Rural and Regional Affairs and Transport References Committee:
Identification of leading practices in ensuring evidence-based regulation of farm practices that impact water quality outcomes in the Great Barrier Reef

ANSWERS TO QUESTIONS ON NOTICE
Australian Institute of Marine Science
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AGENCY: Australian Institute of Marine Science (AIMS)

REFERENCE:

- **Senator McDonald: Hansard Proof, 27 July 2020**
- **Senator Canavan: Hansard Proof, 27 July 2020**
- **Senator Rennick: Questions on Notice, tabled 30 July 2020**

SENATOR MCDONALD QUESTIONS ON NOTICE (HANSARD PROOF: PAGE 4)

Senator McDONALD*: Dr Hardisty, you make an important point about these two issues being conflated. I think that is one of the very issues that we're trying to get to at the heart of these reef regulations, where many issues are being conflated, and it's all adding up to an outcome that's not necessarily a good one for regional communities in the north. So, I want to ask if AIMS has done experiments in its SeaSim facility looking at the effect of pesticides on coral growth rates, and, if so, is one of the effects of pesticides to slow the growth rates of corals?*
Dr Schaffelke: *In the Sea Simulator we have been doing a number of experiments on the effect of pesticides on corals and on seagrasses, and also on other marine plants, such as microalgae. Pesticides have a dose-response relationship, as we call it in scientific parlance. The more you add and the longer you add them, the higher is the response. When we talk about pesticides that's a wide range of specific chemicals. The work that is relevant to the Great Barrier Reef has mostly focused on herbicides that are designed to actually suppress weeds on farms and in gardens and so on, because they are also acting on marine plants. Interesting here is the effect on seagrasses more than on corals, but corals, due to their symbiotic algae, also are in fact plants. The pesticides work has looked at coral larvae, for example, but most of the work has actually indeed concentrated on seagrasses, because they're much more important as marine plants being exposed to seagrasses. I can't give you a specific example of impacts of herbicide on coral growth rates, but I can take that on notice. But I would probably refer the answer to the question on impacts of herbicide to our colleagues at TropWATER, who have done more experiments on coastal plant species and on species that are much more exposed to pesticides. Corals, in general, are not that much exposed to pesticides, because they are just further away from where the influence usually lies. But I will take that on notice and provide you with more detail*
Senator McDONALD: *I want to understand if you are testing coral growth rates with increasing amounts of pesticides in the water. Yet you're saying that pesticides are just not making it out to the reef—the dilution rate is minimal. Can I just confirm that that's what you're saying?*

ANSWER

The effects of pesticides (which includes herbicides, insecticides and fungicides) have been examined by AIMS scientists for over 17 years. The most comprehensive and most recent (March 2020) study examined the effects of 21 different types of pesticides which were tested against 16 different tropical aquatic species[1].

The general focus has been on herbicides because: (a) they are most commonly detected in the catchments and waters of the GBR, (b) can have effects at very low (i.e. part per trillion) concentrations, and (c) corals, although animals, are susceptible to herbicides because they have a symbiotic relationship with microscopic algae that live within their tissues and provide them with energy.

The research has shown that certain types of commonly used herbicides initially affect the photosynthetic efficiency of the algal symbionts of corals and at higher enough concentrations and long enough exposure times cause corals to expel their algal symbionts and bleach (similar to the bleaching observed in corals caused by heat stress)[2].

This dissociation of the symbiosis has numerous well known follow-on effects, including reduced growth and reduced reproductive output[3]. Another separate line of research has examined how herbicides, insecticides and fungicides affect the early life history stages of corals and the ability of juvenile coral larvae to settle on the seabed and then metamorphosize or grow into individual coral polyps[4].

The primary focus of the AIMS aquarium- and SeaSim-based experiments has been about identifying the lowest concentration that can cause 'ecologically relevant' effects. The information is then subjected to an external QA/QC screening process and combined with information from many other similar studies with different species and types of organism to derive water quality guideline values (WQGVs) [refer: *Water Quality Australia - Guidelines for water quality management*].

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[1] A. Negri et al., Ecotoxicology of pesticides on the Great Barrier Reef for guideline development and risk assessments. Final report to the National Environmental Science Program. Reef and Rainforest Research Centre Limited, Cairns (125pp.). (2020).

[2] R. J. Jones, A. P. Kerswell, Phytotoxicity of photosystem II (PSII) herbicides to coral. *Marine Ecology Progress Series* **261**, 149-159 (2003).

