Department of Agricultural Economics & Agribusiness

TECHNOLOGY AND MANAGEMENT IN MAURITANIAN CEPHALOPOD FISHERIES

Hamady Diop and Richard F. Kazmierczak, Jr.

Department of Agricultural Economics and Agribusiness
Louisiana State University Agricultural Center
Baton Rouge, Louisiana 70803-5604
XP2945@lsuvm.sncc.lsu.edu

Staff Paper
95-05

Louisiana State University Agricultural Center, H. Rouse Caffey, Chancellor
Louisiana Agricultural Experiment Station, R. Larry Rogers, Vice Chancellor and Director

TECHNOLOGY AND MANAGEMENT IN MAURITANIAN CEPHALOPOD FISHERIES

Hamady Diop and Richard F. Kazmierczak, Jr.

Department of Agricultural Economics and Agribusiness
Louisiana State University Agricultural Center
Baton Rouge, Louisiana 70803-5604

XP2945@lsuvm.sncc.lsu.edu

Abstract

If the technology in a multi-species fishery is such that there is jointness in inputs and non-separability between inputs and outputs, then management on a species-by-species basis may lead to unintended outcomes, including over-exploitation of the resource. This study investigates the nature of the technical and economic relationships underlying the 1989-1990 Mauritanian cephalopod fishery by estimating a system of dual output supply functions derived from a generalized Leontief revenue function. Model results indicate the existence of jointness in inputs and non-separability between inputs and outputs in the fishery. Cross-price elasticities indicated a number of substitute and complementary relationships, with these relationships changing in magnitude across years. Taken together, the results suggest that any attempts to economically manage the resource should be based on multi-product production theory, not single-species biological response functions. Besides ruling out single-species management, the dominance of substitute relationships in the Mauritanian cephalopod fishery precludes the use of “key species” management of the entire resource.

Introduction

As a group, cephalopods consist of mollusc species having tentacles attached to their heads. While the Mauritanian (Saharan West Africa) cephalopod fishery also includes cuttlefish and squid, octopus typically represents 13% of all cephalopod and non-cephalopod fishery landings and 50 percent of total Mauritanian fishery revenues. Given that fisheries revenues can contribute as much as 40% of national income, 45% of the government budget, and 41% of the balance of foreign currencies (Sok *et al.*, 1989), the importance of the cephalopod fishery to Mauritania, and of octopus in particular, cannot be overestimated.

In attempting to coordinate use of this important national resource, Mauritania faces the challenge of developing efficient management plans in the face of information voids concerning biological stock size, maximum sustainable yields (MSY), and economic relationships among species (Chavance and Girardin, 1991). To date, efforts at estimating economic relationships for the cephalopod fishery and developing fishery management plans have included octopus as the only product, even though the same group of fisherman using similar gear harvests all three cephalopod species in the same waters. This single species research and management approach has been partially justified on the basis of differing species biology and behavior. However, failure to recognize the interrelationship among the different species that is implied by the harvesting process may lead to unintended, negative outcomes for fishery management policy (Kirkley and Strand, 1988; Thunberg, Bresnyan, and Adams, 1995).

Information about species interactions is critical as Mauritania begins experimenting with access and input restrictions in a fishery that has traditionally been relatively open and unregulated. For example, following debate concerning pricing power in the international cephalopod market, Mauritania created in 1984 the Mauritanian Enterprise for Fish Commercialization (SMCP). By acting as the sole buyer and marketer of fishery products, the SMCP hoped to reduce catch landings of Mauritanian resources in foreign harbors, increase the collection of foreign currency from fishery sales, and develop enhanced market opportunities for fishery products (Gilley and Maucorps, 1987). But, by setting up a schedule of fishing activity and export taxes that averaged nearly 10 percent, Mauritania may also have reduced revenues to the domestic fishing industry and indirectly reduced effort in the fishery. While this process has generated substantial government revenues, little formal information exists to support these kinds of management and marketing decisions by the SMCP and the Mauritanian government.

The goal of this study was to examine the technical economic structure of the Mauritanian cephalopod fishery and suggest ways in which Mauritanian fishery managers can design more appropriate direct and indirect fishery management policies. First, system background information and the general conceptual framework of the analysis are presented. Second, a plausible economic structure is proposed and examined. Third, supply relationships for the major outputs of the cephalopod fishery are jointly estimated. Restrictions consistent with a production technology exhibiting non-joint input use and output separability were tested econometrically. Fourth, the economic interactions between inputs and outputs in the Mauritanian cephalopod fishery were analyzed, with particular attention given to changing species relationships between 1989, an open season year, and 1990, a year in which a partially closed octopus season was used as a management tool. Compensated own- and cross-price elasticities are examined to further ascertain the technical and economic interactions embedded in the production technology. Lastly, the implications of the Mauritanian cephalopod fishery structure for government management of fishery resources are discussed.

