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SOMETHING FISHY IN THE ITQ MARKET*

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SOMETHING FISHY IN THE ITQ MARKET

1. Introduction

Much has been written about the advantages of Individual Transferable Quotas (ITQ's) as a policy instrument for fishery management, and about potential improvements in economic efficiency likely to result from the introduction of a Quota Management System (QMS)[1]. On the other hand, there has been very little critical analysis of likely performance of ITQ's in practice[2]. In particular, the fact that proper functioning of the ITQ market is a necessary condition if the full potential benefits of a QMS are to be realised has been widely ignored, and almost no attention has been paid to analysing and understanding the operation of the market for trading in quota[3].

It is an article of faith among economists that these "property rights" should be both transferable and freely tradeable if maximum possible rents are to be realised. Furthermore, it is generally accepted that market prices for quota provide a measure of the size of the resource rent being generated[4]. In the traditional textbook treatment of the determination of quota trading prices, there is an implicit assumption that Individual Transferable Quotas are formally equivalent to other inputs required to catch fish. Moreover, no account is taken of the implications for quota trading prices of the interaction between the extremely variable and risky nature of fishing as a commercial enterprise and the asymmetric properties and temporal partitioning of the entitlement to exploit the fish stock conferred by Individual Transferable Quotas.

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[1]*Most recently this policy instrument was the sole topic at an international conference of fishery economists held in Iceland, and of a subsequent book by Neher (1989).*

[2]*Copes (1986) makes a very persuasive case that too much attention has been devoted to the potential benefits of ITQ's, and not enough to likely problems. His discussion of these problems is very comprehensive, and so will not be repeated here. However, one problem he does not discuss is lack of understanding of the operation of the market for ITQ's.*

[3]*Exceptions include Anderson (1988), and Lindner and Campbell (1989b)*

[4]*For instance, see Arnason (1988)*

According to Copes (1986, p.279) "some early instances can be found of the application of individual quotas, e.g., in the Prairie Lakes fisheries of Canada where they have been used since the 1930s". Despite such isolated instances, up until quite recently license limitation programmes were the only "restricted access" policy to find any degree of favour with fishery managers. It would seem that the initial preoccupation with this form of fishery management was due in large part to its success in preserving the biological health and economic prosperity of the WA Rock Lobster fishery following its introduction by the local Department of Fisheries some 25 years ago. However, subsequent adoption in other fisheries did not always meet with the same long-run success for reasons that have now been well documented in the literature[5], and as a result many fishery economists started advocating adoption of ITQ's.

Recent implementation of a comprehensive QMS in New Zealand provides one of the first opportunities to the study operation of an ITQ market. It will be argued in this paper that to date the market for ITQ's in New Zealand does not appear to have performed in a "textbook" manner, and may not be performing in a manner consistent with economic theory. In particular, there is a suggestion that the process of arbitrage has broken down, or at least has so far failed to deliver an unique market clearing price during the first two years of quota market operation. Moreover, as far as can be determined, most prices paid in the ITQ market are far in excess of any resource rents being earned from exploiting the fish stocks.

This is a matter for concern on several counts. If the quota market does not in fact operate in the predicted manner, then it is possible that a QMS will not deliver all of the expected efficiency gains either. As a corollary, if prices paid in the quota market do not accurately measure economic rent generated in the fishery, then quota prices should not be used as a basis by government for setting "resource rentals" as has been attempted in New Zealand. By the same token, it might not be appropriate to use them as a basis for compensating fishermen excluded from future access to the fishery. Nor will it be possible to monitor the success or otherwise of fishery management programmes as has been advocated, inter alia, by Arnason (1988).

