4.4 Standard Linear Models

Six different equations were tested using a standard log-log, static linear model (see Theil 1978, Johnston 1984). Initially the entire data set (January 1987 to August 1989) was used to estimate various coefficients. On a second run a restricted data set (January 1987 to October 1988) was used in order to isolated any price-quantity relationships before the price crash during 1989. The results are presented in Table 10.

As discussed in section 1, demand studies for fisheries products have created a debate among economists with respect to the degree to which price or quantity is considered exogenous (Burton 1992). Conventional empirical demand systems normally take prices to be exogenous and use price, together with income and substitute effects, to determine the quantities demanded. Implicit in this approach, described as "quantity-dependent", is the assumption that supply is perfectly elastic in the region of the prices being considered and that the price a supplier is willing to accept for a given quantity is determined outside the market by cost factors such as production and transport. An alternative approach, termed "price-dependent", arises when supply is inelastic and the quantity demanded is constrained. At the individual consumer or supplier level the "quantity-dependent" approach is applied, provided the individual consumers and suppliers are price takers. However, at the market level, if supply is inelastic, prices will alter until the quantity demanded is equal to the quantity supplied. This leads to quantity being considered as exogenous.

The two approaches outlined above are the two extremes of a continuum in which the degree to which either price or quantity is exogenous varies. Burton (1992) has shown that demand for wet fish in Great Britain is modelled more convincingly using the "price-dependent" approach. Given that virtually all of the wet fish supplied to the U.K. market is from capture fisheries with catch quotas and that there is little leeway for storage of the given product form it is perhaps unsurprising that quantity is exogenous at a market level. However, the structure of the world shrimp market is quite different, with aquaculture production and cold storage facilities introducing considerable flexibility to the supply.

The two extremes were therefore tested by using "quantity dependent" specifications in the first three equations and "price-dependent" specifications in the second three equations.

The elasticity estimates from the "price-dependent" equations were inconsistent with both the qualitative data analysis undertaken in the previous section and with earlier studies. The estimated demand elasticities were all very small, and in many cases the income elasticity was negative, suggesting shrimp to be an inferior good. These results were considered unreliable, and the "price dependent" models were therefore dropped from the analysis.

The two sets of "quantity-dependent" specifications gave generally similar results, but those using the restricted data set (Table 10, equations 10, 11 & 12) were considered to be more reliable because of the much better fits obtained. These are discussed further.

The price elasticities all have plausible signs, except for the own-price estimate for small shrimp (0.97) in Equation 12. Large shrimp are found to be highly elastic with respect to own price (-2.18) and medium shrimp relatively inelastic (-0.73) with respect to own price. Cross-price elasticities indicate that small shrimp are complements to both large and medium size categories with respect to the price of large and medium sized shrimp (Equations 11 and 12), but substitutes with respect to the price of small shrimp (equations 10 and 11). Medium sized shrimp are indicated as substitutes for large shrimp with respect to both medium and large shrimp prices (equations 10 and 11).

While in most cases the estimates of elasticities are consistent with the qualitative demand analysis in section 4.3.1, the inconsistent own-price estimate for small shrimp together with the conflicting cross-price elasticity estimates between small shrimp and other sizes, made it unrealistic to use these estimated elasticities to predict impacts on shrimp fisheries. Rather, we examine the results of an alternative method of analysis in the next section.

Table 10 Summary of Results From the Standard Linear Models

EQUATION	DEPENDENT VARIABLE	CONSTANT	ln Y	ln PL	ln PM	ln PS	ln QL	lnQM	lnQS	Q1	R2	ADJ R2
USING FULL DATA SET (1987.1 - 1989.4)												
4	QL	10.2	n/s	-1.03	-0.51	1.5				-0.21	0.49	0.42
se		2.13		0.77	0.71	0.46				0.08		
5	QM	9.48	n/s	-0.13	-0.42	0.61				-0.24	0.36	0.27
se		2.19		0.6	0.73	0.47				0.08		
6	QS	10.3	n/s	-0.06	-1.04	0.74				-0.19	0.42	0.33
se		2.04		0.74	0.68	0.44				0.08		
7	PL	7.28	-0.53				-0.11	0.1	0	n/a	0.49	0.41
se		0.97	0.11				0.05	0.06	0.07			
8	PM	5.42	-0.26				-0.01	0.05	-0.17	n/a	0.29	0.18
se		1.38	0.16				0.08	0.08	0.1			
9	PS	3.71	-0.33				0.25	-0.04	-0.12	n/a	0.33	0.23
se		1.68	0.2				0.09	0.1	0.2			
USING ADJUSTED DATA SET (1987:1 - 1988.6)												
10	QL	9.97	n/s	-2.18	-0.28	1.68				-0.23	0.74	0.67
se		10.51		1.01	0.59	0.39				0.08		
11	QM	-14.82	2.55	0.66	-0.73	1.54				n/a	0.55	0.43
se		10.45	1.18	1	0.6	0.45						
12	QS	12.85	n/s	-1.18	-0.68	0.97				-0.18	0.58	0.47
se		3.03		1.15	0.67	0.44				0.09		
13	PL	3.32	n/a				-0.08	0.07	-0.05	-0.04	0.32	0.14
se		0.48					0.06	0.07	0.08	0.02		
14	PM	3.64	n/a				0.04	0.02	-0.21	n/s	0.27	0.14
se		0.65					0.11	0.11	0.14			
15	PS	7.58	-0.93				0.24	0.18	-0.15	n/s	0.65	0.55
se		3.45	0.43				0.11	0.11	0.13			

4.5 Generalised Choice Model

This analysis is based on a generalised choice model originally developed by McFadden (1974), in his analysis of transportation alternatives, and adopted by Wang and Kellogg (1984) in their study of the lobster market in the USA. The model consists of an aggregate demand equation and a set of choice equations for the three size categories of shrimp.

