An Economic Analysis of Catamaran Fishing on Niue Island

SCOTT COFFEN-SMOUT

Department of Agriculture, Forestry and Fisheries
P.O. Box 74, Alofi, Niue Island
South Pacific

Abstract

The economics of small-scale commercial fishing on Niue Island is appraised through estimation of a production function for catch and effort. The analysis is based on data from fishing trip log sheets of an alia catamaran. As expected, effort has a significant effect on catch, although a given change in effort produces less than a proportional change in catch, assuming all other factors remain constant. From a private sector perspective, increased fishing effort may be profitable as effort seems to be underutilized on an average month of fishing on the alia catamaran. Provided that all of the fish caught are sold, increased effort may be lucrative, while the potential for profit exists, creating an alternative mechanism for the distribution of wealth throughout the island community. Social obligations for the distribution of fish may render commercial fishing uneconomic. However, given the local demand for fresh fish, it is feasible for Niuean fishers to earn a good income through fishing.

Introduction

The catch of a commercial fishing vessel is, among other things, a function of the inputs used in fishing. Fish catch depends upon effort in the form of fishing skills and technology, as well as the seasonal, biological and geographical aspects of fisheries. The relationship between catch and effort may be regarded as a production function which gives the technically efficient yield at various levels of effort.

The objective of this paper is to appraise the economics of small-scale commercial fishing on Niue with an aluminum 8.9-m Western Samoan "alia" catamaran, through estimation of an empirical production function for catch and effort. Questions to

answer include: If effort doubles, by what proportion does catch increase? What is the economic efficiency of effort? Is the market value of the product high enough to cover the cost of fishing, and provide a profit incentive for fishers? What effects do the social obligations for fish distribution have on the economic viability of commercial fishing?

Several economic appraisals of Pacific inshore fisheries have been completed to date. Uwate et al. (1988) provide baseline information on the economic performance of 9-m fishing vessels in Fiji. King and McIlgorm (1989) provide a methodical approach to such appraisals integrating biological aspects of the stock with economic and marketing aspects. Lawson (1984) describes general methods of determining long-term viability through financial project appraisal techniques. Panayotou (1985) provides useful findings on the constraints and opportunities facing small-scale fisheries development in Asia through a general overview of policy and socioeconomic aspects. Halapua (1982) examines the economics of subsistence fishing in Tonga from the perspective of why capital investment alone is inadequate for fisheries development. Although the capitalization of Pacific subsistence fisheries generates technical changes, the precedence of social obligations over market demand is a barrier to fisheries development. Profit realization and market incentives are not the only motivating factors for subsistence fishers in the Pacific, but rather, their demand for money is linked with the satisfaction of immediate subsistence requirements. Johannes (1989) notes that "social barriers to capitalistic behaviour are widespread, occupational pluralism is the norm, profit does not motivate, capitalism is not the engine of production and wealth does not pay dividends; rather it attracts considerable social costs."

In contrast to these studies, this paper uses a rigorous statistical analysis to appraise the economic viability of the commercial operation of an alia catamaran on Niue. This appraisal requires the following information: the cost of fishing per unit of effort, an estimation of catch rates, and a consideration of the social obligations governing the distribution of fish. Basic price and cost information is available. Little stock resource information exists, but bottom fish catch rates and the potential for fishing on Niue were determined by three fishing surveys (Fusimalohi 1978; Mead 1980, 1988). Catch rates during the surveys ranged from 2.8 to 8.5 kg/line-hour and averaged 5.8 kg/line-hour. At that time it was

concluded that Niuean fishers could obtain good incomes through a combination of bottom fishing and trolling. Trolling catch rates on the government alia catamaran in 1986, for example, ranged from 0.66 to 2.2 kg/line-hour with an average of 1.6 kg/line-hour (pers. obs.). The disposition of catch has been determined through a household questionnaire, indicating the proportion of catch which is either sold, shared or consumed at home (Dalzell et al. 1991).

This analysis uses time-series data collected from the government-run alia catamaran hire service which is provided for Niueans to catch fish for, among other things, social and cultural obligations such as ear piercings and hair cuttings. These data are adequate to allow analysis of a catch and effort production function based on an aggregate measure of trolling and bottom fishing effort. Catch, effort data and fuel consumption data from 835 alia catamaran fishing trips from November 1980 to May 1991 were used. The data were obtained directly from fishing trip log sheets maintained by the Niue Fisheries Division. A summary of the data reveals that the average catch weighed 48.2±49.1 kg/trip, and ranged from nil catch to 384 kg. The average fishing trip lasted 8.8±2.8 hours, with a range from 23 to 1.5 hours. The average fuel consumption was 52.4±21.1 l/trip, and ranged from 132 to 2 l. Fuel costs during the time period increased from NZ$0.66/l in 1980 to $1.34/l in 1991 (US$1=NZ$1.80 in 1991).