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[5]*See Campbell and Lindner (forthcoming)*

2. A Review of the Quota Pricing Literature

As noted above, very little of the fishery economics literature deals explicitly with the determination of ITQ prices. Textbook treatment of the topic often relies on a presumed equivalence between the impact of ITQ's and optimal output taxes. For instance, Anderson (1986, p.218) states that the effect of an optimal tax on catch :

> " *will be technically identical to the individual quota-transfer program. The only difference will be that profits will be collected by the government.*"

However, Clark (1985, p.157) cautions that :

> "*it is a well-known principle in the economics of regulation that price controls (e.g., taxes) and quantity controls (e.g., quotas) have equivalent effects on production. ..... This principle, however, is by no means universally valid; under conditions of uncertainty, for example, taxes and quotas are not equivalent*"

It also is quite common to imply that the market for ITQ's would play a similar role in a QMS fishery to that played by the land market in agriculture[6]. Perhaps this association can be explained by the fact that ITQ's as a form of policy instrument are not unique to fishery management, but merely a specific form of production quota which places an upper bound on output of individual firms.

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[6]*E.g. see Anderson (1986, p.228)*

In agriculture, such quota are more commonly referred to as a `marketing quota`, and have been employed in a number of countries as the foundation for supply management schemes designed to raise (domestic) prices above market-clearing levels. For instance, quotas were used to control wheat production in Australia in the 70's, and remain part of the egg and dairy marketing schemes.[7] Nieuwoudt (1976) notes that in South Africa there are negotiable production quotas for wine, sugar cane, milk (Natal) and wattle farming. In the EEC, Burrell (1985, p.335) notes that in 1984, "a Scheme of milk quotas backed by a 'super levy' on over quota production was imposed on EC dairy producers", while Babcock (1989), Watson et. al. (1984), Williams (1983) among others have studied peanut and tobacco production quotas in the USA.

However, among free market economies, Canada seems to be the country where this form of policy instrument has found greatest favour. Certainly the agricultural economics literature on pricing of marketing quota is dominated by Canadian references. Veeman (1982) states that :

> "*the existence of substantial and, in general, increasing quota values provides convincing evidence that supply controlling marketing boards for fluid milk, eggs, broilers, turkeys, and tobacco have successfully exerted monopoly power in pricing and output decisions.*"

while pricing of Canadian Milk Marketing Quotas have been discussed `inter alia` by Arcus (1978); Barichello (1982); Furtan and Clark (1981); and Stonehouse and MacGregor (1981, 1982). The aim of much of this literature is simply to provide decision-making criteria for purchasing quota at the individual farm level, and at best is of limited relevance to any study of quota price determination in a competitive market.

The feature of this literature that I want to focus on here is the prevailing view that quota prices provide a reliable guide to economic rents. The following two quotes capture the essence of this aspect of the literature. Nieuwoudt (1976, p.194) claims that agricultural marketing quota in South Africa

> "*have a market price which is the capitalised value of the expected future rent streams accruing to quota owners.*"

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[7] *References to the operation of these schemes include Alston (1986), Fisher (1975), Gruen (1961), Parish (1962)).*

and Veeman (1982, pp.24,26) argues with regard to the capital value of "marketing quotas" for Canadian agricultural products that :

> *"assuming away the problems of uncertainty, quota rights would acquire a value indicating the extent of economic rent associated with this right"*
>
> *"the process of determination of a market price for quota rights is akin to ..... the price determination process for farmland"*

While rarely acknowledged explicitly, such conclusions require at least two fundamental assumptions, one being that the industry operates in a deterministic world, and the other being that it is always in steady state long-run equilibrium. In order to establish a benchmark as a basis for subsequent discussion, it will be convenient to first consider the following highly over-simplified deterministic model of the operation of an ITQ trading market which has been adapted from Anderson (1989). Using comparative statics[8] this model will be used to show that prices paid for quota in an annual lease market will measure annual management rent provided that :

- the market is competitive
- quota trades are not conditional on trades of other assets such as vessels,
- quota trades are not otherwise distorted by tax or regulatory considerations
- the market is in long-run equilibrium
- it is a deterministic and certain world[9].