As discussed in section 4.3, this study aims to determine the overall relationship between price and quantity of different size categories of shrimp, and determine the demand for imported shrimp in each of the different size categories. The standard log-log, static linear model used in the previous section does not have the flexibility to satisfy both these aims, but the generalised choice model, with distinct size choice components allows estimates to be made. In effect, the consumer behaviour modelled when considering imports is that of the US importers and wholesalers.

The generalized choice model was chosen specifically for this task because of its suitable conceptual structure. The general choice model assumes that a consumer (trader) decides on a level of shrimp consumption based on shrimp prices, prices of other goods and income. The consumer (trader) then chooses different amounts of different sizes so as to maximise his or her utility. This conceptual structure agrees well with the US shrimp market structure from a traders point of view as described in section 4.3. Obviously an individual consumer will not make choices in the manner described above when purchasing shrimp, but when consumers are aggregated and an average behaviour determined then the general choice model concept is appropriate. Underlying the assumption about the suitability of the general choice model is the assumption that the behaviour of traders is a good approximation to the average consumer behaviour. As discussed in section 4.3.2, the more skilful a trader is the truer this assumption will be.

The aggregate component of the general choice model specifies total quantity of imports into the USA as a function of disposable income, US shrimp prices, total quantity of domestic shrimp landings and seasonal factors:

$$\ln Q_{IMP} = A_0 + A_1 \ln Y + A_2 \ln P + A_3 \ln Q_{DOM} + A_4 D1$$

Where:

Q_{IMP} = total quantity of US shrimp imports, ie., $Q = \Sigma Q_i$ (imports),

Q_{DOM} = total quantity of US domestic shrimp landings, ie., $Q = \Sigma Q_i$ (domestic landings),

Y = disposable personal income,

P = weighted price of shrimp ie., $P = \Sigma P_i X_i$,

$D1$ = seasonal dummy, 1 for the closed season in the shrimp fishery and 0 for others,

Q_i = quantity demanded of size category i,

P_i = price of size category i

X_i = market share of size category i, ie., $X_i = Q_i/Q$,

A's = parameters to be estimated

NB size categories (i) are large = L; medium = M, small = S

The second part of the model consists of the shrimp size choice component. The market share ratio of two shrimp sizes is specified as a function of disposable income, the prices of the three shrimp sizes and seasonal variables:

$$\ln (X_S/X_L) = B_{(XS/XL)0} + B_{(XS/XL)1}\ln P_L + B_{(XS/XL)2}\ln P_M + B_{(XS/XL)3}\ln P_S + C_{(XS/XL)4}\ln Y + C_{(XS/XL)5}D1$$

$$\ln (X_M/X_L) = B_{(XM/XL)0} + B_{(XM/XL)1}\ln P_L + B_{(XM/XL)2}\ln P_M + B_{(XM/XL)3}\ln P_S + C_{(XM/XL)4}\ln Y + C_{(XM/XL)5}D_1$$

Where: $\Sigma X_i = 1$, and B and C are parameters to be estimated

The various elasticities are derived easily (Wang and Kellogg 1984, quoting Chern and Just 1980,1984) using the symmetry of the model.

Elasticity of the market share of the various size categories (i) with respect to the price of a particular size category j (E_{Xij}) can be derived as follows:

$$E_{XSj} = (B_{(XS/XL)}{}^*{}_j * X_L) + ((B_{(XS/XL)} - B_{(XM/XL)}) * X_M)$$

$$E_{XMj} = ((B_{(XM/XL)}{}^*{}_j - B_{(XS/XL)}{}^*{}_j) * X_S) + (B_{(XM/XL)}{}^*{}_j * X_L)$$

$$E_{XLj} = (-B_{(XS/XL)}{}^*{}_j * X_S) - (-B_{(XM/XL)}{}^*{}_j * X_M)$$

The aggregate elasticity of demand with respect to the price of a particular size category j (Ej) is derived as follows:

$$E_j = (A_2/P) * ((\Sigma P_i * X_i * E_{Xij}) + (X_j * P_j)$$

Where. A_2 = the coefficient of P in the aggregate demand equation (Equation 1), and
P = the mean price of aggregate and individual size categories respectively

The demand elasticities of size category i with respect to the price of own and other size categories (j) are the conventional own and cross-price elasticities, and are derived as follows:

$$U_{ij} = E_j + E_{Xij}$$

The results of the model are given in Table 11a. In the aggregate demand equation (1) the income variable was not significant and dropped from the final equation The price variable (PALL) has the expected sign but is not significant (se = 0.83) The domestic supply variable (TQDOM) is significant (p = 0.06) but has an unexpected sign The overall performance of the equation is indicates an adjusted R^2 of 0 48 The independent variables in the small/large (2) and the medium/large (3) choice equations displayed the expected signs and were all significant except for the medium price variables. The adjusted R^2 is 0.19 for the small/large choice equation (2) and 0 27 for the medium/large equation (3).

The results of the model indicate that aggregate demand for shrimp in the US market is price inelastic (-0.77). This finding is consistent with previous studies for shrimp in the US market (Bell 1976, Rackowe 1983, and Yang 1992) which are discussed in section 3. The income variable was dropped from the equation, however earlier estimates suggest that the income elasticity of demand for shrimp, in the US market, is unitary (0.99, Yang 1992) or elastic (Bell 1976, Rackowe 1983 and Houston 1989).

