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Original Article

Predicting standing crop using lagged fingerling density of freshwater fish in the Na Thap River of southern Thailand

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Abstract

This study aimed to develop statistical models for predicting fish standing crop in weight of specific freshwater fish based on fish fingerling density six months earlier. The monthly data in Na Thap river of southern Thailand, were collected between June 2005 and December 2010. Standing crop in weight for each native species varied with fingerling density 6 months previously. The trends of the fish standing crop in weights and fish fingerling densities depend on seasonal patterns of the area. Five freshwater fish species of this study were found to have a statistically significant relation between standing crop and fingerling density 6 months earlier. This finding reconfirmed that the linear regression method can be used as a tool for fish standing crop prediction and can then be applied for rehabilitating fish productivity and generally enhancing aquatic ecosystems.

Keywords: inland fisheries assessment, river fish enhancement, time series model, standing crop prediction

1. Introduction

Standing crop is one of the common field-based surveying techniques to evaluate total biomass of aquatic organisms in wet weight or total number of living organisms per given water area or volume, in a particular location at a particular time. It is an analytical tool for diagnosing or predicting productivity of water sources (Fausch *et al.*, 1988, Anderson and Neumann, 1996). Standing crop has regularly been reported as positively correlated with fish density at a previous time, geomorphology of the drainage basin of lakes or streams, and ecological and environmental factors. In addition, survival and quantity of fish fingerlings can also increase lake and river productivity (Jensen, 1999; Sathianandan, 2007). Fingerling densities at preceding months are considered as lagged terms in a model, and appropriate statistical methods can be applied for predicting fish productivity. Time series models with lag terms have been presented based on appropriate statistical methods beneficial not only for forecasting economic growth but also for predicting the abundance of aquatic animals and fish catch assessment (Gudmundsson, 2004; Francis *et al.*, 2005; Chesoh and Lim, 2008). ARIMA model for estimating and characterizing standing crops from habitat and environmental variables was used by several studies (Venugopalan and Srinath, 1998; Preciado *et al.*, 2006). However, applying this technique is complicated because there are several processes to be calculated and considered. Generally, there are three terms for using this model: autoregressive, non-seasonal difference and lagged forecast errors in the prediction equation. For this study, we hypothesized that higher fingerling density would support higher fish standing crop in weights in its ecosystem. Present knowledge on the relationship between the density of fish fingerling and standing crop in

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weight by species is limited. The objectives of this study were thus to investigate variation of standing crop of representative freshwater fish and then to develop an appropriate statistical models for finding the relationship between standing crop in weight and lagged fingerling density at earlier months in a tropical riverine ecosystem.

2. Materials and Method

2.1 Study area and data source

The Na Thap River is located in the Chana district of Songkhla province in the southern part of Thailand. It originates from the mountain range along the Thailand–Malaysia border area and flows into the Gulf of Thailand at Ban Pak Bang Na Thap, a total of 26.5 kilometers in length. This tropical zone along the banks of the river has three aquatic ecosystems: freshwater, brackish and saline. Moreover, its habitat is known as a home for indigenous aquatic fauna and flora (Chesoh *et al.*, 2010). The upstream area of Na Thap River was the sampling site for data collection in this study. The river is rich in biodiversity, with virgin mangroves surrounding the river banks and providing fish for local communities.

Data were collected from June 2005 to December 2010 at two freshwater upstream sites and from September 2006 to December 2010 at a third site, as shown in Figure 1. Six representative species were selected for study on the basis of their ecological and economic importance, as shown in Table 1. Fish were classified by species according to Rainboth (1996) and Taki (1974) guidelines.

Fish standing crop in weight and fingerling density were measured at monthly intervals. The standing crop samples were collected by purse seine nets. The sampled area on each occasion was estimated at 200 square meters (m^2) by 1-meter depth of water, and crop weights were calculated in grams/1,000 m^2 for each species. Fingerlings were collected using bongo nets equipped with flow meters and fingerlings counts per unit water volume were calculated.

