ECOLOGICAL JUSTIFICATION OF BIO-PRODUCTIVITY IN PETER THE GREAT BAY (JAPAN/EAST SEA)

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INTRODUCTION

The purpose of the work is the development of algorithms and realization of a problem of an environmental risks assessment for a possibility of *Gracilaria verrucosa* cultivation substantiation in southwest part of Peter the Great Bay.

This algae has an economic importance as an agarophyte. It has considerable growth rates (up to 8% a day), high concentration of agar (up to 57% based on its dry weight) and it has the best adaptive capacity in contrast with other species of *Gracilaria*. 
Observations have shown that the *Gracilaria* in the course of its growth can withstand very wide limits of:

- salinity (3-33‰),
- temperatures (8-32°C),
- light intensity (0-400 W/m²),
- concentration of ammonium ions (0.2-6•10⁴ mkg/l)
- pH index (6-9)
The area of investigation
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Landsat-7 image. Peter the Great Bay. Rectangle shows the area of investigation
The area of investigation
Data

The archive of abiotic factors values is based on the ship’s observations carried out in Peter the Great Bay in 1952-2009 [3]. Oceanographic data include measurements of water temperature and salinity, content of the dissolved oxygen, nitrates concentration, phosphates and silicates, pH index.

The ship’s observations were supplemented with the data on illumination and content of the dissolved inorganic carbon.
Model

The revealed sources of dangers (values of the limiting parameters are beyond the tolerance limits) can be considered mostly as the point ones.

Danger can be rather fully characterized by values of risks probabilities.
Model

The system, consisting of the $Q_1$, $Q_2$,..., $Q_n$ components, is denoted as the system vector $Q = (Q_1, Q_2, ..., Q_n)$. The $Q_i$ component deviation from its standard operation means the emergency situation $E_i$. $E_i$ emergency ($i = 1, n$) leads to abnormal functioning of system $Q$ constituting the essence of an emergency situation (E).
Model

The logical analysis of the emergency system internal structure and determination of the emergency situations probability – (E), as functions of separate emergencies (E_i), are one of the tasks in dangers analysis.

By applying the probability theory rules, we determine the probability of an emergency situation in the form of the so-called function of danger

\[ p = F_p (p_1, p_2, p_3, p_4, p_5, \ldots, p_n). \]
Model

In the event of the dangers analysis of the Peter the Great Bay southwest part ecosystem, the revealed sources of dangers (the limiting parameters values are beyond the tolerance limits) can be considered as the ones connected in series. Which means any component failure leads to the whole system failure (an emergency situation OR)
Model

The failures are indicated with the same letters as the system components. If \( E_J \) is failure of \( E_J \) component, then the emergency situation OR is an event, i.e.: 
\[
E = E_1 + E_2 + E_3 + E_4 + \ldots + E_n = \Sigma E_J, \text{ when } j=1, m, \text{ where } m — \text{ the number of the system components. Owing to the logical laws of duality lack of an emergency situation OR is an event }
\]

\[
\overline{E} = (E_1 \times E_2 \times E_3 \times E_4 \times \ldots \times E_n)
\]
When the system components failures are considered to be mutually independent, then the probability of an emergency situation OR is equal to:

$$P\left(\sum_{j=1}^{m} E_j\right) = 1 - P\left(\prod_{j=1}^{m} \overline{E}_j\right) = 1 - \prod_{j=1}^{m} (1 - P\{E_j\}) =$$

$$= 1 - [(1 - P\{E_1\}) \times (1 - P\{E_2\}) \times (1 - P\{E_3\}) \times \ldots \times (1 - P\{E_m\})] ,$$

when $j=1,2,\ldots, m$, where $m$ — the number of the system components.
Model

The last formula shows the emergency situation high probability in case of the multicomponent systems. In more complicated cases to use formulas of the sum and product probability, logical function needs to be transformed to some extent, i.e. - to bring it to normal one, and then to a perfect normal form. Then it will include incompatible events.
Model

The ecological justification algorithm when choosing the optimal locations for Gracilaria plantation cultivation.
Model

At the same time the waters for *Gracilaria* plantation cultivation should be chosen as a zone of minimum admissible risks, i.e. zone where all components of object habitat with high probability are within the optimal intervals. Values not exceeding 5% should be considered the upper limit of the total admissible environmental risks.
Result

On the basis of the list of factors determining the efficiency of *Gracilaria* plantation cultivation, based on the collected data archive, by means of the developed algorithm the calculations of the environmental risks in possible realization of problems of *Gracilaria* plantation cultivation in waters of southwest part of Peter the Great Bay have been carried out.
Results

Spatial distribution of water areas potentially suitable for Gracilaria plantation cultivation. (Dot line (in red) shows zones of 5% environmental risks).
Results

It has been shown that zone of minimal environmental risks (less than 5%) is localized within the coastal line, including bays and lagoons. The areas with the least risks include the southernmost lagoons and bays which are considered to be the optimal ones in view of *Gracilaria* plantation cultivation in the southern part of Peter the Great Bay.
The prospects of plantation cultivation and the efficiency of the received results allow to recommend this approach both for practical use, and in education as a simulator for masters and environmental professionals.
Thank you!
Распределения pH_{in situ} в шкале “общей концентрации иона водорода; Dickson, 1984” (а, б) и парциального давления углекислого газа (мкпат.; в, г) в заливе Петра Великого. Верхняя панель — поверхностный горизонт, нижняя панель придонные горизонты. Результаты получены 26 августа – 3 сентября. 62 рейс НИС “Профессор Гагаринский”.
Распределения растворенного неорганического углерода (ммоль/кг; а, б) и щелочности (ммоль/кг; в, г) в заливе Петра Великого. Верхняя панель – поверхностный горизонт, нижняя панель – придонные горизонты.