Pattern variation of fish fingerling abundance in the Na Thap Tidal river of Southern Thailand: 2005-2015

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Abstract. This study aimed to investigate the variation patterns of fish fingerling abundance based on month, year and sampling site. Monthly collecting data set of the Na Thap tidal river of southern Thailand, were obtained from June 2005 to October 2015. The square root transformation was employed for maintaining the fingerling data normality. Factor analysis was applied for clustering number of fingerling species and multiple linear regression was used to examine the association between fingerling density and year, month and site. Results from factor analysis classified fingerling into 3 factors based on saline preference; saline water, freshwater and ubiquitous species. The results showed a statistically high significant relation between fingerling density, month, year and site. Abundance of saline water and ubiquitous fingerling density showed similar pattern. Downstream site presented highest fingerling density whereas almost of freshwater fingerling occurred in upstream. This finding confirmed that factor analysis and the general linear regression method can be used as an effective tool for predicting and monitoring wild fingerling density in order to sustain fish stock management.

1. Introduction

Globally, people consume fish and other aquatic animals as their main sources of animal proteins. These aquatic animals are not only for consumption purposes, but in the ecosystem, they also serve as renewable resources. Food and Agriculture Organization predicted that the world fisheries production will reach 181 million tons by 2022, 161 million tons of which will be consumed by humans [1].

Fish recruitment, including fish birth, survival and catching rates, is an important predictor for the quality of fish population in rivers and other natural water bodies [2]. Abundance and species composition of fish fingerlings are very important as they increase productivity in aquatic ecosystem. Also, the amount of fish fingerling variation can be useful for forecasting fish stock in the future. In Thailand, the average per capita consumption of fish was 30.9 kg annually during the period 2000—2003, which was higher than the world’s average fish consumption. This reflects that there is high demand of fish in Thailand [3]. Several published papers were found to have concerned the prediction of fish catch in Thailand’s waters.

Several studies used linear regression [4], multiple regression [2], and multivariate analysis and ARIMA model [5] for predicting fingerlings. Linear regression and multiple regression are commonly used to find out the association between independent and outcome variables, while
analysis and autoregressive integrated moving average (ARIMA) model are regullary employed to describe data effectively with decreased weight for averaging of past observation. Additionally, ARIMA model is used for constructing the historic autocorrelation of the data and divining these into the future [6]. However, there is a rare study conducted on the prediction of wild fingerling pattern using three ecosystems in tidal river. Thus, this study aimed to investigate the pattern variation of spatial and temporal trends of fingerling abundance in order to develop an appropriate statistical model used as a key tool for carrying out an aquatic animal monitoring and assessment.

2. Methodology
The Na Thap tidal river, 26.5 km in length, was used as the sample area for this study (figure 1). This tidal river has its source from the range of mountains adjacent to the Thailand-Malaysia border and travels through Na Thawi and Chana Districts of Songkhla Province to form a large estuary before draining into the Gulf of Thailand. This river also serves as a habitat of productive aquatic fauna and flora [7]. The three aquatic ecosystems include saline water, brackish water, and freshwater. The upstream of freshwater ecosystem, covering an area of 7.5 km, is used for agriculture and peat swamp forest, whereas the downstream is used for household settlement, shrimp farm and fishing port. In this study, fingerlings were collected monthly by surrounding 10 sampling sites with nets along the Na Thap River from June 2005 to October 2015. The total number of fingerling species classified in taxa per 1.000 cubic meter of water volume was counted and recorded. In short, 58 species of fish fingerlings were obtained from 1,220 observations at 10 stations. The data were rechecked and cleaned for accuracy by field scientists. Any error was corrected.

![Figure 1. Map of The Na Thap tidal river and all 10 sampling sites.](image)

2.1. Statistical analysis
In this study, fingerling density was employed as the dependent variable. Month, year and site were considered as independent variables. Square root transformation was used for satisfied normality distribution (before using factor analysis). Pearson’s correlation was applied to identify and test the strengths of relationships between fingerlings in each species. Factor analysis was deployed to group
58 fingerlings into 3 interpretable factors based on maximum likelihood. The Promax rotation method was applied. Species with high correlation were grouped into the same factor based upon their unique value. The factor analysis provided loading score for individuals and selected the highest score for each species. After using factor analysis, factor scores were calculated from the sum of each species of fingerling in each month, year and site. The data were reduced as shown in the equation 1. If $y_{ij}$ is the fingerling density in month $i$ and species $j$, the factor model is formulated as shown below:

$$y_{ij} = \sum_{k=1}^{p} \hat{a}_i l_{j}^{(k)} f_{ik}$$

Where $p$ column vectors $f_{ik}$ in this model are common factors and the $p$ vectors $l_{j}^{(k)}$ are their loadings. For the model assessment, r-square value, normal Q-Q plot, and fitted value against studentized residuals plot were evaluated. The linear model investigated the relationship between sum of species of density fingerling species in each factor by month, year and site.

