The Use of Surplus-Yield Models in the Economic Analysis of a Fishery*

ANNABELLE CRUZ-TRINIDAD
ICLARM
M.C. P.O. Box 1501
Makati, Metro Manila
Philippines

Abstract

Discounted cash flow techniques, as typically employed in the evaluation of fishery projects, employ constant cost and revenue streams over the duration of the project. The implicit assumption is that additional effort in the fishery does not adversely affect costs and yields. This assumption is often not valid for large-scale fisheries projects. Thus, overestimates of profitability which may send misleading signals to private and/or public investors result in these cases. To correctly account for the effect of changes in the level of effort on costs and revenues during the course of projects, biological surplus production models are used in cash flow analysis. The biological model serves as basis to forecast future levels of catch given changes in the level of effort. A comparison of profitability indicators using the traditional and improved cash flow techniques shows that the indicators generated by the improved technique are more conservative and thus less likely to encourage overcapitalization in the fishery than those generated by the commonly used model.

Introduction

The costs and earnings approach is the most common analytical tool used in the economic analysis of a fishery. Costs and earnings data can be used for the computation of various financial indicators, including the *return on investment (ROI)* which Bailey and Maharudin (1987) used to compare small and medium-scale fisheries in Indonesia; the *payback period*, used by the Philippine Bureau of Fisheries and Aquatic Resources (BFAR 1985a) to evaluate the profit potential of otter trawls, ring nets, and purse seines under the government's *Biyayang Dagat* program; *return on assets*, used by Awadallah (1983) to evaluate Egyptian trawlers operating in the Gulf of Suez; and *return to capital and labor*, used by Tulay and Smith (1979) and Supanga and Smith (1979) to compare the performance of gillnets, push nets, and trawlers operating in San Miguel Bay, Philippines and also by Elliston (1978), Selvadurai and Kong (1977) and Lomax et al. (unpublished data) to evaluate trawlers in Malaysia.

Discounting techniques such as *net present value (NPV)* and the *internal rate of return (IRR)* can be used to analyze and evaluate the profitability of fishery operations that may have cost and earnings streams which vary over the duration of projects.

In the simplest case, a constant catch-effort relationship is implicitly assumed, i.e., it is assumed that the additional fishing effort brought about by the investment will result in a proportional increase in catch and have a negligible effect on the resource (Dixon et al. 1986). However, this relationship is valid only if the resource potential is much larger than the potential yield of the planned fleet and if no one else enters the fishery to be developed. If this assumption is violated, the resulting profitability indicators will be biased upwards, thus sending wrong signals to public and private investors, and thereby encouraging overcapitalization and overfishing.

Fisheries have two key characteristics: limited yield and open access. These characteristics generally result, after a short "boom phase" when a fishery is initiated, in lower levels of production; lower catch per unit of fishing effort (Y/f)[a]; relative increase of small-sized, less valuable species in the catch; and, rising real prices of fish.

In order to adequately account for these characteristics, an improved cash flow technique that makes use of a surplus-yield model can be used. The surplus-yield model specifies a catch-effort relationship which is used to forecast production levels given future levels of effort. The surplus-yield model allows inferences not only on future levels of production but also on costs, i.e., lower Y/f implies that the costs of catching the same amount of fish increases.

The improved technique results in costs and earnings change during the project lifetime, thus resulting in more accurate profitability indicators.

*ICLARM Contribution No. 664.

[a]Editor's note: "Y/f" is used here instead of the conventional "C/f" because the author uses C/f for *cost per unit of effort*.

Materials and Methods

In order to compare the profitability indicators resulting from the use of the traditional and improved cash flow techniques, a hypothetical investment project was simulated. Costs and earnings data were collected from a medium trawler in Lingayen Gulf, Philippines. Table 1 shows a breakdown of initial investment and operating costs. Revenue was estimated based on average catch per trip, which was multiplied by a weighted price (based on average species composition and 3-year average wholesale prices per species or species group). Table 2 shows the computation of revenue based on average catch of 468 kg per trip and 100 trips per year, based on an average trawler trip of two nights and three days. A cash flow was constructed using the traditional method (assuming constant costs and earnings) (see Table 3).