The Mauritanian Cephalopod Fishery

The Mauritanian cephalopod fishery is composed of three majors species: octopus (*Octopus vulgaris*), cuttlefish (*Sepia officinalis*), and squid (*Loligo vulgaris*). Octopus is essentially non-migratory, with its Mauritanian fishing ground covering offshore regions where the water depth ranges from 10 to 200 meters (Girardin, 1988). Octopus have two major reproductive seasons, May to July and September to November, during which they tend to concentrate in the Mauritanian fishing grounds in ways that make them more susceptible to capture (Dia, 1988). In contrast, cuttlefish exhibit distinct migratory behavior in Mauritanian waters, moving from deep ocean to coastal areas (north to south) in response to changes in water temperature and/or reproductive maturity (Dia and Inejih, 1991). The dominant squid species found in Mauritanian landings tends to be captured in relatively near coastal waters, although it too is believed to be migratory. In addition to the three major species, cephalopod fishermen will also harvest and market various finfish species and damaged cephalopods (classified as mixed cephalopods for this study). Of course, mixed cephalopods are discounted heavily by the market.

Hatanaka (1979), the workshop of CNROP/FAO/ORSTOM/COPACE[1] (Josse and Garcia, 1986), Greboval (1986), Gilly and Maucorps (1987), Dia (1988), and Josse (1989) have examined various biological and economic aspects of the Mauritanian cephalopod fishery. Each study used a variation of the surplus yield model and essentially the same government data series. Most of the studies suggested that the cephalopod fishery was an over-exploited resource, with the level of exploitation being approximately twice MSY. Later studies raised doubts about this conclusion on methodological grounds and suggested employing an *ad hoc* correction factor that led to new calculated exploitation levels that were closer to the assumed MSY (CNROP 1990; 1991; 1993). Still, doubts about harvest effort, the real MSY, the economic relationships among species, and the quality of data constitute major limitations of previous Mauritanian fishery studies.

Since each species in the Mauritanian cephalopod fishery has a unique cycle of reproduction and growth, each can be thought of as having a unique biological response function. This perceived

[1]FAO is the Food and Agricultural Organization of the United Nations; ORSTOM is the French Research Center for Overseas Territories; COPACE is the Committee for East Central Atlantic Fisheries (CECAF) of the United Nations.

biological separability has led to single-species management schemes that are reinforced by a market structure that often places a large premium on octopus landings. But, given their simultaneous presence in the fishing grounds and in landings, octopus, cuttlefish, and squid may need to be viewed as joint resources that require coordinated management. This is especially true given that species-specific gear are generally not employed in Mauritania. If the technology is such that there is jointness in the inputs used to harvest octopus, cuttlefish, and squid, the management of the fishery on a species-by-species basis may lead to unexpected outcomes, including over-exploitation of the resource (Duarte,1992). This issue first arose in 1990 when Mauritania, responding to concerns about declining stock size, began closing its cephalopod fishery for one and a half months during the autumn octopus spawning period (October through mid-November). Thus, it is important that the cephalopod fishery be examined to determine the economic nature of input and output relationships. Only by correctly identifying and modeling the technology of the cephalopod fishery will Mauritanian fishery managers have confidence that their actions and policy prescriptions are in the country's short- and long-run interest.

Conceptual Framework

The commercial cephalopod fishery in Mauritania is dominated by trawler vessels that either refrigerate or freeze their catch before landing. Large vessels (above 35 meters in length) dominate the total catch and revenue generated by the fishery. In order to maintain control over the cephalopod landings and prevent trawlers from landing their catches in ports of adjacent countries, Mauritanian fisheries managers restrict the maximum trip length to 60 days, with trawlers typically staying in the fishing grounds for a maximum of 45-48 days (Dia, 1990). The combination of extended trip length and the fact that trips are planned based on perceived species abundance and market prices results in input mixes that can be viewed as fixed, sunk costs (Carlson, 1973). The relatively low variable input costs associated with cephalopod fishing, and thus the near zero marginal cost of additional fishing time, provides the theoretical basis for viewing the input mix for a trip as a single composite input. For this study, a vessel composite input was constructed (the product of days spent fishing during the year and vessel power in kilowatts) based on the assumption that the vessel, or capital stock, is relatively fixed and thus determines the level of variable input use.

If price taking characterizes the output markets, then economically rational fishermen will attempt to optimize the harvest species mix for each fishing trip. Thus, revenue maximization subject to a single composite input appears to be a reasonable portrayal of a fishing firm's short-run decision making process. McFadden (1978) and Diewert (1974) demonstrated that there is a dual relationship between the firm's production technology and revenue function, with revenue maximization being equivalent to profit maximization given firms operating under the conditions outlined above. Thus, the theory of duality may be applied to examine the firm's technical and economic relationships. This approach has been used in recent years to estimate the technological and supply relationships within a fishery (Thunberg, Bresnyan, and Adams, 1995; Campbell and Nicholl, 1995; Dupont, 1991; Squires and Kirkley, 1991; Kirkley and Strand, 1988).

Model Selection

Neoclassical production theory defines duality as the existence, under appropriate regularity conditions, of "dual functions" that embody the same information about technology as contained in the more familiar primal functions. The main advantage of dual over primal functions in conducting economic research on fisheries is that dual functions are generally dependent only on market prices. Market price data is usually easier to obtain and more reliable than data on specific levels of input use, especially in developing countries like Mauritania. In addition, dual functions may be preferred to primal approaches because primal input demands are normally more collinear than prices, thus causing relatively imprecise estimates of the primal system (Pope, 1982). However, dual functions can only be used to describe optimizing responses to input prices, output prices, and technological constraints that face decision makers.