$$f_{ijk} = m + a_i + b_j + l_k + e$$

In this model, $f_{ijk}$ is the sum of fingerling density in each factor, $m$ is a constant encapsulating the overall mean, $a_i$ is the coefficient for month of the calendar $i$ (January = 1, February = 2, ..., December = 12), $b_j$ is the coefficient for year $j$ (2005, 2006, ..., 2015), $l_k$ is the coefficient for the data collection site $k$ (1,2, ...,10) and $e$ is the error from the model. All of the statistical analyses and graphs were performed using R program.

3. Results and discussion

3.1 Preliminary analysis

Figure 2 shows Q-Q plots of square root of fingerling weight in populated samples. The graph shows three different colors of circles for three different species categories. The brown color represents saline water fingerling species, blue color represents freshwater fingerling species, and yellow color represents ubiquitous fingerling species. The size of the circle denotes the average of fingerling occurrence in each species and q-q plot (black color, diagonal line passing through each circle) shows normality distribution. More than a half of species showing in figure 2 presented normal distribution after square root transformation was applied. Blue bar indicates the prevalence of fingerling in each species based on its common name. Overall density of fingerling can be described in table 1. The highest number of recorded prevalence was found in the ubiquitous fingerling (1.212), followed by saline water (1.025), and freshwater fingerling (516). The normality of each factor was checked using 3histogram and displayed in figure 4 (a). This figure shows that the observations of each cluster was right-skewed. Therefore, square root transformation for each factor was applied for normality and shown in figure 3 (b).

3.2 Results from model

Multiple linear regression model was applied for each factor in order to examine the association between abundance and environmental factors. Model assessment was done by creating studentized residuals and fitted values versus studentized residuals plots. The plots for saline water, freshwater and ubiquitous fingerling density are displayed in figure 4, 5, 6 left (a) and right (b), respectively. The studentized residual plot for saline water and freshwater fingerling density illustrated in figure 4 (a) and figure 5 (a) performed better than the studentized residual plot for ubiquitous fingerling density shown in figure 6 (a). The r-squared value for saline water fingerling density (88.3 %) and freshwater
fingerling density (86.4 %) are nearly close to and higher than ubiquitous fingerling density (51.5 %). However, the fitted values versus studentized residuals plots for the three ecosystems shown in figure 4 (b), 5 (b) and 6 (b) followed normal distribution without any pattern.

Figure 2. The abundance and distribution of fish fingerling density during study period. Blue bar denoted the prevalence of fingerling in each species.

Table 1. Overall density of fingerling (Organisms/mL) in each cluster (omitting zero).

| Factor       | Transformation | Min  | Median | Mean  | Max    | SD   | Number |
|--------------|----------------|------|--------|-------|--------|------|--------|
| Saline water | Before         | 1.0  | 1138.7 | 1295.7| 5695.2 | 1183.4 | 1,025  |
|              | After          | 1.0  | 33.7   | 31.8  | 75.42  | 16.9  | 516    |
| Fresh water  | Before         | 12.1 | 474.6  | 514.1 | 2283   | 432.6 | 516    |
|              | After          | 3.5  | 21.8   | 20.3  | 47.8   | 10.1  |        |
| Ubiquitous   | Before         | 18.9 | 193.7  | 215.7 | 866.8  | 101.8 | 1,212  |
|              | After          | 4.3  | 13.9   | 14.32 | 29.4   | 3.2   |        |
Figure 3. Histograms of density of fingerling (organism/mL) in each factor before and after transformation.

Figure 4. Studentized residuals plots from the linear model (a) and plots of the Studentized residuals versus fitted value from the model (b) (for saline water fingerling density).
Figure 5. Studentized residuals plots from the linear model (a) and plots of the Studentized residuals versus fitted value from the model (b) (for freshwater fingerling density).