The first step towards the improvement of the cash flow technique is to establish a catch-effort relationship that characterizes the fishery, i.e., the commercial fishery in Lingayen Gulf. The representation of catch or yield (Y) (commercial catch/year) is more straightforward than effort (f) which is a combination of resources such as the labor, capital, raw materials, time and technology that is used to exploit the resource. Effort was measured here as the cumulative gross tonnage of all trawlers deployed in a given year. Table 4 shows a time series of effort and yield.

The time series data were fitted with a linear regression of the form:

$$\ln(Y/f) = a - b * \ln(f) \qquad ...1)$$

where Y/f = catch per unit of effort (Fox 1970, and see Figs. 1 and 2).

Equation (1) can be used to forecast future levels of Y/f, which is then multiplied by the weight (w_i) of each species (i) and its corresponding price (p_i) to arrive at revenue per vessel fishing day. This value, when multiplied by f, yields annual revenues for the trawler fleet. The improved total revenue (TR) equation is:

$$TR = \Sigma e^{(a - b * \ln(f))} * (w_i * p_i * f) \qquad ...2)$$

of which all terms are defined above.

Table 1. Initial Investment and operating costs of medium trawlers in Lingayen Gulf, Philippines (1989 prices).

Cost factor	₱[a]
Initial investment	
Hull	250,000
Engine	55,000
Gear and accessories	20,000
Machinery and deck equipment	27,000
Miscellaneous (ropes, buckets)	9,000
Total investment	361,000
Operating cost	
Fixed	
Sea rent/license	1,200
Hull repair	50,000
Engine repair	40,000
Repainting	5,000
Drydocking	5,000
Wharfage	4,500
Depreciation	36,100
Total fixed cost	141,800
Variable	
Salaries	47,000
Fuel	504,000
Lubricants	27,200
Ice	24,000
Food	35,000
Operator's license	2,000
Broker's fee	45,767
General repairs	50,000
Total variable cost	734,967
Annual operating cost	876,767

[a]The conversion between Philippine peso and US$ is ₱25 = 1US$.

Table 2. Species composition, percentage contribution and price of trawler catch.

Species composition[a]	Percentage contribution[b] (%)	Average wholesale price[c] (₱/kg)
Slipmouth (small)	15.00	18.09
Hairtail	9.00	19.44
Slipmouth (large)	6.70	30.95
Lizard fish	5.40	20.08
Crevalle	5.20	23.77
Short-bodied mackerel	4.40	29.55
Squid	3.20	25.75
Goatfish	3.00	20.13
Cardinal fish	2.30	40.90
Big-eyed herring	2.20	14.59
Red-bull's eye	2.10	10.94
Trevally	1.70	23.77
Doublewhip threadfin bream	1.50	28.63
Anchovy	1.40	13.28
Moonfish	1.20	18.31
Mojarras	1.10	12.55
Faughni mackerel	1.00	25.89
Barracuda	1.00	25.82
Japanese threadfin bream	1.00	28.63
Big-eye scad	0.75	26.22
Indian mackerel	0.75	25.89
Average weighted price		19.56
Average catch/trip		468 (kg)
Average revenue/trip		9,154 ₱
Average revenue/year		915,408 ₱

[a]Common names from Herre (1953) and Rau and Rau (1980).
[b]Philippine Fisheries Development Authority (1983).
[c]Unpublished price data from Philippine Fisheries Development Authority.

Table 3. Cash flow using traditional technique (in ₱).

Project periods	1	2	3	4	5	6	7	8	9	10
Total investment	361,000	0	0	0	0	0	0	0	0	0
Operating Cost										
Fixed										
Sea rent/ license	0	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Hull repair	0	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Engine repair	0	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000
Repainting	0	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Drydocking	0	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Wharfage	0	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500
Total fixed cost	0	105,700	105,700	105,700	105,700	105,700	105,700	105,700	105,700	105,700
Variable										
Salaries	0	47,000	47,000	47,000	47,000	47,000	47,000	47,000	47,000	47,000
Fuel	0	504,000	504,000	504,000	504,000	504,000	504,000	504,000	504,000	504,000
Lubricants	0	27,200	27,200	27,200	27,200	27,200	27,200	27,200	27,200	27,200
Ice	0	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Food	0	35,000	35,000	35,000	35,000	35,000	35,000	35,000	35,000	35,000
Operator's license	0	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Broker's fees	0	45,767	45,767	45,767	45,767	45,767	45,767	45,767	45,767	45,767
General repairs	0	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Total variable cost	0	639,200	639,200	639,200	639,200	639,200	639,200	639,200	639,200	639,200
Total operating cost	0	744,900	744,900	744,900	744,900	744,900	744,900	744,900	744,900	744,900
Total revenue	0	915,408	915,408	915,408	915,408	915,408	915,408	915,408	915,408	915,408
Net cash flow	-361,000	170,508	170,508	170,508	170,508	170,508	170,508	170,508	170,508	170,508
Interest rate	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.41	0.42
Net present value	850,940	620,960	452,593	326,312	229,491	153,764	93,456	44,638	35,994	27,677