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[8]*Note that the use of comparative statics ignores the dynamics of the process that takes place in adjusting from one long-run equilibrium position to another. Lindner, Campbell and Bevin (1989) prove that it is theoretically possible for rents to initially be negative following introduction of QMS; as well as reviewing* **prima facie** *evidence from New Zealand that following introduction of the QMS, resource rent initially was negative despite the fact that quota trading prices positive.*

[9]*This assumption is also taken to imply perfect knowledge.*

For consistency with the commonly used Schaefer model, define H=a.X.E; where H denotes annual harvest, "a" is a catchability coefficient, X is size of the fish stock, and E denotes fishing effort expended in catching H. In order to abstract from the dynamic complexities associated with the stock externality, it is assumed that the objective of fishery management is to maintain the fish stock at some "desired" steady state level, X^*; and that it is feasible to do so by setting a Total Allowable Catch, (TAC), such that on average H = Q, defined as the annual catch required for $X = X^*$. Given a deterministic world in which a and X are both constant, these assumptions imply that catch per unit of effort is independent of level of effort[10]. If demand for catch from the fishery also is perfectly elastic, then the problem of fishery management can be reduced to one of minimizing catching cost subject to H = Q. In the deterministic case, this simply involves producing E^* ($=Q/aX^*$) in the most efficient manner possible.

Again following convention in the fishery economics literature, it is assumed that the production function for effort exhibits constant returns to scale, and employs both fixed assets, such as boats, K, and variable inputs, L, such as fuel. This is also analytically convenient since that part of the industry exploiting the fish stock can be treated as if it were a single firm. Furthermore, in terms of analysing the determinants of quota prices, willingness to pay for quota by this firm serves as a surrogate for competitively determined prices in the quota market.

Given these assumptions, it is a well established result :

- that average total costs are U-shaped in the short-run when K can not be adjusted
- that average total costs are independent of level of effort in the long-run when K can be adjusted
- that the optimal level of investment in fixed assets, K^*, is the level needed to minimise average total costs at the desired level of output
- that the scale of output at which average total costs are minimised is proportional to K^*

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[10]*Clearly this assumption can only be valid in the long-run as long as H is constrained to equal Q.*

In order to further establish the analytical framework, these general results are illustrated in Figure 1 by comparing differences in the level of investment in fixed assets, and in average costs, between an unmanaged (i.e. open access) fishery, one managed by a TAC but no restrictions on entry, and an optimally managed fishery. For the open access case, sustainable catch equals Q_o, which depletes the fish stock to the point where average revenue equals AR_o. Hence zero resource rents are earned even when there is optimal investment in fixed assets such that the minimum of the curve labelled ATC just touches AR_o at Q_o. If total catch is constrained to Q^* by a TAC, then average revenue will rise over time to AR^*. If investment could be retained at the open access level, then some resource rents would be generated. However, if investment increases due to new entrants attracted by the resource rents, then the cost curves will shift to the right until ATC' cuts AR^* at Q^*, once again resulting in total rent dissipation.

Optimal fishery management requires the opposite result, namely a reduction in investment from open access levels so that the cost curves shift to the left to ATC which is at a minimum at Q^*. If this outcome can be achieved costlessly, then steady state resource rents equal to $(AR^*\text{-}ATC^*).Q^*$ will be generated. In the traditional textbook treatment of the operation of a QMS, it is postulated that because the firm(s) also have to purchase quota for each unit of catch, the cost curves shift up vertically until MC+, denoting the marginal cost inclusive of the per unit cost of purchasing quota, just equals AR^*. Consequently the vertical distance between AR^* and MC^*, being the marginal cost exclusive of quota prices at Q^*, provides a convenient measure of equilibrium quota prices. This is illustrated in Figure 2. Equilibrium is reached when ATC+, depicting costs inclusive of quota purchase, is tangential to AR^* at Q^*. In this situation, aggregate annual expenditure on quota just equals actual as well as maximum potential resource rent.

