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기후 및 해양 요인과 김 생산량과의 관계에 관한 연구

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The Relationship between Climatic and Oceanographic Factors and Laver Aquaculture Production

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Abstract

While some steps in laver aquaculture production can be controlled artificially to a certain extent, the culturing process is largely affected by natural factors, such as the characteristics of seawater, climatic and oceanographic conditions, etc. This study aims to find a direct relationship between climatic and oceanographic factors (water temperature, air temperature, salinity, rainfall, sunshine duration and wind speed) and laver aquaculture production in Wando region, the biggest aquaculture production area of laver, located in the southwest coast of Korea using a multiple regression analysis.

Despite the small sample size of a dependent variable, the goodness of model fit appeared acceptable. In addition, the R-squared value was 0.951, which means that the variables were very explanatory. Model results indicated that duration of sunshine, temperature, and rainfall during the farming period from the end of September to the end of April would be important factors affecting significantly to the laver aquaculture production.

Keywords : Laver Porphyra, Aquaculture, Climate change, Oceanographic conditions, Stepwise regression, Correlation

Ⅰ. INTRODUTION

Given its huge demand as a major export product, laver *Porphyra* aquaculture has long been practiced in Korea. While some steps in laver aquaculture production can be controlled artificially to a certain

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extent, the culturing process is largely affected by natural factors, such as the characteristics of seawater, climatic and oceanographic conditions, etc.(Hong et al., 1987). As such, researches on the relationship between the laver production and the climatic and oceanographic factors are necessary in order to obtain good yields from laver aquaculture. The need for such studies has become even more urgent, especially as the effects of such climatic and oceanographic conditions are increasingly influencing the production.

Despite its importance, few studies have concentrated on this subject because collecting adequate long-term data on various climatic conditions, oceanographic characteristics and production amounts, and simultaneously analyzing the relationships between them is time-consuming. As such, some studies have compared laver production to either one or several changes in climatic and oceanographic conditions, and determined an indirect relationship between them(Chang et al., 1983; Chyung and Kim, 1967; Hong et al., 1987; Yamauchi, 1976; Yamauchi, 1974). In other words, previous studies on the topic have failed to recognize the direct relationships between the laver aquaculture production and changes in climatic and oceanographic factors.

Using a multiple regression analysis, this study aims to find a direct relationship between climatic and oceanographic factors and laver aquaculture production in Wando region, the biggest aquaculture production area of laver, located in the southwest coast of Korea. However, it is very difficult to conduct a multiple regression analysis in this case, because the data pertaining to the climatic and oceanographic factors (i.e., the independent variable) exist more abundantly than the data on the annual production of laver (i.e., the dependent variable). To overcome this problem, we estimate statistically significant variables of climatic and oceanographic factors using a stepwise regression model and then analyze the relationship with the laver aquaculture production.

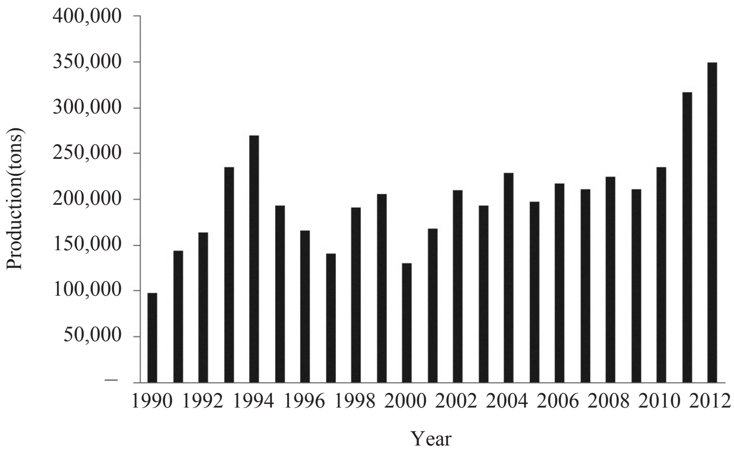
It is expected that this study will be useful for forecasting the laver aquaculture production in response to changes in climatic and oceanographic conditions. The meteorological data used in the analysis were provided from the Metrological Administration Agency while data on water temperature and salinity were provided from the Wando Marine and Fisheries Office. In addition, laver production data were obtained from the annual aquaculture production report of the Bureau of Statistics and the statistical yearbook of the Wando County Office.

