Production Interrelationships in Inland Fishing in Anuradhapura, Sri Lanka: A Simultaneous Equation Approach

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INTRODUCTION AND RESEARCH PROBLEM

The inland fisheries sector plays an important role in the subsistence economy of Sri Lanka. However, no tradition of aquaculture or organised freshwater fishery existed until the introduction of a high yielding exotic fish species cichlid, *Oreochromis mossambicus* in 1952 (De Silva, 1988). With the introduction of tilapia and other exotic fish species such as Catla *(Catla catla)* , Java tilapia *(Oreochromis mossambicus)*, *Tilapia hornorum*, *Tilapia rendalli*, bighead carp *(Aristichthys nobilis*), rohu *(Labeo rohita)* and mrigal *(Cirrhinu smrigala)*, inland fish production has rapidly increased by 2013, accounting for 10.4 per cent of total fish production by producing 66,910 Mt in 2013. Meanwhile, per capita consumption of inland fish was recorded as 2kg per year (Fisheries Statistics, NAQDA, 2014). Apart from its direct contribution to food security, the inland fishery sector plays a vital economic role by accounting for 1.7 per cent of Gross Domestic Product (GDP) and providing livelihoods to around 32,635 active fishermen in the country (Ministry of Fisheries and Aquatic Resources Development, 2014).

However, despite this importance, the sector has not reached full potential. Given a 260,000 ha extent of fresh water bodies and the large number of rivers, estuaries, lagoons, brackish water ponds, floodplain lakes, as well as major, minor and village tanks, there is great potential for improvement in the Sri Lankan inland fisheries sector .

During the past decade the government of Sri Lanka has taken a number of steps such as establishing breeding centres and stocking reservoirs with fingerlings to boost inland fish production. Even though stocking of tilapia significantly increased inland fish production in reservoirs (De Silva, 1991; De Silva, 1992), it was found to hamper the bio-diversity. It was evident that when tilapia is present, the availability of food for indigenous and non-indigenous fish species reduces. This can place some such species at risk of extinction (Canonico et al., 2005; Martin et al., 2010).

Therefore, recently the government has taken a policy decision not to continue stocking fresh water bodies with tilapia fingerlings due to the discussion on the invasiveness of tilapia species in local water bodies. It has planned instead to direct inland fisheries towards carp based fisheries (NAQDA, 2009). Against this background, this study aims to explore the effect of stocking of tilapia and other exotic fish fingerlings on the harvest of tilapia, other exotic fish and indigenous fish species.

Objectives

To estimate the joint production function of multi-purpose tanks treating harvests of tilapia, other exotic fish and indigenous fish as exogenous variables and treating stockings of tilapia and other exotic fish, efforts and types of tanks as exogenous variables.

METHODOLOGY

Empirical Model

Species of fish captured in inland water bodies of Sri Lanka were categorised into three major groups as *a) tilapia, b) other exotic fish species and, c) indigenous fish species.* In a given reservoir the harvest of each category is determined by the input, usage, and tank specific characteristics. Therefore, production function of each of the three species was specified as follows.

$$Y_o = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \gamma_0 Y_e + \gamma_1 Y_l + \delta_i$$
$$Y_e = \alpha_1 + \beta_5 X_1 + \beta_6 X_2 + \beta_7 X_3 + \beta_8 X_4 + \gamma_2 Y_o + \gamma_3 Y_l + v_i$$
$$Y_l = \alpha_2 + \beta_9 X_1 + \beta_{10} X_2 + \beta_{11} X_3 + \beta_{12} X_4 + \gamma_4 Y_o + \gamma_5 Y_e + u_i$$

Where,

Y_o = Tilapia production (kg)

Y_e = Other exotic fish production (kg)

Y_l = Indigenous fish production (kg)

X_1 = Fishing effort (number of boats used)

X_2 = Type of tank (major=1, medium=0)

X_3 = Number of Tilapia fingerlings

X_4 = Number of other exotic fingerlings

Although three production equations can be specified as above, they cannot be estimated using OLS regression. Since the production of each species is interdependent on the harvest of others, there will be an endogeneity problem and the error term will correlate with the independent variables. Thus, OLS estimation will result in biased estimates (McLaughlin, 1987). Therefore, simultaneous equation system is estimated using Three-stage Least Square technique to obtain consistent and unbiased estimates.