Assuming price-taking behavior by fishing firms, a generalized Leontief dual revenue function, similar to that employed by Kirkley and Strand (1988), can be used to define the system of cephalopod supply equations:

$$R(Z,P) = \sum_i \sum_j \beta_{ij}(P_i P_j)^{1/2} Z + \sum_i \beta_i P_i Z^2 \tag{1}$$

where R(Z,P) is the revenue function, P_i is the output price of the ith species, and Z is a composite input that, within the context of this study, represents fishing effort. The generalized Leontief is a flexible functional form which has second-order Taylor series local approximation properties. The only *a priori* restriction imposed on firm technology by the generalized Leontief function is linear homogeneity in output prices, a condition required for theoretically proper revenue functions (Chambers, 1988). This functional form is one of the most useful for testing hypotheses concerning the structure of input use and outputs (Lopez, 1980; 1985). The empirical investigations of Dixon *et al*. (1987) suggests the use of a generalized Leontief functional form because it does not lead to the extreme variations in estimated input and output substitution elasticities seen with other functional forms like the translog. In addition, the choice of the generalized Leontief functional form hinged on the fact that it allows estimation in terms of output levels rather than shares (as is the case for the translog function). Analyzing the data in level form can be more useful in fisheries regulation because it provides information to managers in a form (levels) that they are accustomed to interpreting. Input-compensated output supplies were derived by first including a yearly dummy variable in equation (1) to capture the potential effects of stock availability changes and the partially closed season, and then applying Hotelling's Lemma:

$$\frac{\partial R(Z,P)}{\partial P_i} = Q_i(Z,P) = \beta_{ii}Z + \beta_i Z^2 + \sum_{j \neq i} \beta_{ij}(P_j / P_i)^{1/2} Z + \gamma_i DZ \qquad (2)$$

where D=1 for all monthly observations in 1990, and as a result is a slope shifter on the composite input *Z*. Note that the necessary symmetry conditions require that $\beta_{ij} = \beta_{ji}$, $i \neq j$.

The important underlying technology characteristics to be tested were input-output separability and non-jointness in inputs. If a technology is separable between outputs and fixed inputs, the dual revenue function is separable in output prices and the composite input. This can be examined by testing the restriction that all $\beta_i = 0$ in equation (2). Separability between inputs and outputs implies that the marginal rate of transformation for all output couplets are independent of all factor intensities, or that the entire fishery can be managed as a single stock rather than as individual species. Non-jointness in inputs over all species implies that producers maximize outputs and that the supply of each species is perfectly inelastic. Non-jointness in inputs can be examined by testing the restriction that $\beta_{ij} = 0 \; \forall \, i \neq j$ in equation (2). Separability and non-jointness have been major untested assumptions in economic fishery modeling in Mauritania, even though Hall (1973) has shown that a technology which is separable and non-joint is extremely restrictive and consists of production functions which differ only by a scalar multiple. In essence, this representation of technology implies only a single output.

Data and Estimation

Data used in estimation were part of an improved, comprehensive fisheries dataset developed through a pilot cross-agency project of the Mauritanian government that included the National Oceanographic Center of Mauritania (CNROP), the SMCP, and the Economic Cell for Counseling the Fishery Ministry and Marine Economists (CEAMP). In brief, the SMCP recorded the details of dockside landings and transferred the information on a monthly basis to the CNROP. The CNROP then combined this information with vessels statistics obtained from the CEAMP.

The data set consisted of 188 observations on 94 Mauritanian large trawlers operating in the years 1989 and 1990, the only two years for which comprehensive data were available. Although both small, individually owned trawlers and large, corporate trawlers operate in the Mauritanian cephalopod fishery, the focus of the analysis was placed on large trawlers. Because different size vessels generally have different operational strategies and priorities, it is important to distinguish between them in a statistical analyses. Large trawlers were used in this study because the data for these vessels was complete and they were responsible for nearly 90 percent of the total landings by weight and volume.

The monthly data included octopus, cuttlefish, squid, mixed cephalopod, and finfish dockside prices, the total landings for each species category by vessel, the number of days spent fishing for each vessel, and the power of the boat in kilowatts. Yearly fishing effort, or the composite fixed input in the model, was defined as the product of vessel power and the number of days spent fishing. Similar measures of a vessel composite input have been used by Kirkley and Strand (1988), Placenti *et al*. (1992), and Campbell and Nicholl (1995). Summaries of the data used in this study are given in table 1.

