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Commentary

The chaotic history of using vinegar injections to control *Acanthaster* spp. populations. A comment to Boström-Einarsson L., Bonin M. C., Moon S. and Firth S. (2018). Environmental impact monitoring of household vinegar injections to cull crown-of-thorns starfish, *Acanthaster* spp. Ocean & Coastal Management 155: 83-89

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There seems to be some confusion surrounding the recent renewed interest in the use of vinegar (and other natural acids) to fight outbreaks of the corallivorous crown-of-thorns (COTS) starfish. In a recent paper by Boström-Einarsson et al. (2018), statements were made suggesting that previous studies using vinegar did not succeed in proposing effective, operational control methods. While the notion of effectiveness is indeed open to debate, some of the statements may be misleading. For the sake of clarity here we shed light on the efficacy of previous methods drawn from an exhaustive literature search, including results from “grey literature” which may have gone unnoticed.

In 2011, Japanese researchers from the Okayama University of Science were the first to demonstrate the lethal effects of acetic acid (the active component of vinegar) on COTS, albeit with low mortality rates (Yamamoto and Otsuka, 2013). These researchers carried out more tests whilst resulted in an operational control method using dilute (15–18%) acetic acid, published locally as a project report “Crown-of-thorns starfish control manual: Introduction to the acetic acid injection method” (KBRF, 2012). Their studies showed that “... almost 100% of regular-sized COTS (about 30 cm arm diameter) will die if more than 10 ml of 15% acetic acid aqueous solution is injected into their bodies.” (KBRF, 2012). While highly effective and considered operational by the Japanese team, the method indeed suffered from minor drawbacks; in particular multiple injections of small volumes of acetic acid (up to 5–6 injections of 2.5 ml, according to the size of starfish) were recommended.

In 2014, this approach was taken a step further by a joint French-Vanuatu research team based in Vanuatu. Field trials quickly emphasized that fewer (1–2) injections of larger (10–20 ml) volumes of white

vinegar (and another natural acidic solution, fresh lime juice extract) presented definite logistical advantages and could produce 100% mortality; these results were first published as project reports (Dumas et al., 2014a, 2014b). The approach was formally tested for several injection treatments (10–20 ml/single vs. double injections) and the conclusion that 100% mortality was consistently reached with double injections of 10 ml vinegar was first mentioned in a feature article on the COTS issue in Vanuatu, published in the **January 2015** open-access issue of the SPC Fisheries Newsletter (Dumas et al., 2015). This study eventually resulted in the publication of a refined COTS control method in the open-access journal *Plos One*: “Lime juice and Vinegar Injections as a Cheap and Natural Alternative to Control COTS Outbreaks” (Moutardier et al., 2015). In this paper, Fig. 1 clearly demonstrated that 100% COTS mortality was achieved with two injections of 10ml of either acidic solutions, lime juice or vinegar. Furthermore, in Fig. 2 we showed that “death was induced in all the injected seastars within 1 day, under both experimental and field conditions.” Based on these results, it was advocated that “injections of lime juice and vinegar offer great advantages when compared to current best practices and constitute a cheap and natural option for all countries affected by COTS” (Moutardier et al., 2015).

A study published in *Coral Reefs* (2016) by Australian researchers further investigated some minor variations of the vinegar injections, using 1 to 4 injections and 2 different needle sizes (Boström-Einarsson and Rivera-Posada, 2016). The paper was initially submitted to *Coral Reefs* in June 2015; although they cite the two (Japanese) references that had previously discovered this technique, unfortunately they missed the French-Vanuatu 2014 and January 2015 references. This

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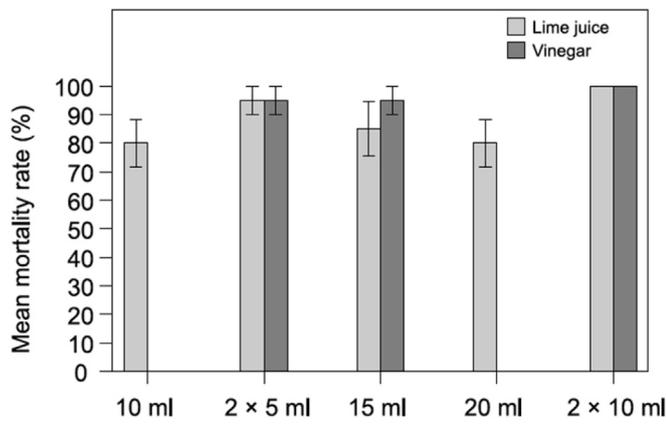


Fig. 1. Mortality rates for COTS subjected to different injection treatments. Means ± SE for lime juice (light grey) and vinegar (dark grey).

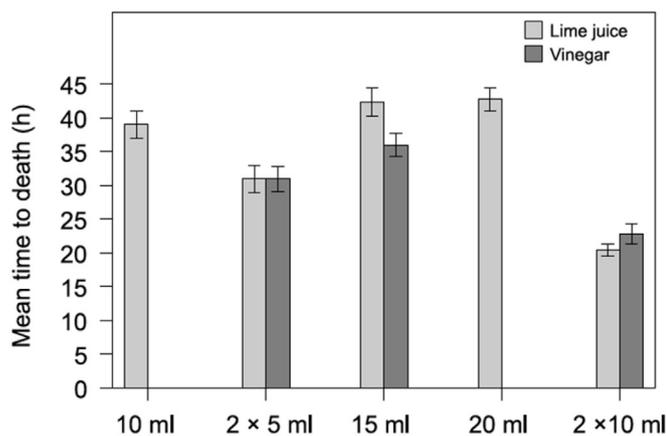


Fig. 2. Time to death for COTS subjected to different injection treatments. Means ± SE for lime juice (light grey) and vinegar (dark grey).

may explain why authors claim to have “discovered that common household vinegar is lethal to *A. planci* individuals when injected at the base of one their arms” (Boström-Einarsson and Rivera-Posada, 2016), which in fact is misleading.

A similar issue arises in the paper by Boström-Einarsson et al. (2018), where the following statement was made: “Injections of COTS with vinegar has been previously trialed in Japan and Vanuatu,

however both studies indicated that mortality rates of injected starfish were less than 100% (Yamamoto and Otsuka, 2013; KBRF, 2012; Moutardier et al., 2015)”. This is inaccurate as the 2015 study by the French-Vanuatu team (Moutardier et al., 2015; Dumas et al., 2015) had already and undoubtedly demonstrated that 100% mortality was consistently reached when using vinegar: « Highest efficiency was reached for both solutions with double shots of (2 × 10 ml) in two different areas on the body: 100% mortality occurred within 12–24 h, which is similar or faster compared with other current injection methods » (Moutardier et al., 2015). (Figs. 1 and 2).

Conclusion

We hope we have accurately clarified the timeline of research carried out on the use of vinegar injections for the control of *Acanthaster* spp. populations, so that in the future all past publications will be cited accurately and credited accordingly. As 2018 is the International Year of the Reef (IYOR), we wish that researchers worldwide can be united in increasing the awareness of the plight of coral reefs, and be united in finding solutions to protect reefs from increasing threats, including the outbreaks of the crown-of-thorns starfish *Acanthaster* spp.

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