Table 11a Regression Results From the Generalised Choice Model

EQUATION	DEPENDENT VARIABLE	CONSTANT	ln Y	ln PALL	ln PL	ln PM	ln PS	ln DOMESTIC	D1	R2	ADJ R2
1	ln QIMP	10.5	n/s	-0.77				0.16	-0.54	0.53	0.48
p		0		0.36				0.02	0		
se		1.46		0.83				0.06	0.11		
2	ln S/L	-0.09	n/s		1.02	-0.53	-0 72		-0.04	0.3	0.19
p		0.77			0.04	0.18	0 2		0.31		
se		0.29			0.47	0 39	0.28		0.04		
3	ln M/L	-9.5	1.05		1.72	0.01	-0.74		-0.12	0.39	0.27
p		0.07	0.08		0.03	0.99	0.05		0.03		
se		5.03	0.57		0.74	0.49	0.36		0.06		

Using mean values of the sample, the aggregate demand elasticity was estimated from the choice equations (2) and (3), the results of which are presented in Table 11b The results suggest that a given percentage change in the price of any particular size will give rise to a smaller change in quantity demanded than the same percentage change in overall price. This is as expected, and consistent with the theory that aggregate demand elasticity, with respect to changes in the price of an individual size category, is less elastic than with respect to changes in overall price. Since the prices of individual size categories are a component of overall price, the summation of the price elasticities for the three size categories (-0.04 + -0 53 + -0.13 = -0 70) is equal to the price elasticity with respect to overall price The aggregate demand elasticity derived in this manner is inelastic at -0.70.

Table 11b Aggregate Demand Elasticity with Respect to Price of Different Size Categories.

PRICE (SMALL)	PRICE (MEDIUM)	PRICE (LARGE)	PRICE (WTD)
-0.04 (0.20)	-0 53 (0 62)	-0.13 (0.21)	-0.70

Table 11c presents the own and cross-price elasticities derived from the generalised choice model. Own price elasticities for all the size categories of shrimp have the correct signs Estimates for small, medium and large shrimp are -0 22, -0.34 and -1.15 respectively. This implies that demand for both small and medium sized shrimp are inelastic with respect to own price, whereas demand for large shrimp is elastic with respect to own price. By way of example, the estimates indicate that a 1 percent increase in the price of small shrimp will lead to a 0.22 percent drop in demand for small shrimp Alternatively, a 1 percent increase in the price of large shrimp will lead to a more than proportionate drop of 1 15 percent in the demand for large shrimp

Table 11c : Own-price and Cross-price Elasticities

QUANTITY	PRICE (SMALL)	PRICE (MEDIUM)	PRICE (LARGE)
SIZE (SMALL)	-0.22 (0 27)	-0 38 (0.34)	-0.04 (0 35)
SIZE (MEDIUM)	-0.73 (0.65)	-0.34 (0.69)	0.16 (0.71)
SIZE (LARGE)	0.41 (0 25)	0.06 (0.30)	-1.15 (0.31)

The estimates presented in Table 11c indicate that small and medium sized shrimp are complements. The cross-price elasticity of demand for small shrimp with respect to the price of medium sized shrimp is -0.38, the implication being that a 1 percent increase in the price of medium sized shrimp would lead to a 0.38 percent decrease in the demand for small shrimp. Large and medium sized shrimp are identified as substitutes. For example, a 1 percent increase in the price of medium sized shrimp would lead to a 0.06 percent increase in the demand for large shrimp.

The cross-price estimates between small and large sizes, with respect to price, are somewhat contradictory. With respect to a 1 percent increase in the price of small shrimp there would be a 0.41 percent increase in demand for large shrimp, suggesting that small and large shrimp are substitutes. However with respect to a 1 percent increase in the price of large shrimp, the results imply a 0.04 percent decrease in demand for small shrimp. The -0.04 percent change implies that large shrimp have a negligible effect on the demand for small of shrimp and vice versa.

Presented in Table 11d are the market share elasticities. These elasticities represent a measure of the response of the market shares of the three size categories of shrimp given a 1 percent change in the price of an individual size category. For example, an increase in the price of medium sized shrimp would induce a 0.34 percent decrease in the market share of small shrimp and a 0 19 percent increase in the market share of large shrimp

Table 11d Elasticity of Market Share

MARKET SHARE	PRICE (SMALL)	PRICE (MEDIUM)	PRICE (LARGE)
SIZE (SMALL)	-0 18 (0.23)	-0.34 (0.31)	-0.00 (0.41)
SIZE (MEDIUM)	-0.2 (0.25)	0.2 (0.33)	0 7 (0.49)
SIZE (LARGE)	0 54 (0.17)	0.19 (0.23)	-1 02 (0.33)

4.6 Demand Elasticity Estimates from Disaggregated Models

In the preceding two sections, three models were used in an attempt to estimate elasticities. These were the standard log-log static linear model, in "quantity dependent" and "price dependent" mode, and the generalised choice model.

As already noted in section 4.4, neither of the sets of results from the standard log-log static linear model agreed well with the qualitative analysis presented in section 4.3, although the results of the "quantity dependent" (or price exogenous) specification appeared much more plausible than those of the "price dependent" specification.

For the generalised choice model presented in section 4.5, the estimated elasticities appear substantially more plausible, most of the own and cross price elasticities have both the sign and approximate magnitude magnitude expected from the qualitative analysis. The own-price elasticity of demand for the individual size categories is estimated to be inelastic for small and medium shrimp at -0.22 and -0.34 respectively, and elastic at -1.15 for large shrimp. Also, medium and large shrimp are indicated to be substitutes.

