Effects of desiccation and salinity on the outbreak of a green tide of *Ulva pertusa* at the artificial salt marsh along the coast of Osaka Bay, Japan

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North salt marsh of Osaka Nanko bird sanctuary
Objectives of this research

1. Field Observation
   To clarify the population dynamics of green tide algae *Ulva* spp. at the salt marsh of Osaka Nanko bird sanctuary in high temperature seasons when their dense blooms were observed.

2. Laboratory Experiment
   To examine the photosynthetic response of *Ulva pertusa* to salinity decrease and desiccation.
Areas of occurrence of green tide in the world (after Fletcher R. L., 1996)

Large quantities of deteriorated *Ulva* spp. collected at the north salt marsh of Osaka Nanko bird sanctuary in summer.

Bottom sediment after removal of a *Ulva* green tide
Profile of circulation of nutrients at the salt marsh

Elimination of nutrients to outside

Birds

Benthic microalgae (ca. 2-125μm)

Benthic animals

Green tide

Blooms

Degradation

Inorganic nutrients

Macrophyte (ca. 60cm)

Salt marsh

Profile of circulation of nutrients at the salt marsh
Northern Osaka Bay

Sluice pipes of the north salt marsh

South artificial salt marsh

North artificial salt marsh

North salt marsh of Osaka Nanko bird sanctuary

High tide

Low tide
Table 1. Profile of the north and south salt marshes of Osaka Nanko bird sanctuary.

<table>
<thead>
<tr>
<th></th>
<th>North marsh</th>
<th>South marsh</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Salt marsh</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area (ha)</td>
<td>4.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Average ground level (m)</td>
<td>L.W.L.*+0.72</td>
<td>L.W.L.+0.73</td>
</tr>
<tr>
<td>Average exposure rate to air (%)</td>
<td>17.3</td>
<td>9.2</td>
</tr>
<tr>
<td>Median diameter of the bottom sediment (mm)</td>
<td>1.2</td>
<td>0.27</td>
</tr>
<tr>
<td><strong>Sluice pipe</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date of construction</td>
<td>Oct. 1995</td>
<td>May 2004</td>
</tr>
<tr>
<td>Number</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>730</td>
<td>800</td>
</tr>
<tr>
<td>Bottom tip of the pipe (m)</td>
<td>L.W.L.+0.20</td>
<td>L.W.L.+0.65</td>
</tr>
</tbody>
</table>

*L.W.L.: Low Water Level*
Methods of Field Survey

Sampling was made at stations in high-temperature seasons of 2005, 2006, 2007 and 2008.

- **Biomass of macrophyte**
  - Wet weight of seaweed was measured with a 0.25 m² quadrat.

- **Biomass of microalgae**
  - Bottom sediment (0-0.5cm depth from the surface) was taken and the concentration of chlorophyll a was determined.

- **Infauna and non-motile epibenthos**
  - Bottom sediment taken with a modified Koken grab (0.045m²) was sieved through a 1mm mesh net and employed for counting the benthic-animal species and number of individuals.
Figure  Distributions of *Ulva* spp. at the north and south salt marshes of Osaka Nanko bird sanctuary in June 2007, September 2007, July 2008 and September 2008.
Figure Changes of biomass of Ulva spp. as a function of silt and clay content, water content, total carbon and total nitrogen in the bottom sediment of the north salt marsh of Osaka Nanko bird sanctuary. Data in June to September 2006 and 2007 were used.
Changes of biomass of *Ulva* spp. and benthic microalgae as a function of the exposure rate to air at the north salt marsh of Osaka Nanko bird sanctuary. All values of the biomass of *Ulva* and benthic microalgae were averaged at 5% intervals of the exposure rate to air. Vertical axis of the value indicates standard deviation.
**Figure** Changes of biomass of infauna and non-motile epibenthos as a function of the exposure rate to air at the north salt marsh of Osaka Nanko bird sanctuary. Data from June to September of 2000, 2006, 2007 and 2008 were used. Vertical axis of the value indicates standard deviation.
Laboratory Experiment

Preparation

The most dominant algae *Ulva pertusa* were fragmented into small pieces (ca. 1.0cm² and 0.01g wet weight). After acclimation, the seaweed samples were exposed at an experimental temperature and humidity higher than 90% for 2-12 hours, and then introduced into BOD bottles which were filled with enriched seawaters. Incubation of seaweed samples were conducted at a light quantum of ca. 100 μmol m⁻² s⁻¹ for 6 hours. Net photosynthesis (p) was calculated from the following equation.

\[ P = \frac{(C_t - C_0)}{t} \cdot \frac{V}{W} \]

- **P**: net production of *Ulva pertusa* (mgO₂ g wet⁻¹)
- **C₀** and **Cₜ**: dissolved oxygen concentrations at the beginning and end of incubation (mgO₂ l⁻¹)
- **t**: incubation time (6 hours)
- **V**: water volume of the BOD bottle (l)
- **W**: wet weight of the sample (g)
Figure Changes of photosynthetic activity of *Ulva pertusa* in relation to the exposure time to air. Incubation was conducted at salinities of 30 at 25, 30 and 35°C with a light quantum of ca.100 μmol m\(^{-2}\)sec\(^{-1}\).