Ⅱ. MATERIALS AND METHODS

1. Laver aquaculture production in Korea

Starting in the 1970s, Laver aquaculture is one of the oldest aquaculture processes practiced in Korea (although some documents date the practice back to as early as the 17th century)(Kang and Ko, 1977). Since the mid-1980s, the production of laver has increased drastically due to developments in aquaculture technology, production segmentation of wet and dry laver, and increased exports to Japan. Currently, almost all laver in Korea is produced through aquaculture.

As shown in Fig. 1, laver aquaculture has been increasing since 1990, with production amounts increasing to over 300,000 tons, especially after 2011. In 2012, total production reached 350,000 tons, amounting to about 23.5% of the total aquaculture production (1,490,000 tons) in Korea. In fact, laver is the fourth largest aquaculture



Source : Fisheries Information Portal (www.fips.go.kr).

Fig. 1. Production of laver aquaculture in the period of 1990-2012.

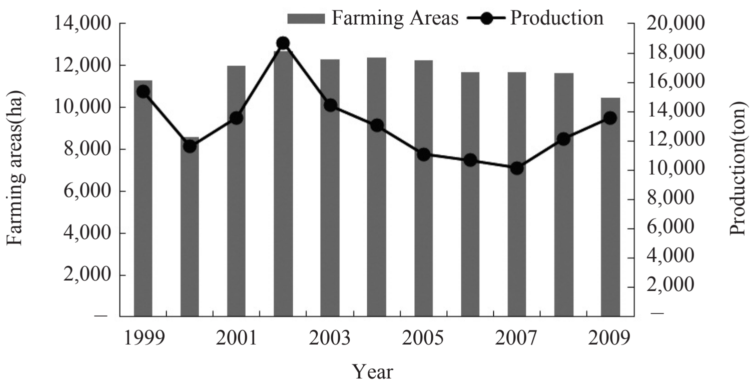


Fig. 2. Changes of laver farming areas and production in Wando region from 1999 to 2009.

product in Korea, after oyster, sea mustard, and kelp. About 60% of laver is produced mainly in Jeollanam-do, the south-western region of Korea. Laver aquaculture is practiced from the end of September to the end of April, and it is largely dependent on climatic and oceanographic factors.

2. Analytical data

The study analyzes the relationship between the production of laver and climatic and oceanographic factors in Wando of Jeollanam-do region from 1999 to 2009. As shown in Fig. 2, laver aquaculture was practiced over 8,600ha in 2000 and 12,000ha in 2002, and it currently covers an area of 11,000ha. A slight decrease in the area under cultivation is noticeable since 2009, mainly due to relocations and subsequent rearrangements. Also, the laver production amounts have increased since 2000, reaching 19,000 tons at the highest point in 2002, but decreasing to 10,000 tons in 2007. This decrease can be attributed to the reduction in numbers of nets (1 net＝2.2m×40m) and climatic

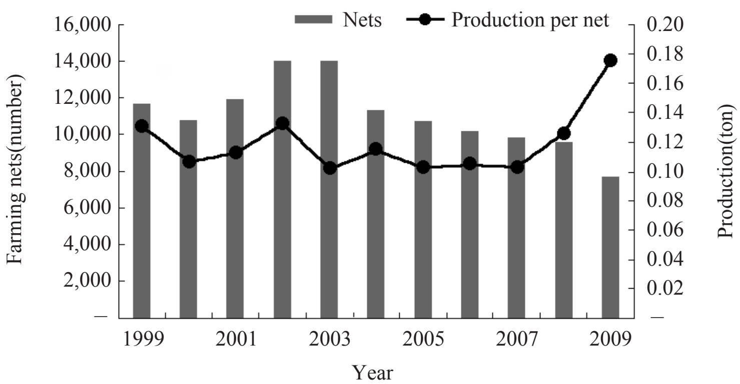


Fig. 3. Changes in number of laver farming nets and production per net in Wando region from 1999 to 2009.

and oceanographic factors like the high temperature of the seawater and strong winds (Ok and An, 2007).

As shown in Fig. 3, the number of laver farming nets can be seen to decrease from 141,000 in 2002 to 77,390 in 2009. However, after maintaining about the same level from 1999 to 2007, the production per net has been increasing since 2008.

Factors affecting the laver aquaculture include water temperature, air temperature, salinity, wind speed, sunshine duration, rainfall and so on. Additionally, pH, velocity of flow, heavy metals in sediments, etc. affect the germination stage and growth of laver (Chang et al, 1983; Iwasaki, 1965; Kang and Ko, 1977; Tada et al., 2010). In this study, we attempt to analyze the relationship between laver aquaculture production and factors like water temperature (WT), air temperature (TE), salinity (SL), rainfall (RF), sunshine duration (SD), and wind speed (WS), from the end of September to the end of April.