R. J. Jones, J. Muller, D. Haynes, U. Schreiber, Effects of herbicides diuron and atrazine on corals of the Great Barrier Reef, Australia. *Marine Ecology Progress Series* **251**, 153-167 (2003).

R. J. Jones, The ecotoxicological effects of Photosystem II herbicides on corals. *Marine Pollution Bulletin* **51**, 495-506 (2005).

A. P. Negri, F. Flores, T. Röthig, S. Uthicke, Herbicides increase the vulnerability of corals to rising sea surface temperature. *Limnology and Oceanography* **56**, 471-485 (2011).

[3] N. E. Cantin, A. P. Negri, B. L. Willis, Photoinhibition from chronic herbicide exposure reduces reproductive output of reef-building corals. *Marine Ecology Progress Series* **344**, 81-93 (2007).

[4] A. Negri *et al.*, Effects of the herbicide diuron on the early life history stages of coral. *Marine Pollution Bulletin* **51**, 370-383 (2005).

A. P. Negri, R. M. Soo, F. Flores, N. S. Webster, Bacillus insecticides are not acutely harmful to corals and sponges. *Marine Ecology Progress Series* **381**, 157-165 (2009).

F. Flores, S. Kaserzon, G. Elisei, G. Ricardo, A. P. Negri, Toxicity thresholds of three insecticides and two fungicides to larvae of the coral Acropora tenuis. *PeerJ* **8**, e9615 (2020).

K. L. Markey, A. H. Baird, C. Humphrey, A. P. Negri, Insecticides and a fungicide affect multiple coral life stages. *Marine Ecology Progress Series* **330**, 127-137 (2007)

The *Scientific Consensus Statement 2017 (Chapter 3)*[5] states: "Pesticides pose the greatest risk to ecosystems closest to the source of the pesticides i.e. freshwater wetlands, rivers and estuaries are exposed to the highest concentrations, followed by coastal ecosystems, seagrass and coral". The pesticide monitoring program conducted by the University of Queensland and GBRMPA[6] monitors pesticides at multiple inshore or coastal sites within the expected extent of flood plumes from rivers discharging into the coastal areas of the Great Barrier Reef World Heritage Area (GBRWHA).

Pesticides are routinely detected in the coastal waters of the GBRWHA, but the levels detected mean they are considered to have a low to negligible risk with possible low-level exposure in wet seasons only. In the mid-shelf and outer-shelf regions they are considered to have a very low to negligible risk and with possible low-level exposure during large wet season events only[5].

SENATOR CANAVAN QUESTIONS ON NOTICE (HANSARD PROOF: PAGE 14)

***Senator CANAVAN**: Okay. You also mentioned the Deloitte reports on tourism et cetera. You might need to take this one on notice. What are the assumptions they make about the reasons for visitation to the Great Barrier Reef area? I know from looking at the reports before that this is a complex question, because they look at visitor nights to the region and, of course, not all of those visitor trips are because of the reef. How do they decide how much of the visitor travel is because of coral et cetera and how much because people losing family, friends et cetera?*
***Dr Hardisty:** You're correct. I'll have to take that one on notice in terms of the detailed methodology for you.*

ANSWER
In the most recent publication of the *AIMS Index of Marine Industry*, December 2018, the authors of the analysis, Deloitte Access Economics, identify that the Tourism Satellite Account (refer: ABS (2018c) Cat No. 5249.0, 2016-17) provides the data on domestic and international tourism value add, and that for marine tourism employment, the same ratio of domestic to international tourism is used, as for value add. Domestic and international marine tourism are estimated as 40 per cent and 19 per cent of domestic and international tourism respectively, using the methodology first outlined by the Review Committee on Marine Industries, Science and Technology in Australia (1989).

In the Deloitte Access Economics report: *At what price? The economic, social and icon value of the Great Barrier Reef,* calculations are made of tourism expenditure in the GBR region. However, this report was not commissioned by AIMS, and we are unable to answer questions on the assumptions underlying the GBR tourism estimates in this report.

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[5] J. Waterhouse et a. (2017) The risk from anthropogenic pollutants to Great Barrier Reef coastal and marine ecosystems. Scientific Consensus Statement 2017: Chapter 3: The risk from anthropogenic pollutants to Great Barrier Reef coastal and marine ecosystems

[6] C. Gallen *et al.*, Marine Monitoring Program: Annual Report for inshore pesticide monitoring 2017–18. Report for the Great Barrier Reef Marine Park Authority, Great Barrier Reef Marine Park Authority, Townsville. 118 pp. (2019). This and other MMP pesticide monitoring reports available here.