However, there do remain several inconsistencies. The cross-price elasticities between medium and small shrimp suggest that they are complements. However, the qualitative analysis presented in section 4.3 gives no indication that this should be the case. If anything, it suggests that it is more likely that medium and small shrimp are weak substitutes. The two cross-price elasticity estimates between small and large shrimp are contradictory, with one estimate estimate suggesting these two categories are strong substitutes, while the other suggests there is very little interaction between them. The latter estimate is much more plausible.

It should be noted, however, that any interpretation of these estimates must bear in mind their low precision. All the estimated parameters, other than the own-price elasticity for large shrimp, have large standard errors.

There are several possible reasons for the low precision obtained. Particular problems are the assumptions required to extrapolate the size distribution of the NMFS imports sample to all US imports, the assumptions required to determine an average price for each size category given the complete lack of data on which countries of origin are supplying which species of shrimp within each size category, and the exclusion from the analysis, due to lack of data, of other factors identified as potentially relevant (see sections 4.2 and 4.3). In particular, the role that trader preference for certain countries of origin plays is poorly understood.

In conclusion, while most of the actual estimates of elasticities of demand obtained are plausible, in view of their low precision and restricted applicability, it would appear unrealistic to use them in further quantitative analysis of the possible effects of changes in the world supply of medium-sized shrimp. The real elasticities of interest for such an analysis measure the effect on price of changes in supply, rather than the effect on quantity demanded of changes in price, as have been estimated here. In principle, the one set of elasticities can be derived from the other, but the nature of the transformation between the two is such that it requires rather precise estimates of elasticities of demand.

Implications of Increased Aquaculture Production for Shrimp Fisheries

As part of the overall project the price-quantity relationships identified in the disaggregated analysis were to be used as a direct input into the bio-economic model. Within the model, the dynamics of the fishery would be driven by the variations in price of the different size categories of shrimp, resulting from projected increases in shrimp production from aquaculture. In other words the dynamics of the fishery could be observed under different scenarios depending on the output of medium sized shrimp from aquaculture The price of large, medium and small size categories of shrimp will vary according to the own and cross-price elasticity estimates that were to be determined above. In conjunction with a biological sub-model and specific fleet operations, this information was then to have been used to identify any changes in the profitability of different capture fishery operations resulting from increased aquaculture production

As discussed in section 4 6, the severe data limitations prevented elasticities being determined with enough certainty to warrant their use in quantifying the impacts of the predicted increased aquaculture production on shrimp production from both aquaculture and capture fisheries.

However, the information collected in sections 2, 3 and 4 make possible a qualitative assessment of the likely impacts on shrimp capture fisheries and aquaculture due to the predicted increase in aquaculture production

Section 5.1 reviews published predictions of increases in aquaculture production. Based on these predictions a qualitative discussion of possible price movements is presented.

This qualitative approach is also used to describe possible impacts on shrimp production methods, revenue and employment (sections 5 4, 5.5 and 5.6 respectively) in light of the production costs of both capture fisheries and aquaculture described in section 5 3.

5.1 Future Production Scenarios

Future production will depend on interactions between demand and supply factors. As shown in section 4, the demand curve for shrimp will depend upon the prices of related goods (both complements and substitutes), consumer incomes and preferences. The supply factors behind the supply curve include available technology and methods, input costs, shrimp stocks and government regulation. For a given set of supply factors, the supply curve shows the quantities of shrimp producers would be willing or able to supply at each conceivable price. Similarly, the demand curve shows the quantities consumers wish to purchase at each conceivable price for a given set of demand factors. An equilibrium is obtained when the quantity demanded is equal to the quantity supplied for a given price. At any particular point in time, the market may not be in equilibrium, but market forces act towards equilibrium quantity and price. The time required for the market to return to an equilibrium is crucial in deciding whether the market analysis treats the market as in equilibrium or non-equilibrium.

The future production estimates by Yang (1992) and Infofish (1991) given below treat the market as in equilibrium and use various sets of supply and demand factors within simple econometric models to forecast future production The qualitative approach used by Csavas (1988) to predict production by Asia is quite different.

Csavas (1988) makes a rough and ready estimate based on the historical aquaculture production trend of Taiwan, taking into account the various species, area available for development, technology constraints and the particular stage of the industry in other Asian countries in terms of their position in the production cycle. Csavas (1988) argues that historical productions trends should be considered in the context of the typical product life cycle[13]. Having identified shrimp culture in Asia as having reached the second phase, characterised by exponential growth, between 1983 and 1985, Csavas (1988) predicted the onset of the third phase which is characterised by falling prices and decelerating growth. Given these qualitative considerations, Csavas (1988) estimated that total production from aquaculture in Asia will reach 800,000 metric tonnes by the year 2000, based on a 9.2 percent average annual growth rate from 1985. If Asia's 80% market share of aquaculture production is maintained, this would place a total of approximately 1,000,000 metric tonnes cultured shrimp on the world market by AD 2000.

Infofish (1991) predicted that demand for shrimp would increase at a maximum annual rate of 2.5% between 1989 and AD 2000 based on World Bank published projections for human population and per capita income growth rates and assumed a future income elasticity equal to unity. This estimate places a maximum of 2,917,800 metric tonnes of shrimp on the world market by the year AD 2000. Given that Infofish (1991) also state that the quantity of shrimp landed by fisheries is unlikely to exceed significantly the current world total of between 1,400,000 and 1,700,000 metric tonnes, production from aquaculture will be approximately 1,200,000 metric tonnes in AD 2000.