Notwithstanding the general lack of studies of price determination in quota markets, there is recognition in parts of the literature that the traditional textbook treatment of the topic is overly simplistic. For instance, Veeman (1982, p.25) hints that such markets are not always in equilibrium by noting that :

> *"when quota rights become the factor limiting production, the economic rent associated with the quota rights ($P_s'P_sAC$) will include some of the rent previously attached to other factors of production such as land (specifically $P_s'P_eBC$)"*

Scott (1989) provides much more insight into the complexity of the issue in a paper tracing the evolution of property rights in fishing. He argues that this historical process has involved adding additional characteristics to fishing property rights as well as expanding pre-existing characteristics. According to Scott (1988, p.10), even though Individual Transferable Quotas are one of the most highly evolved, and most complex forms of fishing property right developed to date, they nevertheless fall well short of a private property right such as land. In fact, notwithstanding the common tendency to draw analogies between ITQ's and land, the former has no intrinsic value because they provide no services or inputs to production, but rather impose a constraint on output. Note that the potential value of this constraint is only realised to the extent that it succeeds in restricting aggregate catch in an efficient manner and so generates <u>future</u> resource rents via the so-called stock externality.

Other authors have focussed on the asymmetric operation of production quotas in a stochastic environment. Clark (1985), seems to have been the first to recognise that expected catch conditional on a quota will be less than unconditional expected catch from the same investment in catching capacity. Fraser (1986) derived further general results about the effect of a marketing quota on the optimal level of planned production in an uncertain environment, while Babcock (1989) has analysed the import of peanut production quotas for planting decisions given production uncertainty. In a somewhat different context, Anderson (1987) argues that import quota licenses are equivalent to financial options which command positive prices even when the expected return of market participation is non-positive, and in an attempt to develop a stochastic framework for analysing quota price determination, Lindner and Campbell (1989) have made an equivalent suggestion with respect to ITQ prices. Some of these ideas will be explored further below, but some empirical evidence on the operation of ITQ markets for New Zealand fisheries will be reviewed first.

3. Puzzles from the New Zealand Experience

New Zealand led the world in the wholesale adoption of Individual Transferable Quotas (ITQ's) to regulate exploitation of most of its fish stocks. The Quota Management System (QMS) is described in detail by Clark and Major (1988) and Clark (1988), as well as being analysed in some detail by Anderson (1988). This system was first developed in 1983 for a limited number of deep-water fish stocks, and then extended in 1986 to almost all remaining significant fish stocks. For most species, ITQ's were allocated on the basis of past tonnages harvested, although some quota was sold to industry via a tendering process. Since the Total Allowable Catch (TAC) is defined in the enabling legislation as the sum of all ITQ's for a given fish stock, the Government also reduced the TAC in some fisheries by buying back some of the allocated quota.

Under the QMS, the basic property right typically involves an entitlement in perpetuity. It is denominated in tonnes of catch per fishing year of the specified fish stock, and any amount up to a limit equal to the total quota holding can be caught how and when the quota holder wishes. These ITQ's are conditional in the sense that an annual "resource rental" (i.e. royalty) is payable by quota holders to government. The level of this royalty is set in advance of the season and must be paid whether or not all of the allowable fish are taken.

Because this property right can be freely traded, quota owners, including the government managers, can lease their quota on an annual basis, as well as buying or selling quota in perpetuity. The details of all such trades, including tonnage traded, price per tonne, and transaction date have to be registered with the Ministry of Agriculture, Forestry and Fisheries (MAFFISH) as part of the QMS. Some of these trades over the first two years of the schemes' operation were made through a computer exchange set up by the New Zealand Fishing Industry Board to facilitate quota trades. However, apart from government to industry trades, most were arranged privately.

Unfortunately the quota trading market for most fish stocks have not been active enough to generate sufficient observations for reliable analysis. Two exceptions are the markets for Snapper in area 1, and for Hoki. It is fortuitous that these two fish stocks are commercially significant examples of New Zealand's deepwater and inshore fisheries respectively. Monthly summaries of trades for annual lease of area 1 Snapper ITQ's, and for outright sale of perpetual quota for the same fish stock, are presented in Figures 3 and 4 respectively. Each figure displays minimum, average, and maximum trading price each month, as well as number of trades per month. At least two features of this data warrant special attention.

One noteworthy feature is the extremely wide price range at which each type of quota is traded. In some months, maximum prices are greater than minimum prices by a multiple of ten or more, and in most months the price range is as big or bigger than the average price recorded. For reasons to be discussed below, at least some of the lower minimum prices can be attributed to false reporting, but even if due allowance is made for this bias in the data, the actual price range is still measured in terms of hundreds of dollars per tonne for annual lease of quota, and in terms of thousands of dollars per tonne for perpetual quota trades. Just why arbitrage should have failed in such a spectacular fashion to equilibrate this market and achieve an uniform price is one of the puzzles raised, but not answered in this paper.