2.2 Statistical analysis

In this study, standing crop in weight was taken as the response variable and fingerling density six months earlier as the determinant in a linear statistical model. Six months was chosen as the lag period because this period approximates the duration taken for fingerlings to adult and also because shorter and longer periods are confounded by seasonal effects. Since such biological measurements often have right skewed distributions that do not satisfy the normality assumption usually made when fitting a statistical model, the data were transformed using square roots before fitting the

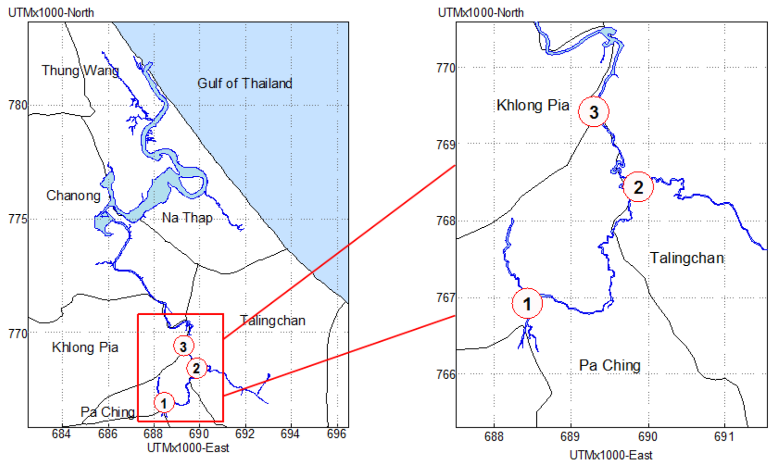

Figure 1. Sampling sites in Na Thap River

Table 1. The target freshwater fish species for study

Code	Common Name	Scientific Name	Family
Sp1	Snakehead fish	*Channa striata*	Channidae
Sp2	Common silver barb	*Barbonymus gonionotus*	Cyprinidae
Sp3	Common climbing perch	*Anabas testudineus*	Anabantidae
Sp4	Snakeskin gourami	*Trichogaster pectoralis*	Osphronemidae
Sp5	Schwanenfeld's tinfoil barb	*Barbonymus schwanenfeldii*	Cyprinidae
Sp6	Malayan leaf fish	*Pristolepis fasciata*	Nandidae

model. This assumption requires that the errors from a fitted model be normally distributed, which is assessed by plotting residuals from the fitted responses against normal quantiles.

After the appropriate transformation of the outcome and predictor variables, both standing crop in weights and fingerling densities were adjusted for seasonal effects by subtracting monthly averages for each site and then adding back the mean. Since this seasonal adjustment method can give rise to negative values when zeros are present in the data, negative values were replaced by zeros and the process was repeated until all seasonally adjusted values were non-negative. The fitted linear model is thus

$$y_t = a + bx_{t-6} \quad (1)$$

In this model y_t is the seasonally-adjusted transformed standing crop in weight and x_t is the seasonally-adjusted transformed fingerling density, respectively, observed at month t.

All statistical analyses and graphs were undertaken using the free and open-source R program (R Development Core Team, 2010).

3. Results

3.1 Preliminary analysis

Figure 2 and Figure 3 show histograms of fish standing crop in weight and fish fingerling density before and after transformation. Standing crop in weight and fingerling density of all species are positively skewed. This skewness was largely removed by taking square roots of the measurements. The result of this study indicated standing crop in weight and fingerling densities of six species of freshwater fish were highest at site 1 as shown in Figure 4. Each dot represents the data of fish standing crop in weights and fish fingerling densities for a month and curves are estimated trends based on the fitted regression model for the six freshwater fish species. The patterns of change depend on the season in which the data were collected, so we can see that the trends of both standing crop in weights and fingerling densities gradually increased in May and further increased in the period October to December, for every year and every species.