Both Csavas (1988) and Infofish (1991) acknowledge the current and possible future constraints on shrimp aquaculture production (discussed in section 2.2.2.2) when predicting future production levels. Yang (1992), however, makes little mention of these factors when modelling total shrimp supply and demand.

Yang (1992) considered marine catches and aquaculture production separately. The model considered shrimp supply from capture fisheries to be a function of the production in the previous year, costs of production, real shrimp prices in the current and previous year, real interest rates and a time trend to account for factors such as technological change and pollution. Shrimp supply from aquaculture production was defined as a function of production and price in the previous year and costs of production. The function describing quantity demanded used per capita consumption, per capita consumption income, the current real price of shrimp and the current real price of a shrimp substitute (other fish in the U.S. and beef in Japan). Several of these variables were dropped from the model before predictions were made, largely due to insignificant coefficients. However, production cost for the capture fishery (primarily fuel cost) was dropped as the coefficient, although significant, had an unexpected sign. The time trend variable was also dropped with no explanation. Supply and demand projections were based on World Bank forecasts for exogenous variables such as interest rate, population size and per capita income, whereas trend values were used for the other independent variables. The World Bank forecast for the rates of growth of GNP in Japan, the U.S. and the rest of the world that Yang used can now be seen as overly optimistic. Projections from the model indicated a 13.6 percent annual growth rate for cultured shrimp production and a 2.6 percent annual increase in shrimp landings. Applied to Penaeid species, these projections place a total of 2,975,867[14] metric tonnes of tropical shrimp species on the world markets by AD 2000, with aquaculture production accounting for 73 percent of the total at 2,174,290 metric tonnes. Applied to the heads-on figures for 1988 quoted by Infofish (1991) a total of approximately 5,227,000 metric tonnes would produced and consumed, with aquaculture accounting for 55% (2,874,000 metric tonnes).

Given the inconsistencies in the method used by Yang (1992), and the relatively similar predictions obtained by Csavas (1988) and Infofish (1991) using quite different methods, it appears legitimate to state that aquaculture production is likely to produce between 1,000,000 and 1,200,000 metric

13 In general there are four basic phases in the a product life-cycle or growth curve of a commodity; development, growth, maturity and decline (Douglas 1987, Koutsoiannis 1982).

14 Based on initial quantities of 604,400 metric tonnes (1989) and 690 100 metric tonnes (1991) for marine landings and aquaculture production respectively (See Table 7)

tonnes of shrimp by the year AD 2000. This translates as an average annual rate of increase of approximately 4 5% to 6% between 1988 and AD 2000 and results in approximately 930,000 to 1,100,000 metric tonnes of Penaeid species being produced and consumed on the world market by AD 2000

As shown by the review of the tropical shrimp fisheries (Chapter 3.1.1.), it seems unlikely that significant increases in production will emanate from marine landings. This is confirmed by the Infofish (1991) statement that wild resources are almost fully exploited and no new grounds are available. Taken in conjunction with predicted aquaculture production trends, the best estimates for the total world shrimp market place between 2,700,000 and 3,000,000 metric tonnes of shrimp on the world market, with tropical aquaculture production making up approximately 40% and Penaeid species accounting for nearly all of that share.

There is a relatively greater degree of uncertainty over the likely upper limit of aquaculture production in AD 2000 compared to capture fisheries, due to the manufacturing nature of shrimp farming Future levels of farmed shrimp production and investment in the aquaculture industry could increase dramatically if there were a breakthrough in farming methods which significantly lowered production costs or risk. These development activities are expected to include the continuation of ongoing research into other species suitable for aquaculture production, disease control, hatchery methods, reduction of post harvest losses and increased use of by catches Perhaps equally possible is the point that aquaculture levels will only maintain current levels, or even decrease, if, for instance, the prevalence of disease increases and environmental regulation limits the use of drugs due to water pollution concerns. Environmental regulation over concerns regarding the eutrophication caused by shrimp farms may also have a negative impact on future production levels. Many of these concerns over disease and environmental regulations will increase in importance as the shortage of suitable areas for aquaculture (as discussed in section 2.2 2 2) becomes more acute

Regardless of these uncertainties in the technological and environmental fields, the growth of aquaculture will slow considerably unless profit margins widen back towards the levels of the mid 1980's. Given the price trends described earlier, it is clear that profit margins can only be widened by decreasing production costs (infofish, 1991).

Table 13 presents three scenarios which are based on estimates for future production from aquaculture as discussed in Chapter 3.2. Total aquaculture production forecasts are made for AD 2000 with annual and total percentage increases indicated.

Table 13 Aquaculture Production Scenarios

	TOTAL PRODUCTION (AD 2000)	ANNUAL INCREASE	TOTAL INCREASE
SCENARIO 1	800,000 MT	1.65 %	16 %
SCENARIO 2	1,000,000 MT	4.5 %	45 %
SCENARIO 3	2,174,290 MT	13.6 %	215 %

5 2 Price Implications for the Individual Size Categories of Shrimp

As discussed in section 5 1, the most plausible future production scenarios place approximately 1,000,000 MT of aquaculture produced shrimp on the international market by 2000AD, representing a 45% increase from the 1992 level of approximately 700,000 MT.

It is interesting to note that between January 1984 and December 1992, while aquaculture production increased over three fold worldwide, the price of Ecuadorian whites in the 31-35/lb size category showed no clear trend, starting and finishing at US$11/kg. This is supported by figures for quantity and value of exports from Ecuador from 1980 to 1988 which show that Ecuadorian shrimp exports increased in volume from 9,500 MT to 51,400 MT (primarily due to increased aquaculture production) while the value of these exports increased from US$ 66.5 million to US$ 348.3 million, increases of 440% and 424% respectively (all figures from Infofish International).

