Table S1 Biological parameters of ballast water samples

| Biological parameters | >D-2[1] | | | | <D-2[2] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | U[3] | | D[4] | | UV&D[5] | | EC&D[6] | | MD&D[7] | |
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Species number | 9.6 | 8~12 | 9.6 | 7~12 | 4.0 | 2~8 | 3.4 | 1~4 | 4.3 | 1.0~7.0 |
| Simpson diversity index | 0.7 | 0.4~0.8 | 0.6 | 0.4~0.8 | 0.5 | 0.2~0.8 | 0.5 | 0~0.7 | 0.6 | 0~1.0 |
| Proportion of Bacillariophyta | 0.2 | 0~0.7 | 0.2 | 0~0.5 | 0.3 | 0.1~0.7 | 0.1 | 0~0.5 | 0.1 | 0~0.7 |
| Proportion of Dinoflagellate | 0.3 | 0~0.8 | 0.4 | 0~0.8 | 0.6 | 0~0.9 | 0.4 | 0~1.0 | 0.4 | 0~1.0 |
| Proportion of Cryptophyta | 0.3 | 0~0.7 | 0.2 | 0~0.4 | 0.0 | 0~0.2 | 0.2 | 0~0.4 | 0.0 | 0~0.2 |
| Proportion of unicellular organisms | 0.9 | 0.4~1.0 | 0.9 | 0.6~1.0 | 0.8 | 0.5~1.0 | 1.0 | 0.7~1.0 | 1.0 | 0.8~1.0 |
| Proportion of multicellular organisms | 0.1 | 0~0.6 | 0.1 | 0~0.4 | 0.2 | 0~0.5 | 0.0 | 0~0.3 | 0.0 | 0~0.2 |
| Results of epifluorescence microscopy | 1234.7 | 1043.0~1587.3 | 652.7 | 246.0~972.0 | 5.5 | 1.8~8.0 | 3.5 | 1.2~7.0 | 2.8 | 0.2~6.7 |

Note: 1. '> D-2' indicates that the number of living ≥10-50μm organisms in this group of samples exceeds the D-2 standard, which is more than 10 cells/mL. 2. '< D-2' indicates that the number of living ≥10-50μm organisms in this group of samples does not exceed the D-2 standard, which is less than 10 cells/mL.3. **U** stands for the untreated ballast water samples collected directly before the BWMS during the ballasting phase. 4. **D** stands for control group discharge water samples subjected solely to dark storage (without BWMS treatment) during the deballasting phase. 5. **UV&D** stands for treated discharge water samples collected during the deballasting phase, processed via dark storage and the treatment of ultraviolet (UV) BWMS. 6. **EC&D** stands for treated discharge water samples collected during the deballasting phase, processed via dark storage and the treatment of electrochlorination BWMS. 7. **MD&D** stands for treated discharge water samples collected during the deballasting phase, processed via dark storage and the treatment of membrane filtration and deoxygenation BWMS.

