check structure of information. Consider removing orphan sentence/paragraph.

P4, L24-28: This sentence does not make logical sense. It starts off with information on DMSPp but then seems to include info on DMSPd (release from phytoplankton during grazing) and other non-particulate exudates.

P4, L28-29: There is also the possibility that DMS is being produced from DMSP

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without the production of acrylate (ddd-cleavage pathway): Todd, J. D., Rogers, R., Li, Y. G., Wexler, M., Bond, P. L., Sun, L., Curson, A. R. J., Malin, G., Steinke, M. and Johnston, A. W. B. (2007) Structural and regulatory genes required to make the gas dimethyl sulfide in bacteria. Science, 315, 666-669. (See also P5, L4).

P5, L18: I disagree with: '. . .Until recently, it was thought that biosynthesis was limited to photosynthetic endosymbionts. . .' – (i) Many non-endosymbiotic organisms make DMSP and (ii) it has been long known that the heterotrophic dinoflagellate (= 'animal') Crypthecodinium cohnii can make DMSP, for example: Uchida, A., Ooguri, T., Ishida, T., Kitaguchi, H. and Ishida, Y. (1996) Biosynthesis of dimethylsulfoniopropionate in Crypthecodinium cohnii (Dinophyceae). In: Kiene, R. P., Visscher, P. T., Keller, M. D. and Kirst, G. O. (eds.) Biological and Environmental Chemistry of DMSP and Related Sulfonium Compounds. New York: Plenum Press.

P5, L27 (and elsewhere in text): Remove italics from 'spp.'

P6, L23: Is this true?: '. . .These ROS can diffuse from the algal symbiont into coral cytoplasm . . .' – I wonder whether ROS are too reactive to pass through biomembranes? Isn't this why they are so damaging to biological structures/molecules?

P6, L32: Is this statement correct? I do not recall that the paper by Hopkins et al. (2016) addresses the effects of SST or salinity.

P7, L14: Add apostrophe '. . .hinders corals' ability . . .'

P8, L4: What are those 'time scales'?

P8, L13: Check hyphenation '. . .temperature-sensitive species. . .'

P8, L15: Check hyphenation '. . .macro- and microalgae . . .'

P8, L21-22: So, this suggests that DMSP may not have a role in conferring temperature tolerance? Reconsider the wording.

P8. L25: Change singular/plural: '. . .However, tolerance thresholds within Symbio-

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dinium clades are highly variable (Klueter et al., 2017) and do not always predict DMSP biosynthesis (Steinke et al. 2011). . .'

P8, L26: Steinke et al. (2011) missing from reference list – carefully check all references.

P9, L2: Check hyphenation: '. . .algal-dominated coral-reef communities. . .'. Also, this sentence may require a reference,

P9, L4: Check hyphenation: '. . .pH-sensitive coral-calcification rates . . .'.

P9, L6: Change singular/plural '. . .absorbed by the oceans and affect seawater . . .'

P9, L7: Avoid repetitive word usage '. . .Increased CO2 levels increase . . .'

P9, L14: It may be important to point out that this is for warm-water corals? I suspect that the damage to cold-water corals is much higher still since the dissolution of CO2 into water is enhanced/temperature dependent?

Equation 2: Should the reaction be presented the other way around, because the text refers to erosion of calcareous structures?

P9, L23: Could add effects of temperature/CO2 on DMS/P in isolation and combined? See: Arnold, H. E., Kerrison, P. and Steinke, M. (2013) Interacting effects of ocean acidification and warming on growth and DMS-production in the haptophyte coccolithophore Emiliania huxleyi. Global Change Biology, 19, 1007-1016.

P9, L30: May mention that RCP8.5 is an IPCC scenario?

P10, L24 Check hyphenation '. . .biologically derived negative feedback . . .'

P11, L3: Change wording '. . .undersampled ocean regions . . .'

P11, L8: It is unclear what is meant by '. . .all of which reduce the thermal capacity of the sea surface. . .'. How can the surface concentration of DMS, tidal height, etc. reduce the thermal capacity?