Three-stage least square method of estimating a structural equation consists of three steps in which the first two steps are similar to the two-stage least square method of estimation. That is, in the first stage, the moment matrix of the reduced-form disturbances is estimated and in the second stage, coefficients of one single structural equation are estimated after its jointly dependent variables are "purified" by means of the moment matrix. Going one step further, in the three-stage least square method all coefficients of the entire system are simultaneously estimated using the two-stage least squares estimated moment matrix of the structural disturbances (Zellner and Theil, 1962).

Data

The study was based on secondary data on monthly fish harvests for 22 major and medium reservoirs in Anuradhapura district for the year 2014. Anuradhapura was selected because it has the highest contribution to inland fish production. Data were collected from the NAQDA (Table 1).

Table1: Fish Catch Statistics and Fingerling Stocking Rates of the Reservoirs in Anuradhapura District

Reservoir	Area (ha)	Fish catch (kg)			Stocking Rate (number of fingerlings)	
		Total Tilapia	Total Other Exotic Fish	Total Indigenous	Tilapia	Other Exotic
Padaviya	2,672	401,125	25,061	40,355	25,000	0
Nachchaduwa	1,781	115,127	142,511	18,799	7,800	179,960
Rajanganaya	1,619	390,760	60,284	33,667		0
Hurulu Wewa	1,619	147,429	154,607	0	0	75,000
Mahakanadarawa	1,457	404,914	139,619	30,296	0	0
Kala Wewa	1,440	432,860	101,574	59,879	0	0
Balalu Wewa	1,200	409,370	48,138	54,580	0	0
Nuwara Wewa	1,197	328,548	137,636	24,185	45,000	70,200
Wahalkada	1,166	152,398	107,188	0	0	0
Vilachchiya/ Maha Vilachchiya	971	416,186	157,147	25,454	0	154,960
Angamuwa	445	85,870	0	0	0	0
Galkulama/ Maha Galkulama	350	220,311	7,602	1,265	50,000	0

Nika Wewa	325	197,266
Turuwila	280	75,186
Manankattiya	276	97,878
Kalankuttiya	271	76,945
Sangilikanadarawa	263	88,183
Eru Wewa	261	96,733
Katiyawa	261	62,071
Horiwila	243	72,757
Tisa Wewa	243	70,243
Aluth Divul Wewa	239	135,683

Source: NAQDA 2014

0	0	0	0
41,785	0	0	0
122,869	0	25,000	25,000
0	0	0	60,000
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
361,88	0	0	0

Table 2: Results of the Estimation of Simultaneous Equation Model

Variables	Unit	Mean	Std. Dev.	Tilapia	Other Exotic	Indigenous
Effort	number of boats	57.76	32.46	2577.37** (0.008)	388.18 (0.371)	280.92* (0.089)
Type of tank	medium=0,major=1			116510.8* (0.051)	43378.95 (0.115)	16783.91 (0.105)
Tilapia fingerlings	number of fingerlings	6945.45	15078.48	2.66** (0.043)	0.36 (0.544)	0.16 (0.470)
Other exotic fingerlings	number of fingerlings	25687	51943.12	-0.844** (0.032)	0.44** (0.017)	-0.10 (0.142)
Constant				13905.19 (0.766)	7096.91 (0.745)	-8277.78 (0.315)
R-square				0.6733	0.5743	0.5042
Number of observations				17	17	17

Table 3: Input-Output Elasticities of the Selected Tanks in Anuradhapura District

	Tilapia fish	Other Exotic Fish Species	Indigenous Fish Species
Effort	0.38	0.38	1.24
Stockings of tilapia fingerlings	0.05	0.04	0.08
Stockings of exotic fingerlings	0.056	0.19	0.19

RESULTS AND FINDINGS

The results of the structural equation model are reported in Table 2 and the production elasticities calculated based on the estimates are reported in Table 3. The R-squares of the estimated models range between 0.5042 and 0.6733 indicating a reasonable model fit. The significance of the individual variables in each model is separately discussed below.