Figure 6. Studentized residuals plots from the linear model (a) and plots of the Studentized residuals versus fitted value from the model (b) (for ubiquitous fingerling density).

The results from the model using sum contrast method for the three factors was illustrated in figure 7, 8, and 9. The three figures showed the pattern distributions of fingerlings in month, year, and site. The red horizontal line is the overall mean of fingerlings. The first capital letter of the word of each month was used for identifying each month in order: J is January, F is February, M is March, etc. The
abundance of fingerlings increased from January to April and gradually decreased from May to December. The overall abundance showed a constant pattern of fingerling density from 2005 to 2009 and a sharp decrease from 2010 to 2011. There was a gradual increase in density of fingerlings after 2011 to 2015. The highest abundance of fingerlings was noticed in site 1 (downstream), which decreased to the upstream.

Figure 8 shows the pattern distribution of freshwater fingerling density from the model. The fingerling abundance was constant from January to February and slowly decreased from March to April. The lowest density of fingerlings was noticed in April, which steadily increased until December. It was a decreasing trend from 2005 to 2010 in general. However, its increased with the increase in year after 2011. Higher abundance of freshwater fingerlings was noticed in site 8 and 10 (upstream) compared to the abundance of other sites.

For ubiquitous fingerling density (figure 9), wave pattern was noticed for month. The abundance of fingerlings was less than the overall mean from 2005 to 2011. In contrary, it was greater than overall mean after 2011 till 2015. Site 1, 3 and 4 presented the highest abundance, and then the abundance sharply decreased until site 10.

Figure 7. Pattern distributions of saline water fingerling density in month, year and sampling site.

Figure 8. Pattern distributions of freshwater fingerling density in month, year and sampling site.
4. Discussion

Factor analysis is a powerful method generally used in studies such as socio-studies [8] and an effective tool for ecological assessment [9]. Therefore, factor analysis can reduce the dimensionality of those outcomes for removing duplicated information from a set of correlated variables. In this study, we applied this method with fingerling density. After using factor analysis, we could reduce 58 species of fingerlings into 3 interpretable factors based on salinity preference including saline water, freshwater, and ubiquitous fish fingerlings. These results were also consistent with their habitat characteristics in the ecosystem.

Our model showed that saline and freshwater fingerlings had a good fit, whereas ubiquitous fingerlings showed a poor fit. Increasing trend in hot season and decreasing trend in rainy season occurred in saline fingerling density. Those occurrences were opposite to the presenting trend of freshwater fingerling density. The saline water fingerling density was the highest in March and April. This evidence occurred because of the tropical monsoon effect. Our findings were consistent with previous report of the prediction of standing crop using lagged fingerling density of freshwater fish [9] and fish catch in Songkhla [10]. Moreover, the weight and density of freshwater fingerling species of standing crop were found at maximum levels during heavy rainy seasons, especially in November to December [11]. The ubiquitous fingerling density increases and decreases all the time. This finding may be the result of different habitat preferences of various ubiquitous fingerling species that exhibit fluctuative movement between the upstream and the downstream, and some of which migrate into and out of floodplain. In addition, the seasonal effects on the high percentage of estuarine fish species were found during dry season and the effects on the percentage of freshwater fish species were found during wet seasons in tropical lagoon in South-West Nigeria [12].

All of those three ecosystems of the Na Thap tidal river show a systematic pattern of three fish fingerling clusters based on their habitat preference throughout the year. The overall fish fingerling density (2005—2011) was less than the average, while from 2012 to 2015, the fingerling density increased. This is consistent with the data of weir construction in upstream and river mouth dredging to re-open the sand-choked mouth of the Na Thap River from 2009 to 2011. Saline water and ubiquitous fingerlings showed the same pattern of abundance, in which the highest fingerling density occurred from the downstream to middle zone of the river where saline water to brackish water are found. On the other hand, high freshwater fingerling density can be found in the upstream or freshwater ecosystem. Although the presented model can fit well, some environmental factors, particularly water quality parameters, catchability and ecosystem functional association to fingerling behaviour, are not taken into account. This presents the limitation of our study.
5. Conclusion
In conclusion, the abundance of fingerlings is associated with the month, year and sampling site and varied by distinct habitat preferences. This finding confirmed that factor analysis and general linear regression method can be used as an effective tool for predicting and monitoring wild fish fingerlings in order to sustain fish population management.

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