The data were examined for heteroscedasticity by applying the Harvey test to each supply relationship in equation (2). Prior expectation was that heteroscedasticity would be introduced through the square of the composite input variable (Squires and Kirkley, 1991). The null hypothesis of no heteroscedasticity was rejected ($\alpha \leq 0.05$) and the data subsequently transformed by weighting each observation by the inverse of the estimated standard deviation of the corresponding error term (Judge *et al.,* 1985). Condition indices, variance inflation factors, and correlation diagnostics suggested that multicollinearity was not a serious problem in the data set. In addition, when estimating a system of equations there is always the potential that the error vectors from different equations might be correlated. If detected using the Breusch-Pagan (1980) Lagrange multiplier (LM) statistic for testing the null hypothesis of a diagonal covariance matrix in sets of regression equations, this phenomenon can be accounted for in the system estimation by using Zellner's seemingly unrelated regression (SUR) method (Judge *et al*., 1985). The estimated system can be written as

$$y = Z\delta + \varepsilon \qquad (3)$$

where y is (Nx1) vector of observations on catch (N=188), Z is a (NxP) matrix of jointly exogenous variables in the system, δ is a (Px1) vector of unknown parameters, and ϵ is a (Nx1) vector of disturbances. All exogenous variables are in the Z matrix, and there are no jointly endogenous variables in the SUR system. The estimation employed a joint generalized least squares procedure to obtain residuals that were used to estimate the error covariance matrix. In turn, the error covariance matrix was used to obtain the SUR estimates, an approach that results in improved estimation efficiency.

Tests for symmetry, non-jointness in inputs, and separability between inputs and outputs were conducted using the chi-square distributed likelihood ratio procedures outlined in Judge *et al*. (1985, pp. 493-496). When theoretical conditions were not met, they were imposed and the system was re-estimated. Theoretically consistent estimates were then used to calculate the relevant elasticities. All estimations and statistical tests were conducted using SAS (Statistical Analysis System).

Conventional own- and cross-price elasticities of supply, elasticities of marginal revenue with respect to effort, and supply elasticities with respect to effort were calculated conditional on the observed mean values and using relationships derived from equations (1) and (2). Theory requires that own-price supply elasticities be positive, but cross-price supply elasticities can be positive or negative. A positive cross-price supply elasticity indicates that the outputs are complements such that management policy that restricts the harvest of one species will also restrict the harvest of the other. A negative cross-price supply elasticity indicates that the outputs are substitutes such that management policy that restricts harvest of one species will lead to increased exploitation of the other. In either case, single-species management actions will have little or no effect on other species if the magnitude of the elasticity approaches zero (inelastic). However, if the magnitudes indicate an elastic relationship, then harvest of the species are significantly interdependent and single-species management may be inappropriate.

Results and Discussion

Unrestricted ordinary least squares (OLS) estimates of supply in the cephalopod fishery (equation 2) yielded a test statistic that rejected the null hypothesis of a diagonal covariance matrix (Table 2), thereby suggesting that an SUR approach would be a more consistent estimator. Given an SUR framework, parameter estimates in the output supply system are theoretically consistent only when they are symmetric. A test for symmetry, $\beta_{ij} = \beta_{ji} \ \forall i \neq j$ in equation (2), rejected the null hypothesis, requiring that the system be re-estimated with symmetry conditions imposed. The test of overall restricted model significance with symmetry imposed strongly rejected the null hypothesis that all model coefficients were zero, indicating that the estimated model was significant in describing supply relationships in the cephalopod fishery (Table 2).

With symmetry conditions imposed, jointness in inputs and separability in outputs could be tested. Tests of the restricted system estimates rejected the null hypothesis of non-jointness in inputs, or $\beta_{ij} = 0 \ \forall i \neq j$ in equation (2) (Table 2). The restricted system estimates also led to rejecting the null hypothesis of separability ($\beta_i = 0$ in equation 2), indicating that separability does not exist between inputs and outputs. These results suggest significant technical interactions among species in the cephalopod fishery, joint production technology, and the inability to manage the fishery by focusing on a single species without causing effects on other species in the fishery. Additional tests of the cephalopod supply system were conducted to determine the significance of the year-based dummy variable. Tests rejected the null hypothesis of no year interactions, indicating that the relative influence of effort on supply changed between 1989 and 1990 (Table 2).

The estimated coefficients for the supply equations are reported in Table 3 along with standard errors in parentheses. Own-price coefficients are not directly estimated because demand is a function of prices normalized on own-price (equation 2). As expected given overall model significance, most of the supply equations had a number of statistically significant coefficients. Effort coefficients were statistically significant and positive in all supply equations. Squared effort coefficients were all negative and statistically significant for octopus, cuttlefish, and mixed cephalopod product supplies, indicating that the input had a declining marginal productivity. However, the magnitude of the squared effort coefficients indicated that potential changes in marginal productivity would be extremely small. The yearly effort dummy variable was significant in the finfish, cuttlefish, and squid supply equations, being uniquely negative in the case of cuttlefish. This suggests that any management policy directly or indirectly associated with effort, including partially closed seasons and export tax policies that lead to reduced domestic prices, will not affect all species supplies in the fishery the same way. Thus, while institutional pressures within Mauritania might encourage the SMCP to base purchasing, taxing, and marketing on a government revenue maximizing calculus, these decisions must account for the potential dynamic effects on the biological resource and, ultimately, the fishery's economic stability.

Various price ratio coefficients also had statistically significant effects on the determination of supply. Price ratios with both octopus and cuttlefish were a significant influence on finfish supply, while octopus and cuttlefish supplies were affected by price ratios with all other product categories. Both mixed cephalopod and squid supplies were significantly influenced by price ratios with octopus and cuttlefish. The significance of price ratios in determining mixed cephalopod supply was somewhat surprising given the assumed by-catch nature of this product category.