SENATOR RENNICK QUESTIONS ON NOTICE: TABLED 30 JULY 2020

Question 1: Can AIMS give an estimate or figure for the rate of coral growth rates by coral type across the entire reef catchment? Please note I ask this distinct from questions around coral cover growth rates.

ANSWER

The GBR has over 450 species of hard (reef-building) corals[7], with many different growth forms, life spans and traits such as their mode of feeding and reproduction. Coral growth rate is a fundamental indicator, important for understanding of coral reef recovery after disturbance events, as well as reef-building.

Coral growth varies between species, years and habitat. A recent collation of published growth rates[8] gives an average of 13.5 millimetres per year (standard deviation 23.9) across 101 species. Some branching coral species, such as staghorn corals, can grow more than 10 centimetres each year, while other species, like the massive *Porites* coral used for historical coral growth records are very slow growing with annual averages of 1-2 centimetres per year.

Coral growth is measured by different methods, depending on the species and the objective of the measurement. The methods include repeated measurements of tagged individual coral colonies (both in captivity or in the field), e.g. using image analysis methods or, in the past, using callipers or staining of corals that are then destructively sampled and their skeleton analysed. Some species of massive coral also are suitable to have cores taken using a hollow drill head for analysis of growth bands with x-radiography or a CT scanner.

However, at present, none of these methods is practical to complement GBR-wide assessments on coral reef health for annual reporting. For such assessments, growth calculated from coral cover estimates is the world-wide accepted indicator. AIMS publishes annually a report on the status and trends of coral cover on the Great Barrier Reef, based on our 35-year data series of the AIMS long-term monitoring program, which is also freely available, and promoted on our website. Assessment of the health of inshore reefs are undertaken as part of the Marine Monitoring Program, coordinated by the Great Barrier Reef Marine Park Authority (GBRMPA), with reports and data freely available. AIMS long-term monitoring methods, including quality control and data management procedures, are described in regularly updated Standard Operational Procedures[9]. Each year, about 120 reefs are being surveyed, representing reefs along the length and breadth of the GBR[10].

For research purposes, as opposed to routine monitoring and reporting of coral reef condition, AIMS analyses rates of extension (an indicator of growth, analysed by x-radiography) and skeletal density (analysed by gamma densitometry) to calculate coral calcification in cores collected from long-lived *Porites* corals. These data have been used to provide broad-scale and

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[7] Hutchings, P., Kingsford, M. and Hoegh-Guldberg, O.(eds) 2019, The Great Barrier Reef: Biology, Environmentand Management, 2nd edn, CSIRO Publishing, ClaytonSouth, Australia.

[8] Madin, J. S., K. D. Anderson, M. H. Andreasen, T. C. L. Bridge, S. D. Cairns, S. R. Connolly, E. S. Darling, M. Diaz, D. S. Falster, E. C. Franklin, R. D. Gates, M. O. Hoogenboom, D. Huang, S. A. Keith, M. A. Kosnik, C.-Y. Kuo, J. M. Lough, C. E. Lovelock, O. Luiz, J. Martinelli, T. Mizerek, J. M. Pandolfi, X. Pochon, M. S. Pratchett, H. M. Putnam, T. E. Roberts, M. Stat, C. C. Wallace, E. Widman, and A. H. Baird. 2016. The Coral Trait Database, a curated database of trait information for coral species from the global oceans. **3**:160017.

[9] https://www.aims.gov.au/docs/research/monitoring/reef/sops.html

[10] Mellin, C., E. E. Peterson, M. Puotinen, and B. Schaffelke. Representation and complementarity of the long-term coral monitoring on the Great Barrier Reef. Ecological Applications. https://doi.org/10.1002/eap.2122

long-term (over hundreds of years) insights into *Porites* calcification and how the environment influences these, i.e. a window in the past of the GBR. It is important to note that extension or calcification trends of individual massive corals cannot be used to extrapolate the overall growth rate of the surrounding reef community. Most massive species are extremely tolerant to environmental disturbances and, because of this, are so long-lived. Growth trends need to be combined with ecological surveys to assess reef community dynamics through time. Comprehensive observational surveys only started in the early 1980s on the GBR (see above).

Using material available in the AIMS Coral Core Archive, AIMS published in 2009 (with a published correction in 2013) a major Great Barrier Reef-wide analysis of *Porites* calcification spanning hundreds of years. This analysis showed a decline in calcification from about 1990-2005. To further explore patterns and potential causes, AIMS undertook and published several analyses of *Porites* calcification since 2009. These studies show that *Porites* growth rates are mostly changing in response to temperature, and in particular to marine heatwaves which lead to reduced growth rates following the 1998 and 2002 bleaching events[11].