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P11, L 9: Change wording to ‘increased diffusivity’?

P11, L11: I find it difficult to see how this paragraph is relevant to the specific topic/title of manuscript – unless cold-water corals are considered here? The manuscript sometimes lacks focus.

P13, L32: More info on ‘. . .and other volatile organic compounds (VOCs) . . .’ would be useful here. What other gases are being released?

P14, L5: What is meant by ‘. . .tidal lunar cycle . . .’ – is this not the same? Lunar cycle drives the tides?

P14, L26: Avoid use of ‘extreme’ (it’s all relative). May be ‘high solar irradiance’?

P15, L8-9: Check hyphenation ‘. . .rainfall-sensitive agriculture . . .’

P15, L 18: ‘. . .or condenses onto existing particles . . .’

P16, L9-10: Coral bleaching is not a stressor ‘. . .impacts of environmental stressors such as coral bleaching. . .’. Rewording necessary.

P16, L 10: Check spacing: ‘. . .coral reefs is also. . .’

P16, L19: Avoid ‘extreme’ and check hyphenation ‘. . .are cost- and resource intensive . . .’

P16, L21: What is meant by this ‘. . .Additionally, field surveys cannot capture processes that may be occurring down-wind of the substance’s origin. . .’? Numerous atmospheric/marine chemistry studies do exactly this? And how is that true for studies on DMSP? Unclear – would need a re-write or more information?

P16, L26: Check hyphenation ‘. . ..cost- and time efficient.’

P16, L31: Consider capitalisation ‘. . .Hotspot and Degree Heating Week (DHW) . . .’

P16, L33: Check punctuation ‘. . .maximum, which, when accumulated over a 12-week moving window, provide a measure . . .’

P17, L1: Here and elsewhere, consider presentation of water temperature/degree symbol spacing. It should be 8 °C but some journals also use 8°C (never 8° C).

P17, L20: Check hyphenation '. . .temperature-tolerant coral species . . .'

Section 8 and elsewhere: Check use of tenses. For example '. . .In a modelled scenario, injecting 5 Tg SO2 annually into the stratosphere above Caribbean coral reefs reduces SST, irradiance and sea-level rise and results in a substantial decline in the number of mass coral bleaching events predicted to occur over the next 50 years (Zhang et al., 2017). . . .'; '. . .Similarly, Kwiatkowski et al. (2015) reported that enhancing SO2 concentrations in the tropical stratosphere reduces SST and the risk of coral bleaching over the next 30 years under an RCP4.5 scenario. . .'; '. . .Latham et al. (2013) found that an enhanced source of sea-spray aerosol over the GBR, Caribbean and French Polynesia offsets the warming effects . . .' Also: consider use of 'reduce' (could be confused with chemical reduction) and use 'decrease' instead?

P18, L1 and 4: Avoid repetitive word usage 'another'.

P18, L5: Consider rewording '. . . .over reefs of high economic and environmental value.'

P18, L21: '. . .There is substantial evidence that coral reefs are strong sources of dimethylated sulfur compounds . . .' It is true that corals are producing a lot of DMSP. However, our recent attempt to simulate the DMS sea-to-air flux from coral reefs using the 'model cnidarian' Aiptasia (which likely has its limitations. . .) finds that the flux normalised to sea surface area is lower in coral reefs than the average global oceanic flux: Franchini, F. and Steinke, M. (2017) Quantification of dimethyl sulfide (DMS) production in the sea anemone Aiptasia sp. to simulate the sea-to-air flux from coral reefs. Biogeosciences, 14, 5765-5774.

P18, L 31: '. . .This biogenic aerosol source is in danger of becoming weaker with ongoing coral reef degradation. . .' Earlier, the case was made for DMS being the same/increasing when seaweeds replace corals?

References: Check for use of italics for scientific names (e.g. Symbiodinium in Deschaseaux et al. 2014b, Klueter et al. 2017).

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