



## Biological justification of the developed methods

### Executive Summary

Because of the short-comings of ballast water exchange there is a need for alternative treatment methods. A number of treatment methods have been suggested, and the aim of the MARTOB project was to examine some methods in the laboratory and onboard ship or onshore trials. The biological assessment of each method was performed as used as a comparison between the methods.

For the laboratory tests the main conclusions are as follows:

- All the UNEW high temperature treatments above 55°C were very effective for *T. battagliai* and *N. virens*. For *A. tonsa* the highest mortality achieved was 88.5%, however no significant difference was found in the % kill of *A. tonsa* and the other two species when testing the different temperatures.
- TNO's hydrogen peroxide methodology was very effective towards *N. virens* achieving a total mortality in all cases. *A. tonsa* was reduced above 95% in all but one case (test (1), with a % kill of 93). *T. battagliai* achieved a 96% kill in treatment (6), however for all other tests it was always below 88%.
- The combination of filter (125 µm), US and UV from VTT achieved a removal that was always higher than 98%. However none of the other treatments did (UV, US, ozone and the combination of US+UV). From the methodologies tested on their own, ozone appeared to attain the best effect.
- The de-oxygenation treatment of SINTEF with nutrients had a high efficacy (above 95% mortality) from the fifth day for *A. tonsa*. Effective reductions for *T. battagliai* and *N. virens* occurred at day 7 (97.1% and 100%, respectively). *T. battagliai* was the least sensitive species out of the three. *A. tonsa* was one of the most sensitive even when no nutrients were added to the bacteria culture.
- BENRAD oxidation method (based on a combination of ozone (O<sub>3</sub>), two UV systems and two different catalysts) was very effective (always above 98%) when using the 100µm filter. However, when the system was tested on its own, the kill rate never achieved more than 80%.
- From the results of BERSON's hurdle technologies, the treatment that worked best was the Thermal + De-oxygenation, which had a 100% efficiency for all three species. We must be very careful, though, as we cannot assure that with replicates this would still be so. Comparing the efficiency of UV+H<sub>2</sub>O<sub>2</sub> with and without filter (150µm), the results showed that the filter did affect the survival of the organisms (mainly at low H<sub>2</sub>O<sub>2</sub> concentration), as the percentage in organisms removal increased for *A. tonsa* (principally), *T. battagliai* and *N. virens* when the filter was used.

In the case of the onboard ship trials the results are:

- For the HT treatment, or more correctly the HT + fire pump treatment, increasing the treatment temperature above 60°C did not improve the effectiveness. There was an increase in nauplius

mortality over time, i.e. the longer they had been in the tank the more effective the treatment. Due to the killing effect of the fire pump, it is difficult to quantify the effect of the HT treatment. However the result from the organisms in the control samples suggests that the HT treatment alone would have killed at least 90% of the zooplankton in the ballast water. In combination with the fire pump the HT treatment only achieved the new IMO standard of less than 10 viable organisms per m<sup>3</sup> only in about 40% of the trials.

- Both in the control tanks and the treated tanks in the DEOX trial, the total concentration of zooplankton, i.e. both live and dead, decreased during the trial. The decrease was fastest in the treated tanks and after 5 and 7 days the average total concentration was significantly lower in treated than in untreated water; 25-50 organisms/m<sup>3</sup> in treated versus 400-430 organisms/m<sup>3</sup> in untreated water. The average concentration of viable organisms in the water samples from the treated tanks was only 1-3 per m<sup>3</sup>, while the samples from the untreated tanks contained 10-150 viable organisms per m<sup>3</sup>. The DEOX treatment in combination with the killing effect of the fire pump therefore achieved the new IMO standard, but it is not possible to determine if this standard would have been achieved without the fire pump.