It is important to address the question of how closely these data approximate the operations of private fishers on Niue. While the average crew size for the alia catamaran is two, including the skipper, crew size for an aluminum dinghy is one. Nonetheless, the range of 4.0 to 5.0-m private aluminum dinghies which currently operate around Niue have comparable effort levels and gear types to the alia catamaran. Larger dinghies are similarly configured to the alia, with four handreels for trolling and bottom fishing, while smaller dinghies have two handreels, but usually also troll one handline. Hence, the data presented here are a reasonable approximation of private fishing ventures.

Fishing on Niue

The majority of Niuean fishers fish for large pelagic species, while bottom fishing is practiced by only a few full- and part-time

fishers using handreels based on the FAO/Western Samoa design, or with locally designed reels. Flying fish, round scads, big-eye scads and occasionally skipjack tuna are used for bait, as well as being caught for food. The bottom fish resources are limited due to the steep slope bathymetry, and are therefore vulnerable to overexploitation. If commercial exploitation of bottom fish resources were to take over from the present subsistence fishing, the result might be overexploitation. There could also be some interaction between subsistence fishing and commercial fisheries. Bottom catch composition is dominated by snappers of the genera *Lutjanus*, *Etelis* and *Pristopomoides*; and groupers of the genera *Cephalopholis* and *Epinephelus*. Other bottom fish catches include oilfish and snake mackerel of the family Gempylidae.

Trolling using handlines with live or dead bait is a traditional fishing technique of Niuean canoe fishers. The introduction of small aluminum dinghies in the early 1970s led to an increase in trolling for large pelagics. Dinghy fishers use a variety of commercial lures and rigged bait to capture large pelagics such as wahoo (*Acanthocymbium solandri*) and yellowfin tuna (*Thunnus albacares*), which together account for about 80% of the landings. Other major large pelagics include skipjack tuna (*Katsuwonus pelamis*), dolphin fish (*Coryphaena hippurus*) and barracuda (*Sphyraena* sp.). The abundance of large pelagics is subject to year-to-year fluctuations and seasonality, with catch rates for wahoo and yellowfin being greatest in May-September, and in October-January for skipjack.

Methods: The Model

In the analysis, the input variable effort (E) is used to explain catch variation. This variable is most important from an economic perspective, although other variables such as seasonality, geographical location and a measure of the skipper's operational experience could be included in future analyses when appropriate data become available. Admittedly, this is a simple treatment of a dynamic process, but serves to capture broad trends if they exist.

To evaluate the influence of effort on catch, a production function was estimated by ordinary least squares regression techniques. The production function is specified in its multiplicative form as:

$$Y = \alpha E\beta \cdot e^z \qquad \qquad ...1)$$

where α and β are regression coefficients (parameters) to be estimated, and e is the base of natural logarithms. The variables are defined as follows:

1. Y is the monthly catch in kilograms (kg). Initial exploratory data analysis suggested that this definition is more compatible with the model than expressing catch per trip. Since catch as used here is an aggregate measure of pelagic and bottom fish, its species components may exhibit differential catchabilities.

2. E is the total monthly effort in hours. Exploratory data analysis suggested that this definition is more appropriate than considering effort per trip. Since the alia catamaran is normally configured to operate with four handreels based on the FAO/ Western Samoa design, one hour of fishing effort is equivalent to 4 line-hours.

Since effort as used here is an aggregate measure of trolling and bottom fishing effort, its gear components may exhibit differential catchability coefficients. Given the fact that fishing mortality is proportional to effort, and that changes in fishing efficiency are not measured here, it is assumed that catchability coefficients remain constant during this time series of data. It is also assumed that effort is fixed in the short term, without being optimized on an annual basis. Furthermore, this analysis assumes a steady-state equilibrium of the fishable biomass. Analysis of catch per unit of effort with respect to effort over time indicated no statistically significant relationship between these two variables. Hence, this steady-state equilibrium assumption appears reasonable.

3. The random error term z is assumed to have a normal distribution with appropriate properties to enable a standard regression analysis to proceed. Variability in the original data was log-normally distributed, so this assumption appears reasonable. Hence, the logarithmic version of the catch and effort model is:

$$\ln Y = \ln \alpha + \beta(\ln E) + z \qquad \qquad ...2)$$

The estimated coefficient β in equation (2) represents a measure of the change in catch with respect to effort. Intuitively, a positive coefficient for effort is anticipated *a priori*.