Data on the amount of production, which is a dependent variable, are obtained from the statistical yearbook of Wando County Office, which provides the details of amounts produced per laver aquaculture net (PN). For independent variables (i.e., climate and oceanographic factors), we refer to the data from the Meteorological Administration Agency (for water temperature, rainfall, sunshine duration, and wind speed) and the Wando Marine and Fisheries Office (for water temperature and salinity). The descriptive statistics of the variables used in the analyses are as summarized in Table 1.

Table 1. Summary statistics for variables used in the analysis

Variable	Mean	Standard deviation	Minimum	Maximum
PN(ton)	0.120	0.022	0.176	0.102
WT(°C)	13.5	5.31	25.2	6.2
TE(°C)	10.03	7.06	28.3	−6.2
SL(‰)	25.0	1.8	28.2	17.0
RF(mm)	2.7	12.27	250.6	0.0
SD(hour)	5.6	3.63	12.4	0.0
WS(m/s)	4.3	2.38	17.5	0.8

3. Analytical method

This study attempts to find the direct relationship among the aforementioned variables using a multiple regression analysis for laver aquaculture production in Wando of Jeollanam-do region, which is the biggest aquaculture production place for laver in Korea. However, it is very difficult to do a multiple regression analysis, because data for the dependent variable (annual production of laver) exist for 11 years only, while those for climatic and oceanographic factors (the independent variable) are recorded daily.

To overcome this issue, the study averaging the daily data on climatic and oceanographic factors and consolidate them into monthly data. However, a multiple regression analysis is still not possible due to the discrepancy in the amount of data; therefore, we first analyze the correlation between annual data on laver production and monthly data on climatic and oceanographic factors. Thus, we retrieve the monthly variables of climatic and oceanographic factors within 10% statistical significance, and we estimate those variables of climatic and oceanographic factors that are significant to the laver aquaculture using a stepwise regression analysis.

Stepwise regression analysis is the step-by-step iterative construction of a regression model that involves automatic selection of independent variables. Stepwise regression can be achieved either by trying out one independent variable at a time and including it in the regression model if it is statistically significant (forward selection method), or by including all potential independent variables in the model and eliminating those that are not statistically significant (backward elimination method), or by a combination of both methods.

Ⅲ. RESULTS

1. Results of the correlation analysis

The results of the correlation analysis between annual laver production and monthly data of climatic and oceanographic factors are shown in Table. 2. Variables significant within the 10% are April water temperature (WT_AP), October temperature (TE_OC), January temperature (TE_JA), April temperature (TE_AP), September

Table 2. Results of the correlation analysis

PN	WT_SE	WT_OC	WT_NO	WT_DE	WT_JA	WT_FE	WT_MA	WT_AP
	−0.229 (0.249)	0.042 (0.451)	0.178 (0.300)	−0.116 (0.367)	0.112 (0.371)	0.171 (0.307)	−0.303 (0.183)	−0.527 (0.048)*
	TE_SE	TE_OC	TE_NO	TE_DE	TE_JA	TE_FE	TE_MA	TE_AP
	0.269 (0.212)	0.447 (0.084)**	0.238 (0.240)	−0.213 (0.264)	0.449 (0.083)**	−0.130 (0.352)	−0.356 (0.141)	−0.508 (0.070)**
	SL_SE	SL_OC	SL_NO	SL_DE	SL_JA	SL_FE	SL_MA	SL_AP
	0.651 (0.015)*	0.117 (0.366)	0.087 (0.400)	0.131 (0.350)	0.351 (0.145)	0.071 (0.418)	0.116 (0.367)	−0.186 (0.292)
	RF_SE	RF_OC	RF_NO	RF_DE	RF_JA	RF_FE	RF_MA	RF_AP
	0.042 (0.451)	−0.580 (0.031)*	0.054 (0.438)	−0.237 (0.241)	0.282 (0.201)	0.050 (0.442)	0.268 (0.213)	0.275 (0.206)
	SD_SE	SD_OC	SD_NO	SD_DE	SD_JA	SD_FE	SD_MA	SD_AP
	−0.571 (0.033)*	0.201 (0.277)	0.392 (0.116)	0.180 (0.298)	0.055 (0.436)	−0.519 (0.051)**	−0.648 (0.016)*	−0.121 (0.361)
	WS_SE	WS_OC	WS_NO	WS_DE	WS_JA	WS_FE	WS_MA	WS_AP
	0.194 (0.284)	−0.160 (0.319)	0.036 (0.458)	0.332 (0.159)	−0.605 (0.024)*	0.029 (0.467)	0.295 (0.190)	0.115 (0.368)

Note : Figures in parentheses are p-values.
* and ** indicate statistically significant at 5% and 10%, respectively.

salinity (SL_SE), October rainfall (RF_OC), September sunshine duration (SD_SE), February sunshine duration (SD_FE), March sunshine duration (SD_MA), and January wind speed (WS_JA).