Coefficients and standard errors from the simple linear model for each freshwater fish species are shown in Table 2. Fish fingerling density in the previous 6 months was associated with fish standing crop in weight for five of the six species of freshwater fishes. The standardized residual plots for each species of freshwater fish in the Na Thap river, after square root transformation of the outcome and determinant are shown in Figure 5. The normality assumption for errors is acceptable for all models. Figure 6 shows a plot of the transformed fish standing crop in weights and fish fingerling densities after adjusting for seasonal patterns. The legend gives the data from each site; full circles are from the data at site 1, hole circles are from the data at site 2 and squares are from the data at site 3 during the study period. We can see that the common climbing perch has the steepest slope

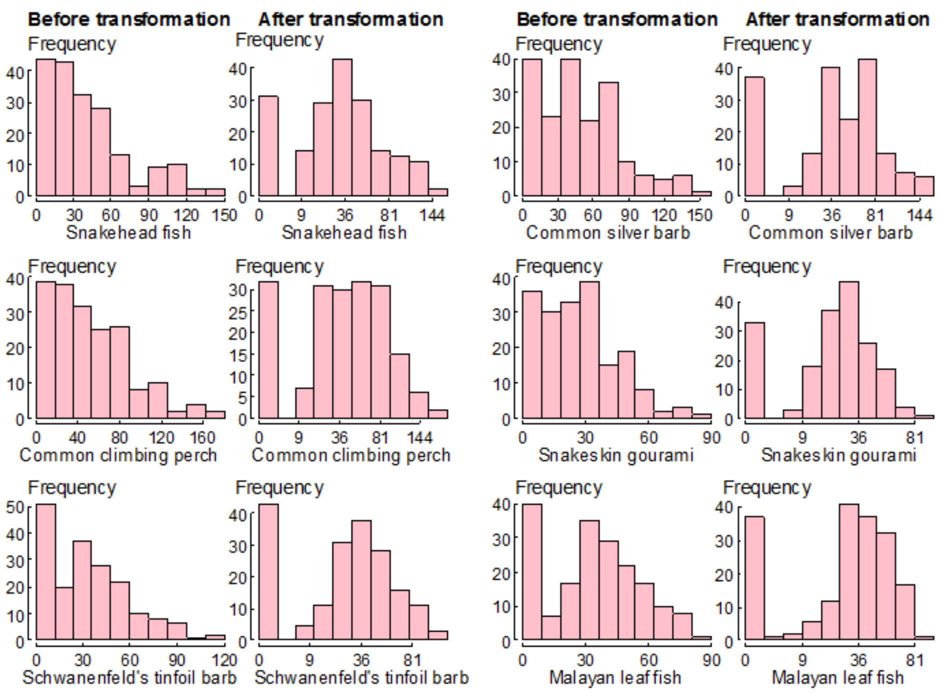

Figure 2. Histograms of standing crop in weights (g/1000 m^2) before and after square root transformation.