(%) Expressed as exposure rate to air
Figure Changes of photosynthetic activity of *Ulva pertusa* in relation to salinity at 20±1°C with a light quantum of ca. 100μmol m⁻² sec⁻¹. Vertical axis of the value indicates standard deviation.
Figure Changes of photosynthetic activity of *Ulva pertusa* at salinities of 20, 25 and 30 in relation to the exposure time to air. Incubation was conducted at 25, 30 and 35°C with a light quantum of ca. 100 μmol m⁻² sec⁻¹. Vertical axis of the value indicates standard deviation.
Conclusions

1. The results obtained here suggest the possibility of controlling green tides of *Ulva pertusa* by adjusting ground levels of the artificial salt marsh at the exposure rate of ca. 40% to air (≈ 5-6 hours desiccation) without any negative impacts on the biomass of benthic microalgae, infauna and non-motile epibenthos.

2. The combination of exposure to air with an intermittent supply of fresh water will promote the effect of reduction of *Ulva pertusa* bloom since low salinity markedly inhibit their photosynthesis.
Thank you for your great support to Japan. We need much more power (not electric but spiritual).
Table 2. Amounts of nutrients and trace metals added to 1000ml of seawater

<table>
<thead>
<tr>
<th>Substance</th>
<th>Amount</th>
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<tbody>
<tr>
<td>Filtered seawater</td>
<td>1000 ml</td>
</tr>
<tr>
<td>NaNO₃</td>
<td>50 mg</td>
</tr>
<tr>
<td>K₂HPO₄</td>
<td>5.06 mg</td>
</tr>
<tr>
<td>ZnSO₄·7H₂O</td>
<td>230 μg</td>
</tr>
<tr>
<td>MnCl₂·4H₂O</td>
<td>1.44 mg</td>
</tr>
<tr>
<td>CoSO₄·7H₂O</td>
<td>47.8 μg</td>
</tr>
<tr>
<td>FeCl₃·6H₂O</td>
<td>487 μg</td>
</tr>
<tr>
<td>H₃BO₃</td>
<td>11.4 mg</td>
</tr>
<tr>
<td>EDTA</td>
<td>10 mg</td>
</tr>
<tr>
<td>pH</td>
<td>8.0</td>
</tr>
</tbody>
</table>
Figure 2. Distributions of *Ulva* spp. at the north and south salt marshes of Osaka Nanko bird sanctuary from June to August, 2006.
Figure 3. Distributions of *Ulva* spp. at the north and south salt marshes of Osaka Nanko bird sanctuary in June 2007, September 2007, July 2008 and September 2008.
Figure: Exposure rate to air and areas of each ground level at north and south marshes.

Figure: Distributions of exposure rate to air at north and south salt marshes on July 27 to August 7, 2006.
図 アナアオサとジュズモの光合成と温度との関係
（塩分30psu）
表 1 南港野鳥園における2000年と造成当時との環境特性の比較

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<tbody>
<tr>
<td>含水率 [%]</td>
<td>18.3</td>
<td>43.0</td>
<td>38.5</td>
<td>37.2</td>
<td>15.3</td>
<td>47.4</td>
</tr>
<tr>
<td>IL [%] (有機物量 )</td>
<td>2.2</td>
<td>10.5</td>
<td>5.9</td>
<td>5.9</td>
<td>1.9</td>
<td>8.5</td>
</tr>
<tr>
<td>T-S [mg-dry/g]</td>
<td>0</td>
<td>0.85</td>
<td>0.16</td>
<td>0.72</td>
<td>0</td>
<td>1.35</td>
</tr>
<tr>
<td>個体数 [個体/m²]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ヨコエビ類</td>
<td>3333</td>
<td>9116</td>
<td>22000</td>
<td>11494</td>
<td>0</td>
<td>943</td>
</tr>
<tr>
<td>多毛類</td>
<td>0</td>
<td>1005</td>
<td>15185</td>
<td>1060</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>昆虫類</td>
<td>4741</td>
<td>488</td>
<td>16148</td>
<td>159</td>
<td>5333</td>
<td>8333</td>
</tr>
<tr>
<td>総湿重量 [g-wet/m²]</td>
<td>9.6</td>
<td>23.8</td>
<td>93.2</td>
<td>19.7</td>
<td>5.7</td>
<td>29.3</td>
</tr>
</tbody>
</table>

* 1983年の値は横山(1984)から引用
南港野鳥園（成熟した人工湿地）の浄化機能（窒素）

北池
2002.3.13-14
マイナス値は干潟へのトラップ

2002.7.31-8.1
プラス値は外海への排出

北池湿地は約100mgN/m²/日の窒素浄化能力あり

南池
2006.10.31-11.1
窒素フラックス（mg N/m²/day）
植物現存量（海藻）

干潟創造実験場

半自然干潟
和歌川河口干潟
人工干潟
阪南2区干潟創造実験場
阪南2区人工干潟
現地実験場

2002.10.9
2005.10.18
2006.6.14
2006.7.26
2006.8.23
2006.11.1
2005.10.18
2006.6.14
2006.7.26
2006.8.23
2006.11.1
2001.10.29
2002.9.4
2003.9.24
2004.9.16-17
2005.9.21-22
2006.9.21-22
2003.7.30-31
2004.7.15-17
2004.10.28-29

海藻重量（g wet/m²）

野鳥園北池
野鳥園南池
動植物現存量（小型底生動物）

野鳥園南池（埋在性底生動物は少ない）

和歌川河口干潟のウミニナ類

小型底生動物現存量(g wet/m²)