A closer look shows that in September, production, salinity, and sunshine duration seem to be significant. However, production showed a positively and a negatively significant relationship with salinity and sunshine duration, respectively. In October, production was positively correlated with temperature and negatively correlated with rainfall. In January, it was positively correlated with temperature and negatively correlated with wind speed. For the months of February and March, only sunshine duration was significant, and both were negatively correlated. In April, water temperature and air temperature were significant, and both were negatively correlated. Therefore, it is concluded that although there are deviations per month, both climatic and oceanographic factors have significant effects on the laver aquaculture production.

2. Result of the regression analysis

Results of the stepwise regression analysis on the variables of production and climatic and oceanographic factors are as shown in Table 3. In the analysis, individual and group significance of coefficients were tested using t and F tests, respectively. Multicollinearity among variables was detected by calculating the variance inflating factor (VIF).

Variables significant within the 5% were selected, and despite the small sample size of a dependent variable, the goodness of model fit appeared acceptable. In addition, the R-squared value was 0.951, which means that the variables were very explanatory. As a result of Durbin Watson verification, the issue of autocorrelation did not arise. Furthermore, no multicollinearity among variables was found (VIF < 10).

According to the analysis of the relationship between the production cycle and the variables, sunshine duration is the greatest influencing factor for the growth of laver. This seems logical, given that sunlight is essential for photosynthesis. Since the sunshine duration needs to be shortened to increase the amount of conchospores, SD_SE assumes significance.

Additionally, it was observed that even for February, a month in which the highest amount of laver is produced, the shorter the duration of sunshine, the better. As the time around October is the germinating period, and a lower temperature helps laver to grow faster, the TE_OC variable is also acceptable. Also, in October, less rainfall has a positive effect on production.

The lower temperature in April is also better, as growth is arrested at high temperatures. As such, the TE_AP variable is important. Thus, the

Table 3. Results of the regression analysis

Parameters	Coefficients	Std. error	*p*-value	VIF
Constant	45.511	6.730	0.0293	–
RF_OC	−4.457	1.233	0.0153	1.643
SD_SE	−2.850	1.262	0.0335	1.291
SD_FE	−6.969	2.071	0.0200	1.650
TE_OC	10.789	1.954	0.0027	1.088
TE_AP	−3.651	1.419	0.0498	1.335
R-square	0.951	Durbin-Watson statistic		1.85
F-statistic	19.324	Prob (F-statistic)		0.003

variables retrieved in this study are shown to have a significant effect on the laver production cycle and the amounts produced.

Ⅳ. DISCUSSION

The study attempted to analyze the direct relationship between laver aquaculture production and climatic and oceanographic factors (water temperature, air temperature, salinity, rainfall, sunshine duration, and wind speed) in Wando, Jeollanam-do region. Despite the paucity of data, the goodness of fit of the model was estimated to be very good and autocorrelation and multi-collinearity issues did not appear to pose any problems. The very high value of R-squared means that it was able to accomplish the goal of this study. As laver aquaculture is largely affected by natural (climatic and oceanographic) conditions, the results of analysis on the relationship between these factors and production will provide important guidelines for developing future methods for improved laver aquaculture.

Duration of sunshine, temperature, and rainfall appeared to be important climatic and oceanographic factors affecting the laver aquaculture production. Concretely, it was analyzed that duration of sunshine has a negative relationship with the laver aquaculture production. It was also shown that rainfall in October has a negative relationship with the laver aquaculture production, while temperature in October has a positive relationship with the laver aquaculture production. In addition, it was estimated that duration of sunshine in February has a negative relationship with the laver aquaculture production and temperature in April has a negative relationship with the laver aquaculture production,

When considering that impacts of climate changes are getting much and longer, it can be possible to predict the laver aquaculture production with changes of climatic and oceanographic factors. In particular, the results of this study can be usefully utilized by aquaculture outlook related institutions such as Fisheries Outlook Center in Korea Maritime Institute for forecasting the laver aquaculture production.

On the other hand, the study had access to only 11 years' worth of data, which limited the extent of the study. A wider database in the future could help us estimate more in-depth relationships, which could, in turn, help in forecasting more specific changes of laver aquaculture in response to climatic changes.

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