Similarly, the price of US Gulf shrimp (primarily from capture fisheries) in the 31-35/lb size category also showed no trend, varying around US$9/kg.

It is clear from the figures quoted above that, averaged over the period 1980 to 1992, the supply curve for size 31-35/lb shrimp in the US market is essentially flat, with very different quantities being supplied at the same price. Unfortunately, little information can be extracted regarding the demand curve, except to say that demand must have increased during the period and that the higher the own-price elasticity, the smaller the increase in demand required to hold prices level. A small increase in demand could easily be explained by the increase in US population and per capita income over the period 1980 to 1992.

The European market has behaved in a similar fashion to the US market over the same time period, with India brown shrimp in the 41-50/lb size varying around US$6/kg with no discernable trend.

The price of Indian white shrimp in the 21-25/lb size has varied around US$24/kg in the Japanese market from 1984 to 1992. However, the picture for price of shrimp in US$'s in the US, European and Japanese markets described above differs markedly from that for the Yen in the Japanese market over the same period. The price of Indonesian white shrimp in the 26-30/lb size dropped linearly from levels around 3000 Yen/kg in 1984 to 1500 Yen/kg in 1988. Since 1988, the price has remained around the 1500 Yen/kg mark. Yen prices for Phillipine black tiger in the 25-30/kg size have changed in a similar fashion. It is not clear whether this different pattern for Yen prices is due to exchange rate movements or reflects a drop in prices due to increased supply.

Regarding the US market, it is clear that the demand curve has shifted to a certain extent, reflecting a change in consumer behaviour and increased per capita consumption. The importance placed on brand recognition and marketing by US shrimp traders discussed in section 2 reflects the realisation that US market prices will only be maintained if consumer behaviour can be modified and per capita consumption increased. The description of the US and European long run trends shows that it is not possible, with present data, to predict where per capita consumption will plateau in either market. It is not clear whether per capita consumption in the US and European markets will ever approach the levels currently observed in the Japanese market. At present there are few indications of the extent to which US consumer behaviour can be further modified and therefore there is uncertainty over how much more medium shrimp can be absorbed by the US market before a decline in the price of medium shrimp occurs.

It is possible that the emergence of markets for shrimp in other countries, including the primary countries of origin, will absorb the extra production and US market prices will remain relatively level.

Summarising the above points, the available long run data suggests that between 1980 and 1992, the increased world wide supply of aquaculture shrimp has had little impact on the levels of prices in the US.

The description of the US market and qualitative demand analysis based on the NMFS data suggested that, due to the large differences in price paid for the large and medium size categories and the different market segments they occupy, it is likely that the effect of a change in quantity supplied in one category will have only a small effect on the price of the other category, or no effect at all over the magnitude of the changes observed in the NMFS data. The medium and small size categories may interact more strongly due to the more similar market segments they occupy. The NMFS data suggests it is highly unlikely that there will be any large interaction between the large and small size categories

5.3 Cost of Production

This section calculates estimates of the different ranges of production costs associated with the different methods of production in both the capture and culture sectors The values indicated show the relative costs of production which are used to give an indication of the likely changes in production methods resulting from the possible price changes which are discussed in Chapter 4.6.

5.3 1 Capture Fishery

The cost of operations in the capture fishery depends on various factors pertaining to the type of vessel and level of fishing operation involved. The cost estimates presented in Table 6 are calculated from a number of case studies from different fisheries in an attempt to illustrate the differences between types of operation and location of the fishery. Three categories are considered: artisanal, semi-industrial and industrial.

Table 14 : Cost of Production for Different Types of Fishing Operations.

CATEGORY	DESCRIPTION	TOTAL COST	LANDINGS (KG)	PRODUCTION COST ($/KG)
ARTISANAL:				
MADAGASCAR (FAO 1989)	VALAKIRA STATIC TRAP			$0.31/KG
SEMI-INDUSTRIAL				
KUWAIT (EL MUSA 1987)	WOODEN DHOW, STERN TRAWL WITH INBOARD ENGINE.	$33,000	11,950	$2 76/KG
INDUSTRIAL.				
KUWAIT (EL-MUSA 1987)	STEEL HULL, LARGE INBOARD ENGINES.	$163,000	27,900	$5.84/KG
TANZANIA (FAO 1990)	17-38 m STEEL HULL, 290-922 Hp ENGINES, DOUBLE RIGGED.	$22,125	4,505	$4.91/Kg
MEXICO (ANON 1990)	DOUBLE-RIGGED TRAWL, 300 Hp INBOARD ENGINES.	$112,500	13,500	$8.33/KG

Source : El Musa (1987), FAO (1989); FAO (1990); Anon. (1990).

The total costs recorded in Table 15 represent both fixed and variable costs associated with the vessel operations over a 12 month period. Landings represent the total weight of shrimp (head on) caught during the same 12 month period.

It must be noted that accurate cost and earnings data is notoriously difficult to obtain and therefore the nominal values presented should be regarded as representative rather than definitive. Nevertheless the values do indicate clear production cost differentials between the different categories, with the industrial vessel operations supporting the highest production cost per kilogram of shrimp.

5.3.2 Aquaculture

The cost of production depends upon the type of operation. Generally speaking they are characterised as extensive, semi-intensive and intensive. As production systems become more intensive the stocking densities increase, production area is reduced, technology becomes more sophisticated and capital costs are raised. The desired outcome from this type of farm intensification is a higher production per unit area.

Extensive farms need little management and shrimp may be stocked with other herbivorous fish. Low levels of technology are used and shrimp are usually harvested with cast-nets or bamboo traps.