Table 4. Yield-effort time series of medium trawlers in Lingayen Gulf, Philippines.

Year	Marine landings of commercial fishery (t)	Gross tonnage of commercial vessels (GRT)
1978	2,502	418
1979	1,884	752
1980	1,391	738
1981	2,050	910
1982	2,033	716
1983	2,060	740
1984	1,449	645
1985	1,380	650
1986	1,710	654
1987	1,296	754

Source: BFAR (1980, 1983, 1985b, 1987).

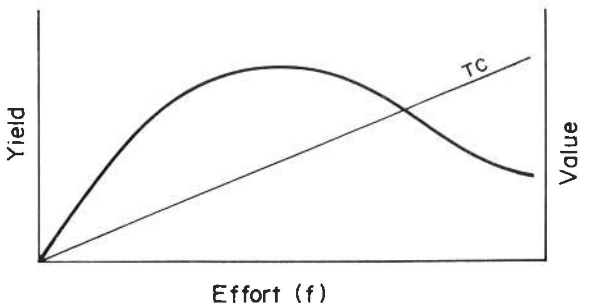

Fig. 1. Schematic representation of a Fox-type surplus production model with added scale for costs and returns. TC refers to total cost line.

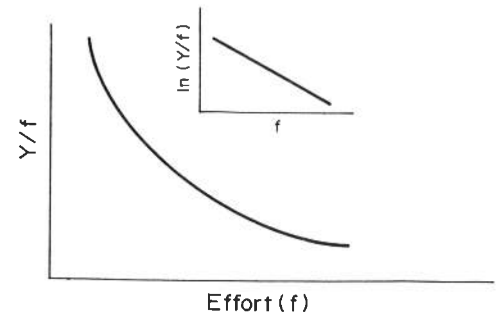

Fig. 2. Schematic representation of yield/effort plot (and its log transform) as used to estimate parameters of Fox' production model.

The forecasted levels of Y/f is also used to arrive at an improved cost equation (TC) of the form:

$$TC = C/f + \Delta C/Y \qquad ...3)$$

where C/f = cost per unit of effort
C/Y = cost per unit of catch

The variable C/f is a constant value which represents private costs, i.e., costs per fisherman or boat. C/f represents operational costs and is denoted as total costs in the traditional cash flow technique. The improved costs equation includes a catch-all variable $\Delta C/Y$ that accounts for all externalities resulting from the change in the level of effort. For example, an increase in the level of effort which causes a decline in Y/f would result in a corresponding increase in "real" costs because it becomes more and more expensive to catch the same amount of fish.

C/Y is estimated by dividing the constant C/f by future levels of Y/f. Note that as Y/f decreases, C/Y increases. The difference in C/Y from successive periods thus becomes $\Delta C/Y$. The resulting values of TR and TC are then used to generate profitability indicators using an improved cash flow technique.

Results and Discussion

The trawler is the most important commercial gear operating in Lingayen Gulf. Ochavillo et al. (1989) note that there are 26 trawlers (2 large and 24 medium) operating in the Gulf in 1987 which, together with 3 Danish seines and 2 purse seines, comprise the commercial fishery. The commercial fishery accounts for an average of 20% to total production in the Gulf but has a higher average of 12.5 tonnes/fisherman when one considers a fleet of 34 trawlers with 8 crew members each, as compared to the municipal fishery which has a productivity of 1.6 tonnes per fisherman, as estimated from data in Pauly et al. (1989). The impact of an increase in effort in the commercial fishery is much greater than in the municipal fishery. Thus, the yield-effort relationship of the commercial fishery should be given due consideration when appraising the profitability of trawlers.