Given the significance of the yearly dummy variable, the matrices of own-price and cross-price elasticities were calculated (at the observed means) separately for each year. In 1989, all product categories except mixed cephalopods had positive and inelastic own-price supply elasticities, although only the own-price elasticity for octopus supply was statistically significant (Table 4). Calculated cross-price supply elasticities for 1989 suggested a number of economic interactions that may have important implications for management of the cephalopod fishery. Statistically significant substitute relationships existed between finfish and octopus, octopus and cuttlefish, octopus and squid, and octopus and mixed cephalopods. Complementary relationships existed between finfish and cuttlefish, cuttlefish and squid, and cuttlefish and mixed cephalopods (Table 4). The existence of these substitute relationships highlights the concern that single species management of the cephalopod fishery may have negative effects on non-regulated species stocks through unanticipated shifts in harvests. In addition, the lack of complementarity across all species, and especially across the important, high-valued cephalopod product categories, suggests a degree of selective harvesting and incomplete joint production on the part of fishermen. These results also may be partially attributed to the tendency of Mauritanian fishermen to high-grade, or cull all but the most highly priced species during the initial part of a fishing trip, subsequently filling their vessel holds with other species as the time approaches to return to port.

Given the cross-price elasticities reported for 1989, and the fact that the Mauritanian government imposed harvest restrictions on octopus in the form of a partial closed season in 1990, model results reflect the experienced increased exploitation of finfish and squid stocks in 1990 (Table 1). Calculated own-price supply elasticities for 1990 were positive except for the mixed cephalopods, with only the value for octopus being statistically significant (Table 5). In general, finfish supply elasticities decreased in magnitude between 1989 and 1990, while cephalopod supply elasticities increased in magnitude. Little change was observed for the octopus own-price supply elasticity, while large changes occurred in both finfish and cuttlefish own-price supply elasticities. The relative technical economic relationships among the species remained stable between 1989 and 1990, with no shifts in product substitutability or complementarity. The cuttlefish cross-price elasticity with respect to octopus increased dramatically between 1989 and 1990 to become highly elastic, suggesting that continued restrictions on octopus harvests might significantly increase cuttlefish harvests in the future. The calculation and testing of individual supply elasticities with respect to effort in each year indicated that there were no statistically significant changes between years.

Some preliminary evidence of the impact of changing stock levels and/or management strategies on the cephalopod fishery can be observed by examining the individual supply elasticities with respect to effort in each year (Table 6). These elasticities of intensity describe the relationship between the output supplied and the level of composite fixed input use. Statistically significant, positive, yet inelastic relationships between effort and octopus supply occurred in both 1989 and 1990, while statistically insignificant 1989 supply elasticities with respect to effort for finfish and squid became statistically significant and nearly elastic in 1990. However, variability in the data was such that the null hypothesis of constant effort elasticities between years could not be rejected.

Conclusions

This study investigated the nature of the technical and economic relationships underlying the 1989-1990 Mauritanian cephalopod fishery by estimating a system of dual output supply functions derived from a generalized Leontief revenue function. Model results indicate the existence of jointness in inputs and non-separability between inputs and outputs in the fishery. In addition, statistically significant yearly effects were observed with respect to fishing effort. With the exception of the by-catch category of mixed cephalopods, all own-price elasticities were positive (as theoretically required) and generally quite inelastic. Only the own-price elasticity for octopus supply was statistically significant. Cross-price elasticities indicated a number of substitute and complementary relationships, with these relationships changing in magnitude across years.

Calculated elasticities of revenue and supply with respect to effort suggest that management restrictions on octopus harvest may have led to shifts in the relationship of effort to landed harvest in a number of species. While it is impossible to identify the proximate cause of these effects, the fact that non-selective gear is used suggests increased levels of octopus discards under management restrictions and not changes in the catch structure. If this is true, then the use of a partially closed octopus season may be counter productive as a management tool may inadvertently damage the long-run biological stability of the octopus resource.

These results have a number of implications for management of the cephalopod fishery. Significant non-separability in outputs and jointness in inputs suggests that any attempts to economically manage the resource should be based on multiproduct production theory, not single-species biological response functions. Unless explicit recognition of the economic interactions among species are incorporated into the regulatory development process, cephalopod fishery management may induce either over- or under-exploitation of specific species resources. Given the significant estimated substitute relationship between octopus and all other cephalopod product categories, restrictions on octopus harvesting may lead to increased exploitation of the remaining species in the cephalopod fishery. In addition to ruling out single-species management, the dominance of substitute relationships in the Mauritanian cephalopod fishery precludes the use of “key species” management of the entire resource as suggested for other fisheries (Thunberg, Bresnyan, and Adams, 1995).

