Research and Development of a Supporting Information System for Optimization of Salmon Release Operations and Monitoring the Coastal Environment on the Okhotsk Coast, Japan

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Introduction

Chum salmon (*Oncorhynchus keta*) is one of the important fishery resources in the North Pacific. Recently, under a changing climate, the return of chum salmon in Hokkaido has begun to decrease. More precise juvenile release operations are required for adapting to climatic changes, including warming sea temperature, and this can be accomplished by modifying the sea entry condition. It is necessary for this precise operation to predict the coastal marine environment in the release period and monitor short-term changes in coastal residency. Miyakoshi et al. (2007) applied satellite sea surface temperature data to compare the release timing of hatchery-reared juvenile chum salmon to spring coastal sea surface temperature during high and low survival periods. They demonstrated that satellite remote sensing and GIS (Geographic Information System) techniques are useful to identify optimum release timing for favorable coastal survival of chum salmon. The main objective of this study is to develop a supporting information system with WebGIS for optimization of salmon release operations and monitoring the coastal environment in the Okhotsk coast, Japan.

Materials and Methods

The salmon, which travelled to the sea from a river, feeds on zooplankton at a coastal region at a time when the water temperature is roughly 8–13°C; here the salmon grows until it begins its migration to offshore waters. The favorable water temperature of the area along the coast exists for a short period and when temperatures reach more than 13°C earlier, a juvenile salmon can only grow in a limited area along the shore (Miyakoshi 2018). It was recently pointed out that this is one of the factors driving the recent decrease in salmon resources. We expect that we can release juvenile salmon at a more appropriate time through the implementation of a system, which can predict the coastal water temperature before the release time.

We developed a supporting information system for the optimization of salmon release operations on the Okhotsk coast. This system was designed as a web-based visualization tool with two service sites, i.e., the monitoring of marine environment (marine site) and supporting of salmon release operation (release site) (Fig.1).

Fig. 1. Structure of prototype Web-GIS.

To predict the SST over the next three months, we employed an Auto Regression (AR) model in R package (<https://www.econometrics-with-r.org/14-3-autoregressions.html>) using the long term Satellite SST datasets, GHRSSST Level 4 MUR Global Foundation Sea surface Temperature analysis (v4.1) (<https://podaac.jpl.nasa.gov/dataset/MUR-JPL-L4-GLOB-v4.1>) from 2003 to 2020. We applied this AR model to estimate the days when water temperature reached 5–13°C, representing the coastal stay period (Kobayashi 1977). When we can estimate the days of favorable water temperature for release, we can estimate the final fork length at offshoring time with a chum salmon growth model with back-calculation method (Smale and Taylor 1987; Campana 1990). We include this estimation system as a simulator function in release site.

To display short term monitoring of the marine environment (sea temperature, salinity, current, and water masses in various layers), we employ the output of an eddy-resolving analysis model based on four-dimensional variational assimilation and a high (2 km) resolution forecast model covering Japanese coastal areas developed by the Japan Meteorological Agency (Sakamoto et al. 2019). The Soya warm current is a very important marine system occupying the coastal environment along the Okhotsk coast (Ohshima et al. 2017; Karaki et al. 2018). We applied the water mass classification definition (Takizawa 1982) to distinguish water mass, including Soya warm current, using the numerical forecast model output.

Results and Discussion

In the marine site (Fig.2), we employed the output of an eddy-resolving analysis model based on four-dimensional variational assimilation and a high (2 km) resolution forecast model covering Japanese coastal areas developed by the Japan Meteorological Agency. We also use GCOM-C satellite SGLI data, sea surface temperature (SST) and chlorophyll-a, with 250 m spatial resolution operated by JAXA.

Fig. 2. Example of marine site in prototype Web-GIS.

Fig. 3. Example of release site in prototype Web-GIS.

In the release site (Fig.3) there are two functions, one is the SST prediction function and the other is the salmon release simulation function. On the SST prediction page, we have obtained the next three months of SST predictions in each of 16 rivers along the Okhotsk coast. On the salmon release simulation page, when we input the number of the release operation, date, release fork length, and number of release salmon, we can then obtain the mean fork length, which is one of the indices of survival/return rate in the period of offshoring from coastal residency. When we change the input parameters, we can turn the final offshoring mean fork length as large as possible.

Concluding Remarks

To optimize the salmon release operation, we developed a prototype Web-GIS as a visualization tool that incorporates a salmon release simulation function. It might be useful during the preparation of release and a release date decision by using water temperature predictions over three months in advance. A prediction map of the marine environment from numerical model outputs, and a week ahead forecast of water temperature, can assist in the release timing during the short time of release operations. The release simulator function can help in risk management through a more accurate release operation.

We challenge to have a co-work, co-production, and co-design with Kitami Salmon Enhancement Program Association to develop information service for optimum salmon release operation in the Okhotsk coast, Hokkaido, Japan. We started to use the prototype system for the salmon release season in spring 2021 and further research and development can improve the chum salmon enhancement operation in the future.

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