Table S2 Water quality parameters of ballast water samples

| Water quality parameters | | >D-2[1] | | <D-2[2] | | |
|---|---|---|---|---|---|---|
| | | U[3] | D[4] | UV&D[5] | EC&D[6] | MD&D[7] |
| Temperature | Mean | 23.88$^{abc}$ | 25.72$^{a}$ | 21.18$^{c}$ | 22.17$^{bc}$ | 25.08$^{ab}$ |
| (°C) | Range | 13.73～28.10 | 21.80～28.00 | 12.63～29.00 | 18.60～25.50 | 21.90～27.63 |
| Salinity | Mean | 9.96$^{ab}$ | 13.96$^{a}$ | 1.98$^{b}$ | 13.80$^{a}$ | 21.01$^{a}$ |
| (PSU) | Range | 0.20～30.6 | 0.20～30.7 | 0.20～17.83 | 0.9～30.7 | 0.4～30.6 |
| pH | Mean | 8.03$^{a}$ | 8.00$^{a}$ | 7.71$^{b}$ | 8.10$^{a}$ | 8.17$^{a}$ |
| | Range | 7.40～8.73 | 7.50～8.49 | 7.43～8.00 | 7.79～8.38 | 8.00～8.30 |
| DO | Mean | 8.25$^{a}$ | 5.90$^{b}$ | 8.29$^{a}$ | 8.31$^{a}$ | 6.59$^{b}$ |
| (mg/L) | Range | 6.80～10.43 | 4.60～6.90 | 5.90～11.21 | 7.47～9.54 | 5.80～7.04 |
| Turbidity | Mean | 70.92$^{a}$ | 14.19$^{bc}$ | 59.58$^{ab}$ | 45.11$^{abc}$ | 1.01$^{c}$ |
| (NTU) | Range | 7.70～197.33 | 1.40～91.70 | 4.26～224.7 | 23.40～76.27 | 0.50～1.90 |
| TSS | Mean | 46.20$^{a}$ | 22.81$^{b}$ | 24.91$^{b}$ | 46.51$^{a}$ | 28.03$^{b}$ |
| (mg/L) | Range | 25.93～56.27 | 1.93～44.00 | 2.40～49.27 | 28.50～67.53 | 1.47～47.00 |
| POC | Mean | 4.81$^{a}$ | 0.78$^{c}$ | 2.62$^{b}$ | 5.69$^{a}$ | 0.91$^{c}$ |
| (mg/L) | Range | 4.00～5.81 | 0.44～1.00 | 0.35～5.69 | 1.51～8.04 | 0.42～1.27 |
| DOC | Mean | 12.48$^{ab}$ | 12.81$^{ab}$ | 9.70$^{bc}$ | 7.29$^{c}$ | 13.92$^{a}$ |
| (mg/L) | Range | 6.41～17.69 | 6.00～17.83 | 6.60～14.30 | 5.97～8.84 | 6.00～22.46 |

Note: 1. '> D-2' indicates that the number of living ≥10-50μm organisms in this group of samples exceeds the D-2 standard, which is more than 10 cells/mL. 2. '< D-2' indicates that the number of living ≥10-50μm organisms in this group of samples does not exceed the D-2 standard, which is less than 10 cells/mL.3. **U** stands for the untreated ballast water samples collected directly

before the BWMS during the ballasting phase. 4. **D** stands for control group discharge water samples subjected solely to dark storage (without BWMS treatment) during the deballasting phase. 5. **UV&D** stands for treated discharge water samples collected during the deballasting phase, processed via dark storage and the treatment of ultraviolet (UV) BWMS. 6. **EC&D** stands for treated discharge water samples collected during the deballasting phase, processed via dark storage and the treatment of electrochlorination BWMS. 7. **MD&D** stands for treated discharge water samples collected during the deballasting phase, processed via dark storage and the treatment of membrane filtration and deoxygenation BWMS.

Table S3 Correlation between water quality parameters, biological parameters, output values of compliance monitoring devices (CMDs) and epifluorescence microscope results of ballast water samples