The existence of jointness in inputs suggests that, to some degree, all inputs are required to produce all outputs. Under this situation, restrictions placed on fishing effort may lead to an overall decrease in the harvest of all species. Grant, Griffin and Warren (1981) suggested that management schemes which reduce fishing effort on a seasonal basis (1 to 2 months during the peak recruitment into the fisheries) have potential for increasing total harvest and harvesting efficiency, as well as revenue and rent, in the northwest African cephalopod fisheries. However, management outcomes will depend on the form of technical interdependencies when effort restrictions target a single species in a multi-species fishery. For the Mauritanian cephalopod fishery, technical interdependencies, jointness, and non-separability all suggest that direct effort restrictions cannot be species specific without leading to major changes in the harvest of other species in the fishery. Given non-specific gear and the tendency to high-grade, indirect effort restrictions, such as species specific export taxes, may also affect the harvesting of other species in the fishery without generating positive biological benefits for the species being targeted by managers. While uniform effort restrictions (in terms of a closed season or export taxes on all species) may be an alternative, the relationships among short- and intermediate term inputs still needs to be investigated. If economic theory is applicable, then the effective regulation of inputs can induce unanticipated expansion of unregulated inputs and lead to inefficient production (DeVanny *et al.*, 1982). Given the importance of the cephalopod fishery to Mauritania, the results of this study indicate the need for more caution in developing and implementing Mauritanian fishery policy.

References

Breusch, T.S. and A.R. Pagan. 1980. The Lagrange multiplier test and its applications to model specification in econometrics. *Review of Economic Studies* 47:239-253.

Campbell, H.F. and R.B. Nicholl. 1995. Allocating yellowfin tuna between the multi-species purse seine and longline fleets. *Marine Resource Economics* 10(1):35-58.

Carlson, E.W. 1973. Cross-section production functions for North Atlantic groundfish and tropical tuna seine fisheries. *Ocean Fishery Management: Discussions and Research.* A. Sokolski, NOAA Technical Report, National Marine Fisheries Service, Circular No. 371.

Centre National de Recherches Océanographiques et des Pêches (CNROP). 1990. Mémorandum du groupe de travail Céphalopodes de Mauritanie. CNROP du 12 au 16 octobre 1989. *Centre National de Rech. Oceanogr. et des pêches de la Mauritanie*, miméo.

Centre National de Recherches Océanographiques et des Pêches (CNROP). 1991. Mémorandum du groupe de travail Céphalopodes de Mauritanie. CNROP du 1 au 4 décembre 1989." *Centre National de Rech. Oceanogr. et des pêches de la Mauritanie*, miméo.

Centre National de Recherches Océanographiques et des Pêches (CNROP). 1993. Mémorandum du groupe de travail Céphalopodes de Mauritanie. CNROP du 20 au 25 mai 1992. *Centre National de Rech. Oceanogr. et des pêches de la Mauritanie*, miméo.

Chambers, R.G. 1988. *Applied Production Analysis: A Dual Approach*. Cambridge: Cambridge University Press.

Chavance, P. and M. Girardin. 1991. L'environnement, les ressources et les pêcheries de la ZEE Mauritanienne. *Bull. Centre National de Rech. Oceanogr. et des pêches de la Mauritanie*, 227 pages.

DeVanny, A., W. Gramm, T. Saving and C. Smithson. 1982. The impact of input regulation: The case of the U.S. dental industry. *Journal of Law and Economics* 20:367-381.

Dia, M. 1988. *Biology et Exploitation du Poulpe (Octopus vulgaris) (Cuvier, 1797) des côtes mauritaniennes*. Thèse Doct. 3ème cycle, Univ. Bretagne Occidentale.

Dia, M. 1990. Les principales ressources halieutiques de la sous région. Bilan de l'état des connaissances sur les principales resources exploitées (biology, écology, dynamic des stocks, exploitation). Example des céphalopodes de Mauritanie. *In Actes du seminaire Recherches-Aménagement.* Centre National de Rech. Oceanogr. et des pêches de la Mauritanie, 11p.

Dia, M. and C.A. Inejih. 1991. In l'environnement, les ressources et les pecheries de la ZEE Mauritanienne. *Bull. Centre Nat. Rech. Oceanogr. Et des Peche de la Mauritanie*:227 p.

Diewert, W.E. 1974. Functional forms for revenue and factor requirements functions. *International Economic Review* 15(1):119-129.

Dixon, B.L., P. Garcia, and M. Anderson. 1987. Usefulness of pretests for estimating underlying technologies using dual profit functions. *International Economic Review* 28:623-630.

Duarte, C.C. 1992. Targeted versus nontargeted multispecies fishing. *Environmental and Resource Economics* 2:259.

Dupont, D.P. 1991. Testing for input substitution in a regulated fishery. *American Journal of Agricultural Economics* 73(1):155-164.

Gilly, B. and A. Maucorps. 1987. *L'Aménagement des principales pêcheries de la Mauritanie et le developpement de la recherche halieutique*. FAO/FI/TCP/MAU/6655:174 p.

Girardin, M. 1988. Les resources en poisson demersal de la Mauritanie. In *Acte du seminaire Recherche-Amenagement.* Centre Nat. Rech. Oceanogr. et des Peche de la Mauritanie:8 p.

Grant, W.E., W.L. Griffin, and J.P. Warren. 1981. A Management Model of the Northwest African Cephalopod Fishery. *Marine Fisheries Review* 43(11).

Greboval, D. 1986. *Aménagement des principales pêcheries de la ZEE Mauritanienne (resultats préliminaires)*. Dakar, Programme COPACE, COPACE/TECH/86/75:72 p.