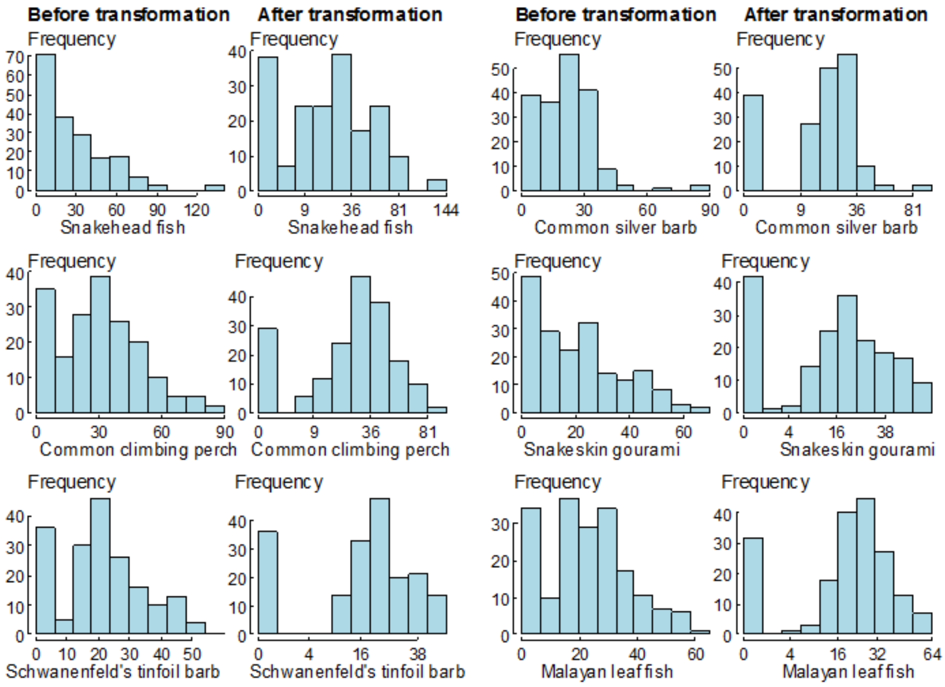

Figure 3. Histograms of fingerling density (larvae/1000 m^3) before and after square root transformation.

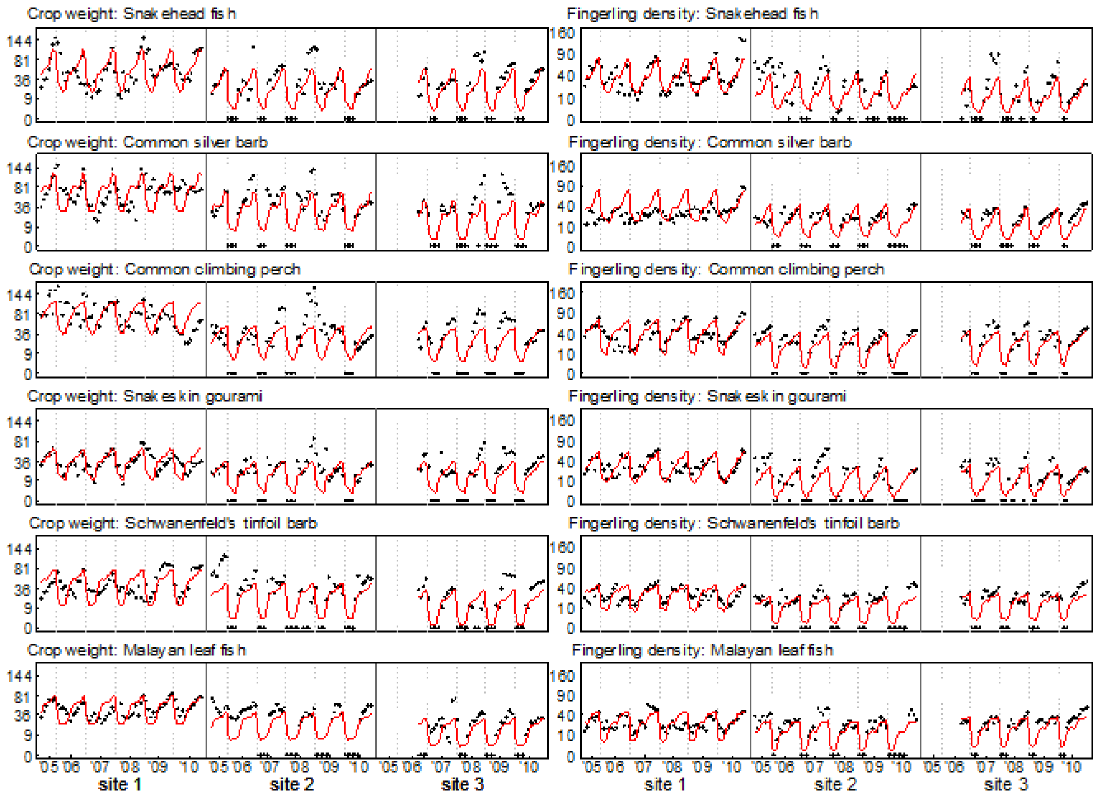

Figure 4. The seasonal pattern of change over the period of standing crop in weight and fingerling density for the six commercial freshwater fish species during June 2005 to December 2010 separated by site.