Pond size:	Up to 100 hectares.
Water exchange:	5 - 10 % per day, provided by tidal flows.
Stocking density:	@ 25,000 juveniles per hectare.
Construction costs:	Low. Use low lying impoundments.
Operating costs:	Low. Organic or commercial fertilizers may be used to encourage natural productivity in ponds.
Production:	50 - 500 kg per hectare per year.
Production cost:	$1.00 - $3.00 per kg (live weight).

Semi-intensive farms introduce a nursery phase where wild or hatchery produced juveniles are stocked at high densities in nursery ponds until they reach a size where they can be stocked at lower densities in growout ponds. The level of technology is fairly sophisticated and good pond management is necessary. The shrimp are harvested by draining the pond through a net.

Pond size:	Between 5 - 25 hectares.
Water exchange:	10 - 20 % per day, aided by mechanical pumps.
Stocking density:	Between 25,000 - 200,000 juveniles per hectare.
Construction costs:	Between $15,000 - $20,000 per hectare
Operating costs:	High. Shrimp feeds are used to augment natural food in ponds, fuel and maintenance is needed for the pumping operations, and ponds have to be renovated between crops.
Production:	500 - 5,000 kg per hectare per year.
Production cost:	$3.00 - $5.00 per kg (live weight).

Intensive farming requires a high level of management and constant monitoring of the ponds. The level of technology is high and sophisticated harvesting techniques are used.

Pond size:	Between 0.1 - 5 hectares.
Water exchange:	30 % or more per day, aided by mechanical pumps.
Stocking density:	More than 200,000 juveniles per hectare.
Construction costs:	Between $25,000 - $100,000 per hectare.
Operating costs:	Very high. Heavy feeding is necessary together with waste removal and aeration of ponds. Fuel and maintenance is needed for the pumping operations, and ponds have to be cleaned between harvests.
Production:	5,000 - 10,000 kg per hectare per year
Production cost:	$5.00 - $7.00 per kg (live weight).

The data above indicates the relative production costs, giving ranges which may vary according to location. The data were compiled from various reports published in Asian Shrimp News and World Shrimp Farming (1990-1992).

Aquaculture production costs are highly sensitive to feed costs, which in the Philippines and Thailand account for 50% of total costs but up to 70% in China. The evolution of feed production technology, and the resulting price and quality, is an important factor in the profitability of aquaculture.

Depending on the level of production costs, the species grown, the growing season and market prices, the optimum size to which shrimp should be grown to in order to maximise economic returns can be calculated. Infofish (1991) state that using the best currently available techniques in each of the producing countries, peak economic performance is obtained by producing black tiger shrimp with a count of 21-25/lb in Asia and 31-40/lb in northern China. In Latin America, peak economic performance is obtained by growing white shrimp to a count between 26-30 and 41-50/lb. The optimum size is dependent on seed availability, which, when low, leads to the shrimp being kept in ponds for an increased time, allowing them to reach larger sizes, typically 21/25 counts/lb. It should be noted that the economically optimum size class determined for black tiger production in South Asia would be classed as large under the present classification. Asia currently supplies 65% of total world shrimp, with 45% of the world supply of cultured shrimp being black tiger. It seems possible therefore that in the near future aquaculture production will place both medium and large sized shrimp on the world market.

5.4 Implications for Methods of Shrimp Production

Assuming static production costs, any reduction in the sales price of medium sized shrimp will force aquaculture production methods to switch away from the intensive farming methods, with production costs between US$ 5.00 and $ 7.00, towards the semi-intensive methods with lower production costs.

For capture fisheries, the implications are not so evident, due to the fact that production costs can vary according to operations and location of fishery. Furthermore these producers often obtain revenues from different sizes of shrimp as well as other marine fish species. One possibility may be a move towards the specific targeting of larger size categories of shrimp via a change in fishing techniques (gears) or the implementation of regulatory management measures such as closed seasons or areas.

5.5 Revenue Implications for Shrimp Producing Sector

Given that the impact of increases in quantity supplied of one size category on the price of other size categories could not be quantified, it is only possible to make generalisations based on the qualitative assessment of the US market. The description of main markets in section 2 suggests that different factors are important in the price quantity relationship in different markets, with the Japanese market perhaps being the most different main market from the US market. Therefore, since revenue implications for the shrimp producing sector depend to a certain extent on aggregated world wide demand for the different size categories, any comments based on US market structure can only be applied hesitantly to any one country of origin. Furthermore, as identified for the case of Mexican and Ecuadorian imports to the US, the order in which source countries are preferred by importers to a given market, and how closely tied to that specific market a country of origin is, has serious implications for price and quantity movements. For instance, virtually all of South and Central American production enters the US and Canadian markets, regardless of the relative prices in other markets.