Results

Table 1 shows the estimated catch and effort production function for 55 months of fishing, estimated from the data shown in Fig. 1. The aggregate catch rate over this period averaged 0.99 kg/ line-hour. The level of effort explained 71.3% of the overall variation in catch with F=131.62. Although a chi-square goodness-of-fit test to examine normality of the residuals suggested that such normality was imperfect at the 10% level (χ^2=2.16, df=1), visual examination of the regression results suggested that this conclusion may be due to a paucity of data at low levels of effort. Therefore, the data were grouped according to low levels and high levels of effort using the natural log value of 4.0 as a dividing line, and the residuals were re-examined in two separate regressions. In both cases, there were no apparent trends in the distribution of the residuals.

In multiplicative form, the resulting catch and effort production function may be written:

$$Y = 8.029 \cdot E^{0.907}$$

where the constant is a biased estimate of α given nonlinearly by the antilog of the α estimated in Table 1.

The parameter β in regression equations (1) and (2) provides a measure of the percentage increase in catch for a 1% increase in effort, assuming all other factors are held constant. This parameter is estimated as 0.907. Thus, a 10% increase in effort yields a 9% increase in catch. Hence, a given change in effort produces less than a proportional change in catch.

Economic Efficiency

Table 2 summarizes the costs associated with the purchase and commercial operation of an alia catamaran in 1991. These calculations assume 150 eight-hour fishing
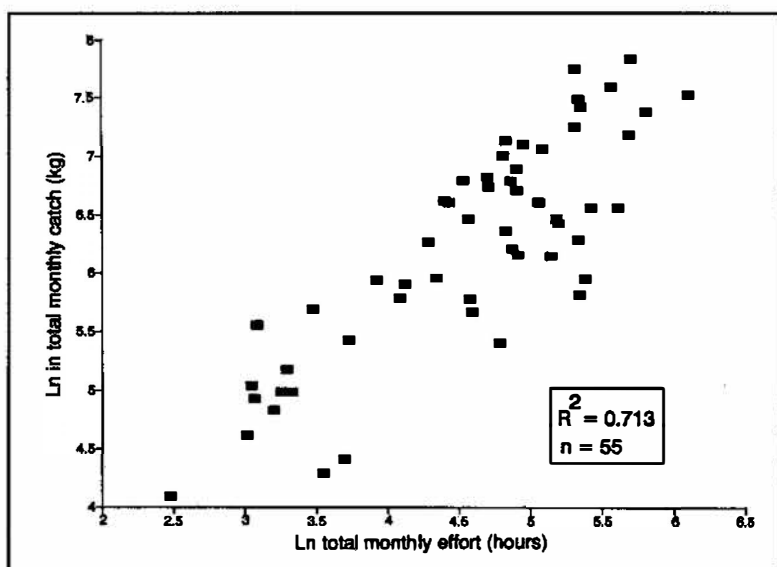
Table 1. Estimated catch and effort production function.

ln Y = 2.083 + 0.907 (ln E)		
SE:	0.506	0.079
tα =	4.117*	
tβ =	11.481*	
Means: $\bar{Y}$ = 476.732	$\bar{E}$ = 90.261	
n =	55	
F =	131.62*	
R^2 =	0.713	
Average market price of fish = $6.00/kg		

*Significant at 1% level.

Fig. 1. Scattergram of catch and effort data.

Table 2. Capital costs, annual fixed costs and operating costs of an alia catamaran.

A)	Capital costs	Total cost (NZ$)	
	Fully rigged alia catamaran	30,000	
		Annual cost (NZ$)	Hourly cost (NZ$)
B)	Fixed costs		
	Wages (skipper and one crew)	9,000	7.50
	Repair and maintenance	1,080	0.90
	Depreciation (over 10 years)	3,000	2.50
	Total fixed costs	13,080	10.90
C)	Operating costs		
	Gear replacement	840	0.70
	Fuel and oil ($62.80/trip)	9,420	7.85
	Bait (2 kg/trip @ $3.60/kg)	1,080	0.90
	Ice (5 kg/trip @ 2.40/kg)	1,800	1.50
	Total operating costs	13,140	10.95
	Total annual costs	26,220	21.85
D)	Annual income		
	477 kg/month x $6.00/kg x 12 months = NZ$ 34,344		

(US$1 = NZ$1.80)

trips per year. Monthly catch for the annual income calculation (D) is the mean catch derived from the estimated production function in Table 1.