The second noteworthy feature is the exceptionally high prices paid both for outright sale of perpetual quota, and for leasing it on an annual basis. During the time period covered by this data, the port price[11] for Snapper was estimated to be between \$3,000 and \$4,000 per tonne[12], so it can be seen that quota was leased out at annual rental rates up to approximately 100% of the gross return from catching Snapper. Moreover, the average price paid for purchase of perpetual quota typically ranged between \$10,000 and \$15,000, while maximum prices were up to double these values. In order for the resource rents derived from catching Snapper to even approximate these values, it would be necessary for the associated catching costs to be close to zero.

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[11]*This is a term used to refer to the estimated price which would be paid in a competitive market for wetfish landed at the wharf.*

[12]*New Zealand Fishing Industry Board,* pers. comm.

Figure 5 presents equivalent data on annual lease trades for Hoki quota. Again the data is characterised by an extremely wide range of prices paid in most months, and by average and maximum prices that represent a very high proportion of the estimated port price of $350 to $500 per tonne[13]. As the market for sale of perpetual Hoki quota was much thinner, monthly data would not convey an accurate impression of price variability. Instead data on individual trades for perpetual quota are presented in Figure 6. Once again the same general picture emerges, although the significant number of trades recorded as being transacted at very low prices also is noteworthy for reasons to be discussed below. Nor was the situation found to be materially different when quota markets for a large number of other fish stocks were examined, and the annual lease quota trading data presented in Figure 7 for area 1 Trevally, which had an estimated port price of between $1,000 and $1,500 per tonne, is broadly representative of almost all such markets.

To sum up, there are at least two aspects of the operation of the New Zealand ITQ markets which are in apparent conflict with the traditional textbook treatment of price determination in such markets. Most of the rest of this paper is devoted to the apparent conflict between the prevailing view in the literature that quota prices equate to resource rents, and the empirical evidence presented above indicating that they wildly over-estimate resource rents. The case for the latter assertion is supported by Lindner and Campbell (1989a), who from independent data estimated that the New Zealand fish catching industry incurred an aggregate economic loss of about $70 million during the 1987/88 fishing year[14] despite paying substantial positive prices for all classes of quota.

The other notable feature of this quota trading data is the extremely wide range of prices being registered within even quite short time periods. Conventional explanations for price dispersion include product heterogeneity, lack of competition, and/or poorly informed market participants. It also is possible that these markets exhibit extreme short-run price volatility due to thin trading, and/or due to highly inelastic demand and supply curves which are subject to unpredictable shift factors.

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[13]*New Zealand Fishing Industry Board,* pers. comm.

[14]*The reasons in economic theory why negative resource rents might be earned during the early phases of a QMS are discussed by Lindner, Campbell and Bevin (1989).*

None of these possible explanations for widely dispersed quota market prices are entirely plausible in relation to the market for ITQ's. On the face of it, ITQ's might appear to be a perfect example of an homogeneous commodity. It is true that ITQ's are much more homogeneous than say land, but not all trades of ITQ's involve exchanging "like for like". In common with most contracts, ITQ's can and do differ with respect to the detail of the contractual arrangements. However such differences, which relate to entitlements to "over-fish", etc, at most can have a relatively minor impact on quota value. Moreover, a detailed examination of individual quota trades revealed many instances of quota with identical terms and conditions being traded at substantially different prices within days of each other.

It also has been suggested that the volatility of quota prices could be attributed to the "thinness" of trading volume on the quota market. While the market is unquestionably always thin for many fish stocks, and for all fish stocks in some months, it can be seen that a substantial number of trades were transacted for annual lease of quota for Snapper in area 1 in months such as October 1987.