Based on the qualitative assessment of the US market structure, if the increasing supply of medium sized shrimp does cause the price of medium sized shrimp to decline, the following comments can be made A decrease in the price of medium shrimp will lead to a reduction in demand for small shrimp and thus lead to lower prices and quantity demanded for small shrimp Similarly, although the effect will be smaller, the price and quantity demanded of large shrimp will also decline. These changes will result in loss of revenue for the production of small and large shrimp, and, due to the inelastic nature of demand for medium shrimp and current supply levels, will also cause a loss of revenue in the medium size category. Thus any reduction in price caused by increasing aquaculture production will reduce total revenues for the shrimp producing sector

Another interesting possibility is that the supply structure may shift increasingly towards an oligopoly as revenues decline, either by design or by free market competition putting producers with higher costs of production out of business. The nature of the shrimp industry is such that individual shrimp fishermen or farmers face a perfectly elastic (horizontal) demand curve. As price takers their individual production cannot influence prices and increased revenues can only be obtained by increasing catches or farm output (and/or reducing costs). However, the demand curve exhibited by the market is usually downward sloping, where a reduction in quantity supplied implies a higher unit price (and vice versa). Thus, for price taking producers, although an individual producer may increase profits by increasing production, if all producers were to do so then revenues could increase or decrease, depending on the whether the price elasticity for that good is greater or less than one. This will not occur to the same extent if a producer is a dominant supplier to the market and has the ability to behave as a price maker A larger market share will increase any chance of successful price setting. Given the structure of shrimp producers, and market shares held by both capture and farmed shrimp producers, it seems unlikely that one individual producer (country) will have sufficient influence on the world price. Collectively however, producers in the Eastern hemisphere account for over 80 per cent of total culture production (China, Indonesia and Thailand account for 57 per cent) For a market where all suppliers are price takers, control of revenue is only possible if producers co-operate in controlling quantities supplied to the markets. Moves in this direction may occur if the rate of increase in apparent consumption slows and real prices fall

5.6 Implications for Employment Within the Sector

Falling market prices, together with stationary or rising production costs, imply that profit margins are likely to narrow The overall effect is likely to be a reduction in the employment opportunities within the sector. One hypothesis is that the marginal producers or operators will be the first to be affected by the economic constraints on the fishery. On the other hand, it may be the ubiquitous intermediary[16] who is the first affected by the falling prices as producers and retailers attempt to retain the dwindling profit margins. As described in section 2, this elimination of intermediaries has already started in the US market, leading to uncertainties over prices and less security of supply

The change in employment patterns may be used as an indicator, identifying other possible changes within the sector. The precise effects on employment, in terms of the magnitude of change and specific sectors that will be affected, will be dependent on the nature of the individual fisheries.

A reduction in fleet size and an increase in individual catches leading to a decrease in cost per unit of production may occur Alternatively, as profit margins decrease fishing effort may be increased, which hinders resource management This is already being seen in the U S

16 Marketing chains in developing countries are often relatively long, involving numerous intermediaries, although this depends very much on the location of production or the degree to which the producer operations are vertically integrated

CONCLUSIONS AND RECOMMENDATIONS

6.1 Overall Conclusions From the Study

The principal aim of this study of production and markets was to predict how increased aquaculture production would impact on the revenues of both the shrimp aquaculture and capture fishery sectors. This aim has been met at least quantitatively, however it has proved very difficult to obtain quantitative estimates of own- and cross-price elasticities between the various size categories. This is due to the fact that for all of the main markets for shrimp world wide, consumption data disaggregated by size seem only to be available on public record for a limited sample of imports to the US. A quantitative demand analysis of this sample data was carried out, and plausible price elasticities were obtained. However, the price elasticity estimates were of too low a precision to transform into elasticities describing the affect of changing supply levels on price.

The information collected on the US market that was used to determine model specification for the quantitative demand analysis did allow qualitative estimates of the impact on the shrimp production sector of predicted levels of increased aquaculture production. This qualitative analysis indicated that unless there is a shift in the rate of change of consumer behaviour in the US, increased aquaculture production will have limited affect on the revenues of shrimp producers. If there is a shift in the US, then an increased supply of medium sized shrimp will result in a drop in price for medium sized shrimp and an accompanying reduction in both quantity demanded and price of the large and small size categories. The result would be a reduction in revenues for both the aquaculture and capture fishery shrimp producing sectors. Reductions in revenues would result in a shift from intensive to semi-intensive aquaculture production.

6.2 Recommendations

Based on these conclusions, the main recommendation of this study is that the management strategies for tropical shrimp resources must explicitly take into account the international market forces which affect them.

There is a need for the identification and collection of key shrimp market data on an international level. Shrimp of all size categories are internationally traded commodities. The widely dispersed shrimp producers (referring to shrimp producing countries, and encompassing operators in both the capture and aquaculture sectors) are therefore exposed to major uncertainties from both the resource and the markets. As a result a producer will generally require data related to four major variables. On a national scale, information pertaining to the shrimp resource and the investment (labour and capital) associated with the resource exploitation or production[16] is required. On an international level, information concerning the different markets is required together with the position of competitors.

The initiation of an information service specifically dealing with key shrimp market information would generate a statistical database which could be used for the permanent and objective evaluation of the international shrimp market in terms of supply and demand analyses. This system would allow member states or individuals to compare their own activity with that of other producers, contributing to market transparency and allowing adjustments to be made in response

[16] With respect to shrimp aquaculture.

to changes in supply and demand. In terms of shrimp resource management, this system would allow for the clearer formulation of policy directed at the sector

With respect to the specific data requirements for disaggregated demand analyses, the following recommendations are drawn from the demand analyses documented in Chapter 4 and indicate the type and level of data disaggregation which would, together with existing data identified in Chapter 4.2, facilitate further work in this area.

1 A record of the total quantity of imports entering the different markets with explicit reference to the quantity of each size category (size composition), species and country of origin

2 A record of inventories held in each market, with explicit reference to the size composition, country of origin and species.

3 A record of domestic catches with explicit reference to size and species composition.

Apart from the requirement of robust own and cross-price elasticity estimates which would issue from a comprehensive demand analysis, the provision of realistic advice to resource managers and policy makers is also dependent upon the accuracy of biological and economic data from the fishery. The effectiveness of shrimp resource management or sectoral planning would be assisted by such a multi-disciplinary approach.

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Annex 1 FAO Map of the Major Fishing Areas