In order to examine whether the use of effort is, on average, economically efficient, one must compare the incremental benefit of an additional unit of effort with the incremental cost of effort. The marginal benefit of effort is given by the value of the marginal product of effort (VMP_E), determined by multiplying the output price (P_Y) and the marginal product (MP_E). The marginal cost is the price of effort (P_E). If the value of the marginal product is greater than its price (P_E), effort should be increased. If the VMP_E is less than its price (P_E), effort should be decreased. If the value of effort's marginal product is equal to its price, effort usage is considered to be economically efficient.

To examine the efficiency of effort use, the marginal product of effort is calculated through partial differentiation of equation (2), with effort set at its geometric mean. This is equivalent to deriving $\delta Y/\delta E = \beta Y/E$, where Y is the mean catch, obtained by inserting the geometric mean effort level into equation (2). The calculations are as follows:

$$MP_E = \delta Y/\delta E = 0.907(476.732/90.261) = 4.79$$
$$VMP_E = P_Y \cdot MP_E = (6.00)(4.79) = \$28.74$$

where P_Y is the average price of fish paid to the fishers. These calculations assume that all fish caught are sold at P_Y. Since the value of the marginal cost of effort is \$21.85 from Table 2, effort would seem to be underutilized from the profit-maximizing perspective during an *average* month of alia catamaran operation. Hence, additional effort may be profitable from a private sector perspective.

It is of interest to examine the implications for the economic viability of commercial fishing given the social obligations to share fish among extended family and village members. Examining the disposition of catch from information provided in a household questionnaire (Dalzell et al. 1991), approximately 37% of fish caught beyond the reef is either shared (25%) or sold (12%), while 63% is for home consumption. Assuming the value of the shared catch provides social benefits to the fishers in excess of the monetary value derived from selling fish in an economy where demand for

fish is great, it is possible to determine the economic efficiency of commercial fishing when only 37% of the catch is either shared or sold. This is accomplished by adjusting the mean catch value above, and recalculating the marginal product of effort. This calculation indicates that $VMP_E = \$10.62$, or less than half the value of the marginal cost of effort. If P_Y remains at \$6.00, this reveals that increased fishing effort is unprofitable from a private sector perspective. Hypothetically, to sustain an economically efficient commercial fishing operation which shares or sells 37% of its catch, the price of fish (P_Y) would have to more than double to \$12.34/kg before the value of effort's marginal product would be equal to its price. In practice however, the commercialization of fishing on Niue may result in lower fish prices due to increased quantities of marketed fish being supplied for local demand. On average, 76% of the catch would have to be sold at \$6.00/kg in order for the value of effort's marginal product to equal its price.

Discussion

This paper appraised the economics of small-scale commercial catamaran fishing to understand the factors which determine the successful development of commercial fisheries on Niue. Catch and effort data were fitted to a nonlinear production function, and the results fit the data well. Effort plays a significant role in determining catch, although a given increase in effort produces less than a proportional increase in catch, assuming all other factors remain constant.

Based on the estimated production function of catch and effort, effort use appears underutilized from a profit-maximizing, private sector perspective during an average month of fishing. Assuming that all of the catch is sold at current prices, additional effort may increase profits. Thus, the market value of fish covers the cost of fishing, and it should provide profit incentives for fishers. The existence of profit potential in the annual income calculation in Table 2 creates an alternative mechanism for the distribution of wealth to extended family and village members. However, the degree of traditional social pressures against an integration of capitalist ideals into Niuean society is difficult to estimate. The economic viability of commercial fishing appears to be rendered

tenuous by the social obligations governing the distribution of fish. Nonetheless, it is possible for Niuean fishers to capture economic rent through bottom fishing and trolling.

Two caveats are important for these results. Firstly, information on the market aspects is limited. For example, (1) the elasticities of supply and demand for fresh fish are unknown, and (2) the degree of unmet demand for fresh fish has not been measured, although the level of demand for fish is limited by a population of 2,200 residents. Any increase in fish supply may affect the current market equilibrium, and hence the conclusions above. Secondly, if effort and catch increase, the relative proportions of amounts shared, sold and consumed at home may change given that there may be a limit to home consumption. If total catch increases while the quantity consumed at home remains constant, then the portion of catch available for sharing and selling would also increase.

Since the production function estimated here represents the catch and effort relationship for an average month of alia catamaran operation over an extended period, it may be unwise to advise a dinghy fishers, for example, on the estimated catch at various levels of effort based on this estimated function. Fishers could use these average results by modifying them to reflect their own fishing activity. More importantly, these results may provide some guidance to future fisheries managers and capital loan officers regarding the underlying economic efficiency of an alia catamaran operation should commercial fisheries on Niue eventuate. These preliminary results on the economics of commercial fishing will be enhanced by the provision of additional stock resource information to help guide Niue's commercial fisheries development.

Acknowledgements

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