The yield-effort relationship in the commercial fishery of Lingayen Gulf is expressed by the following parameter estimates and test-statistics:

$$\ln(Y/f) = 9.72 - 1.346\, f$$
$$t_\alpha = 4.025 \qquad r^2 = 0.624$$
$$t_\beta = -3.642 \qquad F = 13.27$$

Fig. 3 shows a plot of the estimated Fox model showing how Y/f decreases as effort is increased. The plot includes actual and forecasted values of Y/f.

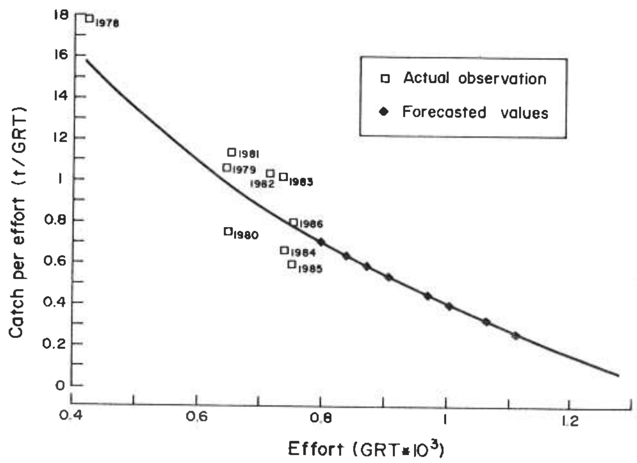

Fig. 3. Yield/effort *vs* effort in the Lingayen Gulf trawl fishery (based on data in Table 4).

The present level of effort (all trawlers) is 754 gross tons while average catch rate (Y/f) is 468 kg per trip. This average catch rate would be maintained if effort were to remain constant. However, if effort were to increase by 2% per year for the next 10 years, average Y/f would drop to 451 kg and if effort were to increase by 5%, Y/f would then drop to 429 kg.

These declines in Y/f affect revenues and costs in the improved cash flow technique. A comparison of the IRR plots of the traditional cash flow technique with two cases of the improved technique shows that the IRRs resulting from the latter are lower (see Fig. 4).

The traditional cash flow technique does not contain a mechanism which permits it to account for changes in the level of effort except as an external feature, i.e., the impact of effort can be reflected as a

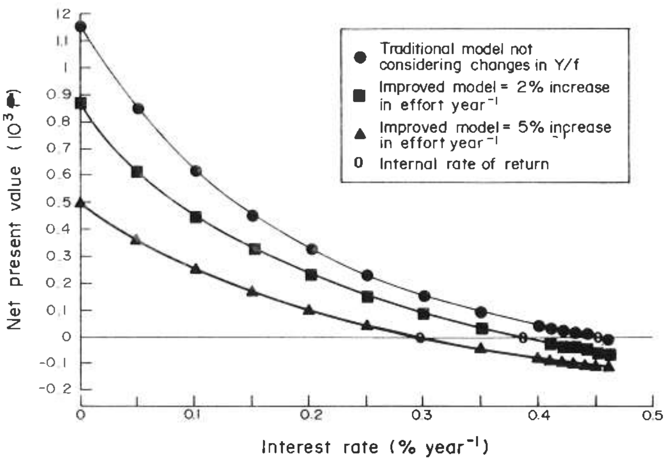

Fig. 4. Results of cash flows simulations using the traditional and improved methods (see text).

change in revenues and costs per se using externally determined values. The improved technique provides a built-in mechanism to account for these changes.

Conclusion

The incorporation of surplus-yield models in cash flow analysis provides a mechanism wherein changes in the level of effort are reflected immediately in the model through its effect on costs and revenues. At high levels of effort, results generated by improved cash flow techniques generally result in lower indicators than those generated by traditional cash flow techniques where the level of costs and revenues is regarded as a constant or where changes in these variables are treated as an external effect.

References

Awadallah, M. 1983. An incomes and costs study of the Egyptian trawl fishery operating in the Gulf of Suez and off the Southern Red Sea coast during 1980-1981. Food and Agriculture Organization of the United Nations, FAO, Cairo.