Another possible explanation of price dispersion is that it is an artefact due to blatant understatement by some market traders of the true price paid for lease or sale of quota. As Anderson (1988) has noted, so long as government attempts to use quota trading prices to determine resource rentals, industry has a clear-cut incentive to engage in this misleading practice. There seems little doubt that some market participants have succumbed to this temptation, but the number of trades taking place at clearly fictitious prices is surprisingly small. Some of the most comprehensive evidence on this issue is provided by trading data from the market for annual lease of Snapper quota in area 1. Figure 8 illustrates the monthly dispersion of prices in this market for the 1987/88 fishing year, while Figure 9 presents a frequency distribution of prices for the same market from December 1986 to March 1989. Most if not all of the trades recorded as taking place at a price less than $200 per tonne are probably fictitious, but it can be seen that the majority of trades were transacted at a price of $1,000 per tonne or greater. It is difficult to believe that price is under-reported in any of this latter set of trades given that this price is in excess of 25% of the port price for Snapper. Moreover, it is apparent from Figure 8 that even if all trading prices less than $500 per tonne are discarded, monthly price data still exhibit very considerable price dispersion.

Given the above evidence, the only other theoretically plausible explanation for the observed degree of price dispersion in a market for such a homogeneous good is that a significant proportion of traders in the quota market are extremely poorly informed, and so are prepared to make trades at prices far removed from the competitive equilibrium price. While this explanation has some credibility in markets such as that for Snapper where many small fishermen own quota, industry sources do not accept this explanation. It also is much less credible as an explanation for price dispersion in the Hoki quota market, since almost all of this type of quota is controlled by a small number of large fishing companies, most of whom employ quota market managers to conduct all of the company's quota trading. Clearly this is an issue requiring further research, and until such time as results from it are forthcoming, the reasons for the observed price dispersion remain something of a mystery.

4. A Primer on Quota Pricing

The particular focus in this section of the paper is on the fact that ITQ's are a constraint on production rather than an input to it, and on the consequences of this difference given the need for industry to continuously adjust to new circumstances, and given the highly variable and uncertain environment in which fishermen operate. For the situation depicted in Figure 2 above to be one of long-run industry equilibrium, long-run average cost must be measured so as to include all costs of capital investment valued on a replacement cost basis. In other words, the price at which second-hand fixed assets, such as fishing vessels, are traded will just equal depreciated replacement cost. In the short-run, this relationship need not hold, since market prices of second-hand boats and like capital assets will adjust continuously to reflect the NPV of future quasi-rents accruing to the asset. Note that the extent to which it does not hold provides a measure of the divergence of the level of current capacity from its optimal level in the long-run.

If existing catching capacity falls short of the optimal long-run level so that market prices for these assets exceeds replacement cost, then there is an incentive to undertake net new investment in catching capacity. Conversely, when there is excess catching capacity, prices for second-hand fishing vessels will be depressed below depreciated replacement cost by an amount which is a monetary measure of the degree of excess capacity. Thus the incentive for net new investment in catching capacity will be negative until such time as long-run equilibrium as defined above is restored. For long lived assets such as fishing boats, this adjustment period may be measured in decades rather than in years. Consequently such a situation will be referred to as one of chronic excess catching capacity to distinguish it from seasonal quota excess-capacity, which will be defined below. Because chronic excess catching capacity has a significant impact on quota prices, this situation as well as that of under-investment in catching capacity will analysed first in a deterministic world before proceeding to consider the implications of a stochastic fishing environment.

Figure 10 depicts a situation of chronic excess catching capacity where existing fixed assets, $K_f > K^*$, so that ATC is minimised at some level of catch greater than Q^*. Because total catch is constrained to Q^* by the QMS, average total costs at Q^* are above this minimum possible level, and hence resource rents are smaller than in the long-run equilibrium situation illustrated in Figure 2. More importantly, fixed costs which are represented by the vertical distance between ATC and AVC, are "sunk" costs in the short-run. It follows that the upper bound on willingness to pay for a unit of quota will be defined by potential total gross margin (TGM) per unit of quota, defined as (AR-AVC), where AVC denotes average variable costs. Since AR>MC at Q^*, equilibrium quota prices required to just eliminate super-normal profits will be equal to (AR^*-MC^*). Note that TGM as defined above is greater than equilibrium quota values, so only part of these sunk costs will be incorporated into quota values, and the remainder will be manifested in the form of residual fixed asset (e.g. boat) values. In other words, quota values will equal the sum of resource rents plus that part of sunk costs labelled as "quota price excess". Furthermore, since average variable costs must be less than minimum average total costs so long as there is chronic excess catching capacity, then quota prices will exceed both realised resource rents and maximum potential resource rents.