Table 2. Coefficients and standard errors for each species

Species	Intercept	Coef.	SE	p-value
Snakehead fish	4.5917	0.2198	0.0799	0.0066
Common silver barb	4.7537	0.3358	0.1028	0.0013
Common climbing perch	1.8072	0.8875	0.1111	<0.0001
Snakeskin gourami	2.4194	0.5531	0.0655	<0.0001
Schwanenfeld's tinfoil barb	3.2418	0.3893	0.1147	0.0009
Malayan leaf fish	4.3742	0.1705	0.1227	0.1666

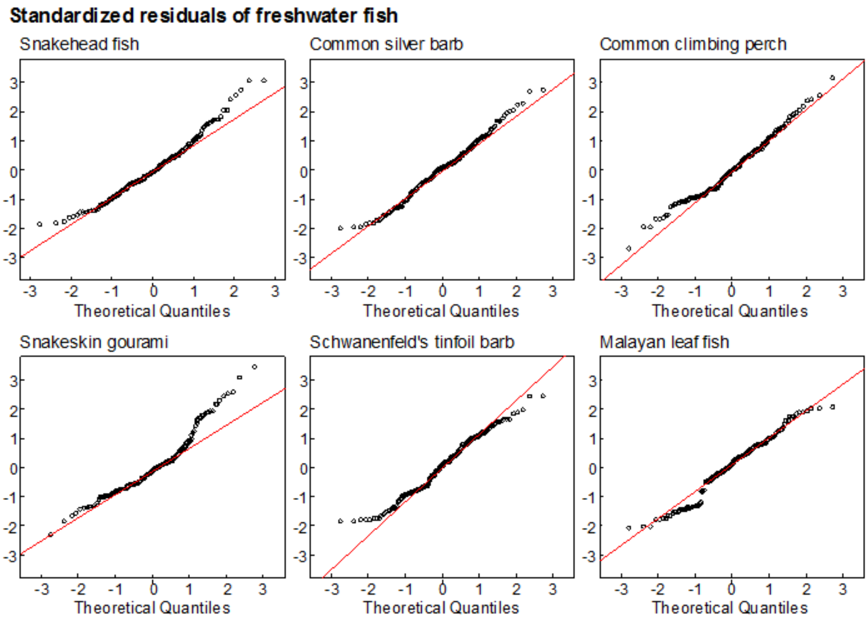

Figure 5. Standardized residuals plots for each species of freshwater fish in Na Thap river