Hall, R.E. 1973. The specification of technology with several kinds of outputs. *Journal of Political Economy* 82:878-892.

Hatanaka, H. 1979. Studies on the Fishery Biology of Common Octopus of the Northwest coast of Africa. *Bull. Far Seas Fish. Res. Lab*. 17:13-124.

Josse, E. and S. Garcia. 1986. Description et évaluation des ressources halieutiques de la ZEE Mauritanienne. Rapport du Group de travail CNROP/FAO/ORSTOM, Nouadhibou, Mauritanie. 16-27 septembre. *COPACE/PACE Séries* 86/37:310 p.

Josse, E. 1989. Les ressources halieutiques de la ZEE mauritanienne: description, evaluation et aménagement. Rapport du deuxième group de travail CNROP/FAO/ORSTOM. *COPACE/PACE SERIES* 89/49.

Judge, G.G., R.C. Hill, W.E. Griffiths, H. Lutkepohl, and T.C. Lee. 1985. *The Theory and Practice of Econometrics, 2nd Edition.* New York: John Wiley & Sons.

Kirkley, J.E. and I.E. Strand. 1988. The technology and management of multi-species fisheries. *Applied Economics* 20:1279-1292.

Lopez, R.E. 1980. The structure of production and the derived demand for inputs in Canadian agriculture. *American Journal of Agricultural Economics* 62:38-45.

Lopez, R.E. 1985. Structural implications of a class of flexible functional forms for profit functions. *International Economic Review* 26:593-601.

McFadden, D. 1978. Cost, Revenue, and Profit Functions. *Production Economics: A Dual Approach to Theory and Applications.* Fuss, M. and D. McFadden (Eds.), New York: North Holland Publishing Company.

Placenti, V., G. Rizzo, and M. Spagnolo. 1992. A bio-economic model for the optimization of a multi-species, multi-gear fishery: The Italian case. *Marine Resource Economics* 7:275-295.

Pope, R.D. 1982. To dual or not to dual? *Western Journal of Agricultural Economics* 7:337-351.

SAS Institute, Inc. 1987. *SAS Guide for Personal Computers, Version 6 Edition.* Cary, North Carolina: SAS Institute Inc.

Sok, M., O.A. Fall, M. Diallo, G. Ancey, V. Berberian, and G. Gonneville. 1989. Actualization des comptes économiques du secteur pêche en Mauritanie pour 1987-1988. *Société d'études pour le developpement économique et social* (SEDES:199 p.

Squires, D.E. and J. Kirkley. 1991. Production quota in multiproduct Pacific fisheries. *Journal of Environmental Economics and Management* 21(2):109-126.

Thunberg, E.M., E.W. Bresnyan, and C.M. Adams. 1995. Economic analysis of technical interdependencies and the value of effort in a multi-species fishery. *Marine Resource Economics* 10(1):59-76.

Table 1

Descriptive Statistics for the 1989 and 1990 Mauritanian Cephalopod Fishery

Descriptor	Mean	Standard Error	Minimum	Maximum
Quantity Landed of:				
(metric tons)	----------	---------- 1989	----------	----------
Finfish	90,062	95,554	6,560	775,336
Octopus	314,451	135,285	6,253	645,038
Cuttlefish	48,196	32,585	875	182,938
Mixed Cephalopods	3,729	4,246	60	20,200
Squid	5,186	6,835	1	38,580
Price (U.S. $/kg):[a]				
Finfish	1.097	0.197	0.750	1.819
Octopus	3.770	0.322	2.602	4.871
Cuttlefish	3.476	0.299	2.893	4.288
Mixed Cephalopods	1.746	0.230	0.468	1.800
Squid	6.326	2.304	1.000	11.705
Vessel Power (kwatts)	1322.46	563.69	705.00	2700.00
Trip Length (days)	258.38	73.36	31.00	360.00
Quantity Landed of:				
(metric tons)	----------	---------- 1990	----------	----------
Finfish	404,321	252,829	14,925	1,210,939
Octopus	197,253	119,440	1,529	714,065
Cuttlefish	92,096	64,765	4000	136,380
Mixed Cephalopods	4,523	3,850	40	21,960
Squid	66,295	40,631	1,859	187,558
Price (U.S. $/kg):[a]				
Finfish	2.995	0.446	1.648	4.740
Octopus	3.818	0.360	2.657	5.038
Cuttlefish	3.905	0.550	2.103	5.274
Mixed Cephalopods	1.731	0.108	1.400	1.800
Squid	3.002	0.306	2.133	3.855
Vessel Power (kwatts)	919.54	397.44	368.00	1693.00
Trip Length (days)	226.27	87.67	22.00	378.00

[a] For descriptive purposes the data was coverted from the Mauritanian national currency (ouguiyas - UM) to U.S. dollars using the constant exchange rate of US$1=100UM. All estimations were conducted in using the original Mauritanian currency values.