| | Temperature | Salinity | pH | DO | Turbidity | TSS | POC | DOC | SN | SDI | PB | PD | PUO | PMO | FDA | VF | EM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | 1 | | | | | | | | | | | | | | | | |
| Salinity | 0.071 | 1 | | | | | | | | | | | | | | | |
| pH | .263* | .297* | 1 | | | | | | | | | | | | | | |
| DO | -.745** | -0.116 | -0.185 | 1 | | | | | | | | | | | | | |
| Turbidity | 0.069 | -.497** | -.501** | 0.182 | 1 | | | | | | | | | | | | |
| TSS | -.287* | .345** | -0.102 | .502** | .340** | 1 | | | | | | | | | | | |
| POC | -.375** | -0.156 | -0.086 | .720** | .418** | .711** | 1 | | | | | | | | | | |
| DOC | .748** | 0.078 | 0.232 | -.464** | -0.064 | -.267* | -.337** | 1 | | | | | | | | | |
| SN | .247* | 0.129 | .338** | -0.133 | -0.042 | 0.138 | 0.056 | .238* | 1 | | | | | | | | |
| SDI | -0.079 | -.365** | 0.016 | 0.081 | .259* | 0.018 | 0.101 | -0.202 | .478** | 1 | | | | | | | |
| PB | 0.016 | .298* | 0.083 | -0.065 | -0.192 | 0 | -.251* | 0.069 | 0.131 | 0.194 | 1 | | | | | | |
| PD | -0.111 | .511** | 0.021 | 0.062 | -.300* | 0.193 | -0.008 | -0.02 | -.353** | -.748** | 0.106 | 1 | | | | | |
| PUO | -0.222 | -.410** | -.364** | 0.124 | .388** | 0.064 | 0.231 | -.348** | -0.2 | 0.038 | -.686** | -0.103 | 1 | | | | |
| PMO | 0.222 | .410** | .364** | -0.124 | -.388** | -0.064 | -0.231 | .348** | 0.2 | -0.038 | .686** | 0.103 | -1.000** | 1 | | | |
| FDA | -0.183 | -0.199 | 0.06 | 0.204 | 0.174 | .331** | .348** | -.255* | 0.191 | .295* | -0.005 | 0.006 | 0.198 | -0.198 | 1 | | |
| VF | -.376** | -0.086 | -0.106 | .333** | 0.091 | .301* | .269* | -0.23 | .239* | .268* | 0.116 | -0.154 | -0.047 | 0.047 | 0.205 | 1 | |
| EM | 0.012 | 0.158 | 0.148 | 0.226 | 0.163 | .513** | .384** | 0.102 | .771** | .289* | 0.145 | -0.108 | -0.109 | 0.109 | .407** | .514** | 1 |

(*P < 0.05, **P < 0.01, SN=Species number, SDI=Simpson diversity index, PB=Proportion of Bacillariophyta, PD=Proportion of Dinoflagellate, PUO=Proportion of unicellular organisms, PMO=Proportion of multicellular organisms, FDA=Outputs of FDA, VF=Outputs of VF, EM=Results of epifluorescence microscopy)

Table S4 List of abbreviations in this study

| Abbreviation | Expanded Term |
|---|---|
| CMDs | compliance monitoring devices |
| VF | variable fluorescence |
| FDA | fluorescein diacetate |
| IMO | international maritime organization |
| D-2 | D-2 discharge standard |
| FDA | fluorescein diacetate pulse |
| MFA | motility and fluorescence assays |
| FCM | flow cytometry |
| UV | ultraviolet |
| EC | electrochlorination |
| MD | filtration-membrane separation-deoxygenation |
| PSC | port state control |
| ETV | environmental technology verification |
| FW | freshwater |
| MW | marine water |
| BW | brackish water |
| POC | particulate organic carbon |
| TSS | total suspended solids |
| DOC | dissolved organic carbon |
| U | the untreated ballast water samples collected directly before the BWMS during the ballasting phase |
| D | control group discharge water samples subjected solely to dark storage (without BWMS treatment) during the deballasting phase |
| UV&D | treated discharge water samples collected during the deballasting phase, processed via dark storage and the treatment of ultraviolet (UV) BWMS |
| EC&D | treated discharge water samples collected during the deballasting phase, processed via dark storage and the treatment of electrochlorination BWMS |
| MD&D | treated discharge water samples collected during the deballasting phase, processed via dark storage and the treatment of membrane filtration and deoxygenation BWMS |
| CMFDA | 5-chloromethyl fluorescein diacetate |
| PE | polyethylene |
| CV | coefficient of variation |
| CV SD | standard deviation of the CV |
| TP | true positives |
| FP | false positives |
| TN | true negatives |
| FN | false negatives |

| | |
|---|---|
| TPR | true positive rate |
| TNR | true negative rate |
| LOD | limit of detection |
| SEM | structural equation modeling |
| ML | maximum likelihood |
| GFI | goodness-of fit index |
| CFI | comparative fit index |
| RMSEA | root mean square error of approximation |
| SRMR | standardized root mean square residual |