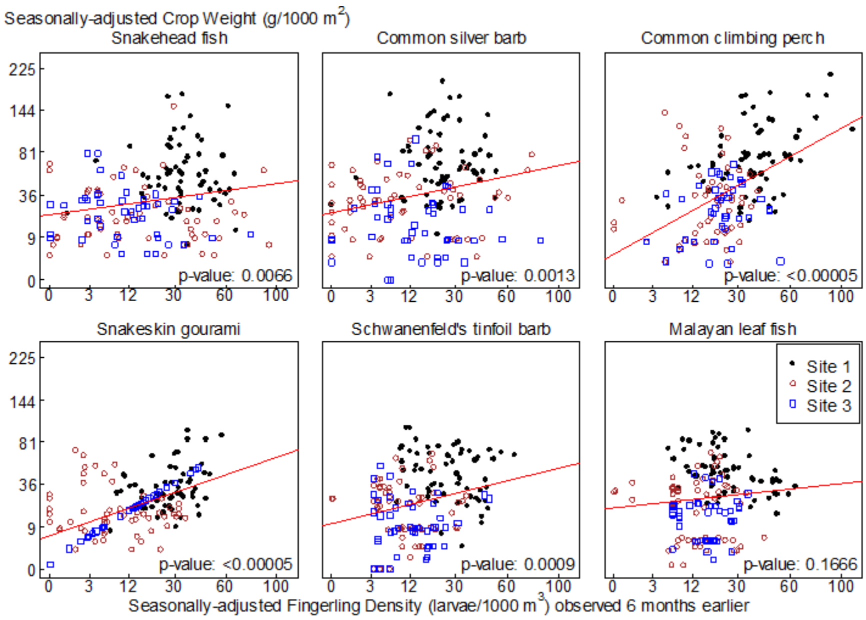

Figure 6. Plots of the seasonally adjusted standing crop in weights and seasonally adjusted fingerling densities observed 6 months earlier for six commercial freshwater fish species

(indicating a higher correlation) with the fish standing crop weights in weights increasing by 0.89 (g/1000 m^2) with a unit increase of fingerling density (larvae/1000 m^3). The fish with the next steepest slope was snakeskin gourami, followed by Schwanenfeld's tinfoil barb, common silver barb, snakehead fish and Malayan leaf fish, with correlation coefficients 0.55, 0.39, 0.34, 0.22 and 0.17 (g/1000 m^2) respectively. All correlations were highly statistically significant, except for the Malayan leaf fish.

4. Discussion and Conclusion

Lag models are commonly used in economics (Coen *et al.*, 1969; Galvao *et al.*, 2011) and also can be found in health studies (Zanobetti *et al.*, 2000; Lim and Choonpradub, 2007). However, they are rarely used in ecological studies. In general, the lag model is a time series model where the outcome is predicted by values from past periods using linear regression. In this study we applied this method with standing crop in weight as the outcome and fingerling density observed 6 months earlier as the determinant. We adjusted for seasonal effects and observed relationships in time series data. The results from the models revealed that standing crop in weights of commercial freshwater fish species in the Na Thap River increased with increasing fish fingerling density in the previous 6 months. This finding confirmed our basic hypothesis that higher fingerling density supported higher standing crop in weight of fishes in the ecosystem.

Our results are consistent with several studies that reporting fish fingerling densities to be positively associated with fish standing crop in weight (Henderson and Hamilton, 1995; Kerr and Lasenby, 2000). The pattern of the fitted regression lines showed that the relation between standing crop in weight and fingerling density depended on the season: summer is normally in the months of mid-February to May while mid-May to mid-October is the moderate rainy season. Both fish standing crop in weights and fish fingerling densities, of all six freshwater fish species, reached maximum levels in heavy rainy seasons, especially in November and December (Angsupanich and Rakkheaw, 1997). For five freshwater fish species, there were statistically significant relationships between the standing crop and fingerling density in the previous 6 months. However, the Malayan leaf fish did not show a statistically significant correlation, probably due to its slowest growth rate (Soe-been and Panboon, 2011).

Fish species differ in biology and physiology. For example the common climbing perch, snakehead fish, snakeskin gourami and Malayan leaf fish possess auxiliary breathing organs that tolerate a wide range of water conditions, whereas schwanenfeld's tinfoil barb and the common silver barb are more restricted to clear running water. However, species composition, fishing effort and correlation of the environmental parameters were not taken into account and that is a limitation of the study. In order to maintain fish biodiversity, abundance and wild–catch fishing production for food security, fish habitat management and stock enhancement also need to compare existing standing crops and fishing activities with those attainable under undisturbed conditions. In addition, policy makers should focus on restricting activities near critical nursery grounds where fingerlings inhabit and establishing fishing period protection. Our finding reconfirmed that the statistical method can be applied more widely for aquatic ecological monitoring and fisheries management. In this study, we analyzed the data collected from Na Thap river in every month over more than 5 years, which a longer than in any other studies of similar ecosystems.

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