Table 2
Statistical Tests of Hypotheses About the Production Technology

Null Hypothesis	Chi-Square Test Statistic	Chi-Square Critical Value ($\alpha \leq 0.05$)	Degrees of Freedom	Conclusions
Diagonal System Covariance Matrix	147.23	18.31	10	Reject Null
Coefficient Symmetry	49.61	18.31	10	Reject Null
All Coefficients Zero	2385.53	49.80	35	Reject Null
Non-jointness in Inputs	111.71	31.41	20	Reject Null
Separability in Outputs	36.67	11.07	5	Reject Null
Dummy Variables Zero	101.09	11.07	5	Reject Null

Table 3

Parameter Estimates for the Mauritanian Large Trawler Output Supply Functions (Symmetry Imposed)

	Ratio of Own-Price With the Price of:							
Supply Equation For:	Finfish	Octopus	Cuttlefish	Mixed Ceph.	Squid	Effort	Squared Effort	Effort Dummy
Finfish		-0.2016 *	0.1312 **	0.0058	0.0149	0.3819 *	-7.51 e-8	1.6759 **
		(0.1229)[a]	(0.0574)	(0.0109)	(0.0351)	(0.2242)	(1.35 e-7)	(0.1157)
Octopus			-0.3417 **	-0.0272 **	-0.1036 **	1.7614 **	-6.58 e-7**	-0.0144
			(0.0630)	(0.0091)	(0.0275)	(0.1296)	(8.43 e-8)	0.0566
Cuttlefish				0.0303 **	0.0791 **	0.3155 **	-5.44 e-8**	-0.1046 **
		Symmetric		(0.0128)	(0.0210)	(0.0596)	(1.76 e-8)	(0.0240)
Mixed Cephalopod					-0.0026	0.0163 **	-2.04 e-8**	-0.0031
					(0.0018)	(0.0075)	(4.81 e-9)	(0.0062)
Squid						0.0423 **	-2.2 e-8	0.2924 **
						(0.0136)	(1.69 e-8)	(0.0186)

[a] Standard errors in parentheses.
** Denotes statistically significant at the 0.05 level.
* Denotes statistically significant at the 0.10 level.

Table 4

Estimated Own-Price and Cross-Price Elasticities for Mauritanian Large Trawlers in 1989

Supply Equation For:	Finfish	Octopus	Cuttlefish	Mixed Cephalopod	Squid
Finfish	0.1830	-0.7043 **	0.4401 **	0.0138	0.0674
	(0.8066)[a]	(0.4293)	(0.1925)	(0.0259)	(0.1588)
Octopus	-0.0587 *	0.3182 **	-0.1771 **	-0.0100 **	-0.0724 **
	(0.0358)	(0.1083)	(0.0499)	(0.0033)	(0.0192)
Cuttlefish	0.2595 **	-1.2531 **	0.5422	0.0756 **	0.3758 **
	(0.1136)	(0.2310)	(0.4763)	(0.0319)	(0.0998)
Mixed Cephalopods	0.2092	-1.8191 **	1.9458 **	-0.1107	-0.2252 *
	(0.3932)	(0.6086)	(0.8220)	(1.9798)	(0.1559)
Squid	0.2041	-2.6311 **	1.9290 **	-0.0449 *	0.5430
	(0.4809)	(0.6984)	(0.5121)	(0.0311)	(1.7225)

[a] Standard errors in parentheses.
** Denotes statistically significant at the 0.05 level.
* Denotes statistically significant at the 0.10 level.

Table 5
Estimated Own-Price and Cross-Price Elasticities for Mauritanian Large Trawlers in 1990

Supply Equation For:	Finfish	Octopus	Cuttlefish	Mixed Cephalopod	Squid
Finfish	0.0152	-0.0591 *	0.0389 **	0.0011	0.0039
	(0.0642)[a]	(0.0360)	(0.0170)	(0.0022)	(0.0091)
Octopus	-0.0950 *	0.3373 **	-0.1838 **	-0.0097 **	-0.0489 **
	(0.0579)	(0.1260)	(0.0518)	(0.0033)	(0.0129)
Cuttlefish	0.9965 **	-2.9304 **	1.1574	0.1750 **	0.6015 **
	(0.4360)	(0.5403)	(1.2099)	(0.0739)	(0.1597)
Mixed Cephalopods	0.1770	-0.9369 **	1.0556 **	-0.2161	-0.0794 *
	(0.3325)	(0.3035)	(0.4459)	(1.1469)	(0.0550)
Squid	0.0236	-0.1849 **	0.1427 **	-0.0031 *	0.0217
	(0.0555)	(0.0491)	(0.0379)	(0.0022)	(0.1446)

[a] Standard errors in parentheses.
** Denotes statistically significant at the 0.05 level.
* Denotes statistically significant at the 0.10 level.

Table 6
Estimated Elasticities with Respect to Effort
in the Mauritanian Cephalopod Fishery

Supply Equation For:	1989	1990
Finfish	0.8816	1.0212 **
	(2.8037)[a]	(0.3343)
Octopus	0.7828 **	0.8903 **
	(0.3839)	(0.4519)
Cuttlefish	0.8775	0.9476
	(1.4565)	(3.9980)
Mixed Cephalopods	0.4445	0.6475
	(4.9394)	(3.0230)
Squid	0.7101	0.9865 **
	(6.0094)	(0.4576)

[a] Standard errors in parentheses.
** Denotes statistically significant at the 0.05 level.