AIMS has not undertaken a comprehensive GBR-wide collection of new coral cores for analysis of *Porites* extension or calcification data since the 2009 study. Such a study would be worthwhile repeating on an approximately decadal scale as these indicators respond very slowly, and the collection is costly. AIMS is currently examining the timing and funding of the next decadal, look-back, coral coring campaign. Coral core collection would be best conducted from about 2022, to allow accurate sampling of growth bands after the most recent coral bleaching events during the summers of 2016, 2017 and 2020.

Beyond the published reports, all of AIMS' extensive coral core data is available on request and can be provided to anyone who seeks it. Indeed, we have provided the existing meta-data, and offered to provide the detailed data, to several farming sector interest groups in Queensland.

Question 2: Can AIMS explain clearly the measurement instruments used, the areas where samples are taken and how large sample sizes are?

ANSWER

The AIMS *Porites* coral growth database has data from 563 cores collected from 90 reefs spanning the length and breadth of the GBR. AIMS can provide a spatial database file which contains the sampling dates and locations and level of within-reef replication for this spatial assessment of coral growth. Historically, long cores were collected from 1-3 colonies per reef. Recent coral core collections made in 2004-5, 2008, 2012-13 and 2017-18 include a minimum of three to a maximum of 42 colonies within a single reef. A minimum of 2-3 cores are collected per colony to ensure the longest continuous growth record is recovered. Methods used for the collection and analyses of *Porites* cores have been published[12] and detailed AIMS Standard Operational Procedures, including description of instruments used, can be made available upon request. Methods include x-ray observation of annual density bands, alizarin staining to verify the annual formation and geochemistry analyses to confirm annual growth bands.

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[11] Lough, J. M., and N. E. Cantin. 2014. Perspectives on Massive Coral Growth Rates in a Changing Ocean. The Biological Bulletin **226**:187-202.
Cantin, N. E., and J. M. Lough. 2014. Surviving Coral Bleaching Events: *Porites* Growth Anomalies on the Great Barrier Reef. PLoS ONE **9**:e88720.

[12] Lough, J.M., Barnes, D.J., 1990a. Intra-annual timing of density band formation of Porites coral from the central Great Barrier Reef. J. Exp. Mar. Biol. Ecol. 135, 35–57.
Lough, J.M., Barnes, D.J., 1990b. Measurement of density in slices of coral skeleton: effect of densitometer beam diameter. J. Exp. Mar. Biol. Ecol. 135, 35–57.

Question 3: Can AIMS give the confidence intervals for their data and outline how many times it has been replicated?

ANSWER
This question can only be answered in relation to a specific analysis or publication and would pertain to the data set used in this instance.

Question 4: Can AIMS give figures on toxic levels for coral and sea grass for relevant nutrients and chemicals?

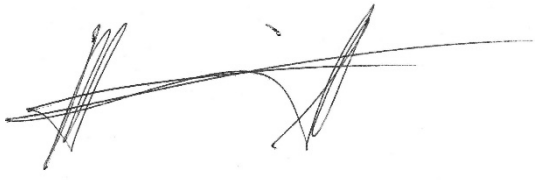
ANSWER
Such values are best provided by the hierarchy of available water quality guidelines, with the highest level being the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018), developed jointly by the Australian and New Zealand governments and the Australian state and territory governments as part of the National Water Quality Management Strategy.

Subsidiary to the ANZG, regional and local water quality objectives for inland and coastal waters of the Great Barrier Reef Region [https://environment.des.qld.gov.au/management/water/policy] and for waters further offshore in the GBRMPA water quality guidelines [http://www.gbrmpa.gov.au/our-work/threats-to-the-reef/declining-water-quality/water-quality-guidelines-for-the-great-barrier-reef] are also available.

Question 5: Can AIMS give accurate estimates or figures on the level of herbicide and pesticide found on the Great Barrier Reef and clearly explain how much blame for these levels can be apportioned to agriculture

ANSWER
AIMS does not undertake herbicide or pesticide monitoring in the GBR. Such data are collected as part of the Marine Monitoring Program, coordinated by the Great Barrier Reef Marine Park Authority (GBRMPA), with reports available here: http://elibrary.gbrmpa.gov.au/jspui/browse?type=series&order=ASC&rpp=20&value=Marine+Monitoring+Program+-+Pesticides.

The complementary end-of-catchment monitoring of pesticides is conducted by the Queensland Government and reports and data are available here: https://www.reefplan.qld.gov.au/tracking-progress/paddock-to-reef/modelling-and-monitoring



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