Factors Affecting Tilapia Fish Harvest

Increase in effort (number of boats) stocking tilapia fingerlings was found to lead to an increase in harvest of tilapia, while increase in stocking of other exotic fingerlings was estimated to decrease tilapia harvest. Precisely, as given by the elasticity figure, a one per cent increase in effort will increase harvests by 0.38 per cent (Table 3). An addition of one tilapia fingerling increases the harvest by 2.66 kg while the increase in stocking of other exotic fingerlings by one decreases tilapia harvest by 0.844 kg.

It was also found that tilapia harvest is higher in major reservoirs than in medium reservoirs. The difference is statistically significant for tilapia and is about 116,511 kg. This could be because of the difference in capacity in the two types of reservoirs.

Factors Affecting Exotic Fish Harvest

Increase in stocking of other exotic fingerlings led to an increase in the harvest of other exotic fish, while increase in stocking of tilapia fingerlings and the number of boats doing so did not significantly impact harvests of other exotic fish. According to the estimate of elasticity, a one per cent increase in stocking of tilapia will bring a 0.19 per cent increase in other exotic fish harvest.

Factors Affecting Indigenous Fish Harvest

It was found that fishing effort has a significant effect on the indigenous fish harvest and the increase of one boat would increase the indigenous fish catch by 280.92 kg. However other factors such as type of tank and stocking of tilapia and other exotic fish fingerlings had no significant influence on indigenous fish harvest. Even though statistically insignificant, the estimates derived for tilapia fingerlings and other exotic fish fingerlings indicate that stocking of tilapia fingerlings has a positive effect on indigenous fish harvest while the effect of stockings other exotic fish fingerlings has a negative effect.

All in all the study confirms that the stocking of fingerlings in tanks is one of the ways to increase the inland fish catch in Anuradhapura district. Especially stocking of exotic fingerlings would increase the inland fish production in the study area and hence reduce protein malnutrition in the area. However, since tilapia harvest is negatively affected by stocking of other exotic fish species, there is a need to be cautious about stocking these two types of fingerlings together in a reservoir.

CONCLUSION

The estimation of production interrelationships in inland fisheries revealed that stocking tilapia has an influence only on tilapia production and it indirectly increases the share of tilapia catch over total inland fish production.

Stocking of other exotic fish fingerlings has a negative influence on tilapia production and reduces the share of tilapia production over total fish production. Other than that, stocking other exotic fish fingerlings has a positive impact on exotic fish catch and increases the share of exotic fish production over total inland fish production.

REFERENCES

Canonico, G. C., Arthington, A., McCrary, J. K., and Thieme, M. L. (2005). The effects of introduced tilapias on native biodiversity. Aquatic Conservation: Marine and Freshwater Ecosystems, 15(5), 463-483

De Silva., K 1991. The predicament of the Freshwater fisheries and aquaculture of Sri Lanka. Naga, the Iclarm Quaterly.

De Silva, S.S. 1988. Reservoirs of Sri Lanka and their Fisheries. FAO Fisheries Technical Paper 298: 128 p.

Inland and aquaculture fish production, 2014. [Online] Available at: <http://www.naqda .gov.lk/brackish water.php> [Accessed 6 July 2014].

Inland and aquaculture fish production, 2014. [Online] Available at: <http://www. naqda.gov.lk/> [Accessed 6 July 2014].

McLaughlin, C. G. (1987). HMO growth and hospital expenses and use: a simultaneous-equation approach. *Health Services Research*, *22*(2), 183.

Ministry of Fisheries and Aquatic Resources Development, 2014. *Annual Report 2014.* [Online] Available at:<http://www.fisheries.gov.lk/elfinder-2.0 rc1/files/stat/Fisheries%20Statistices/Tables.pdf>[Accessed 6 July 2014].

Ministry of Fisheries and Aquatic Resources Development, 2014. *Fish Production Report 2014.* Available at: <http://www.fisheries.gov.lk/content.php?cnid=ststc> [Accessed 6 July 2014].

Zellner, A., and Theil, H. (1962). Three-stage least squares: simultaneous estimation of simultaneous equations. *Econometrica: Journal of the Econometric Society*, 54-78.