Bailey, C. and F. Marahudin. 1987. The economics of marine fisheries: costs and earnings, p. 103-124. *In* C. Bailey, A. Dwiponggo and F. Marahudin (eds.) Indonesian marine capture fisheries. ICLARM Stud. Rev. 10, 196 p.

Bureau of Fisheries and Aquatic Resources (BFAR). 1980. Fisheries statistics of the Philippines. BFAR, Manila, Philippines.

Bureau of Fisheries and Aquatic Resources (BFAR). 1983. Fisheries statistics of the Philippines. BFAR, Manila, Philippines.

Bureau of Fisheries and Aquatic Resources (BFAR). 1985a. Selected fishery projects for the Biyayang Dagat Program. BFAR, Ministry of Agriculture, Manila, Philippines.

Bureau of Fisheries and Aquatic Resources (BFAR). 1985b. Fisheries statistics of the Philippines. BFAR, Manila, Philippines.

Bureau of Fisheries and Aquatic Resources (BFAR). 1987. Fisheries statistics of the Philippines. BFAR, Manila, Philippines.

Dixon, J.A., R.A. Carpenter, L.A. Fallon, P.B. Sherman, and S. Manopimoke. 1986. Economic analysis of the environmental impacts of development projects. Asian Development Bank Economic Staff Paper No. 31. ADB, Manila, Philippines.

Elliston, G.R. 1978. Problems in assessing the costs and earnings of mechanised fishing boats. Reg. Conf. Tech. for Rural Development, KL. 24-29 April 1978.

Fox, W.W. 1970. An exponential surplus-yield model for optimizing exploited fish populations. Trans. Am. Fish. Soc. 99: 80-88.

Herre, A.W. 1953. Checklist of Philippine fishes. Research Report 20, Fish and Wildlife Service, United States Department of the Interior, Washington, D.C., USA.

Ochavillo, D., H. Hernandez, S. Resma and G. Silvestre. 1989. Preliminary results of a study of the commercial trawl fisheries in Lingayen Gulf, p. 31-42. *In* G. Silvestre, E. Miclat and T.E. Chua (eds.) Towards sustainable development of the coastal resources of Lingayen Gulf, Philippines. ICLARM Conf. Proc. 17, 200 p.

Pauly, D., G. Silvestre and I.R. Smith. 1989. On development, fisheries and dynamite: a brief review of tropical fisheries management. Nat. Res. Model. 3(3): 307-329.

Philippine Fisheries Development Authority (PFDA). 1983. Philippine fisheries annual. PFDA, Quezon City, Philippines, 98 p.

Rau, N. and A. Rau. 1980. Commercial fishes of the Philippines. German Agency for Technical Cooperation (GTZ), Eschborn, Federal Republic of Germany.

Selvadurai, S. and A.L.K. Kong. 1977. Marine fish trawling in Peninsular Malaysia: a case study of costs and earnings. Min. Fish. Bull. No. 19. Ministry of Agriculture, Kuala Lumpur, Malaysia.

Supanga, N. and I.R. Smith. 1979. Costs and returns of stationary gears, p. 45-60 *In* I.R. Smith and A.N. Mines (eds.) Small-scale fisheries of San Miguel Bay, Philippines: economics of production and marketing. ICLARM Tech. Rep. 8, 143 p.

Tulay, E. and I.R. Smith. 1979. Costs and earning of mini-trawlers, p. 64-77 *In* I.R. Smith and A.N. Mines (eds.) Small-scale fisheries of San Miguel Bay, Philippines: economics of production and marketing. ICLARM Tech. Rep. 8, 143 p.

Contributions to Fishbyte

Contributions to Fishbyte in the form of short papers, notes, letters to the editor and news items are constantly needed. Six pages of Fishbyte, including figures and references, is an absolute maximum for papers and shorter notes are preferred. Topics on which we focus are methods for fish stock assessment, parameter estimation and data acquisition and systems for the management of fishery resources, including economic, social, political and practical aspects. Contributions should preferably in English but short contributions in Spanish or French will also be accepted. Figures do not need to be camera-ready, i.e., will be redrafted at ICLARM if necessary.

Address all contributions to

The Editor, Fishbyte
ICLARM
M.C. P.O. Box 1501
Makati, Metro Manila
Philippines