The situation illustrated in Figure 10 is more likely to be the rule rather than the exception as it has been theoretically demonstrated by Lindner, Campbell and Bevin (1989) that the introduction of a Quota Management System is likely to generate excess catching capacity, ceteris paribus. In the case of the New Zealand fishing industry, they also provided empirical evidence indicating that the value of the quota price excess due to excess catching capacity during the period covered by this paper was in the range from NZ$70 million to NZ$95 million.

As might be expected, more or less the reverse situation would apply in a case of chronic under-capacity. In fact, Figure 11 illustrates a case where quota prices would drop to zero because $MC=AR^*$ at some level of $Q<Q^*$. Clearly quota prices under-estimate resource rents when there is under-capacity as it can be seen from the diagram that resource rents are being generated in this case, albeit at a level less than the maximum potentially available rents. The deterministic framework employed so far is now abandoned in favour of a more realistic approach which recognises that fishing takes place in a stochastic environment.

As any fisherman will be quick to point out, fishing is a very chancy business. Not only are there wild fluctuations over time in the propensity of fish to take the bait, but the actual level of fishing power which can be generated from any given investment in fishing capacity is subject to the vicissitudes of bad weather, mechanical breakdown, gear failure, etc.. As a result, total catch at the end of day, (or fishing season) is, ex ante, a highly uncertain stochastic variable which will depend only in part on production decisions made by fishing firms.

Under a Quota Management System, realised catch may fall short of potential catch because of constraints on aggregate catch imposed by Individual Transferable Quotas. From a conceptual point of view, this can be treated as placing an upper bound on the size of the actual catch which could be caught in any given fishing season. Hence decisions to buy or sell quota need to be treated within a stochastic optimal investment framework.

Since output is still subject to very considerable uncertainty once resources have been committed to catching power and the acquisition of necessary ITQ's, it will be assumed that catch rates are the only stochastic influence on realised annual catch, To further simplify the discussion, consider a case where there is "optimal" investment in catching capacity as illustrated in Figure 2, but where *ex post* there are only bad years and bumper years in the sense that catch rates are either 25% less than, or 25% greater than the catch rate implicit in Figure 2. The effect on marginal and average catching costs of each of these two possibilities are illustrated in Figure 12.

The first and most basic point to note from Figure 12 is that a QMS constrains the optimal level of output in bumper years (from Q+ to Q*), but has no compensating effect on output in bad years (Q-). Therefore, for any given level of investment in fixed assets, expected output under a quota management scheme will be less than expected output in the absence of a quota[15]. It is a moot point whether fishery managers are likely to recognize this propensity of a QMS to reduce expected catch and to adjust the level of the TAC accordingly.

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[15]*Clark (1985), Fraser (1986), Lindner and Campbell (1989b), and Babcock (1989) have derived this result for various types of marketing quota.*

As a corollary, in a fishery managed under a Quota Management System, the optimal level of industry investment in catching capacity for a fish stock of given size will be less than that for a sole ownership fishery, *ceteris paribus*. A rigourous proof of this claim is provided elsewhere[16], but the root cause is quite straightforward, and directly consequential on the asymmetry in the operation of marketing quota which sets an upper bound to actual annual catch for any given level of investment in industry catching capacity. This is one of the distinguishing characteristics of Individual Transferable Quotas as a form of property right. As already noted, the negative impact on long-run industry profitability of those years when catch rates are below average is not fully offset by higher profits in years of above average catch rates. Consequently, not only will the marginal product of catching capacity under a Quota Management System be lower than in an otherwise equivalent sole ownership fishery, but the difference will be an increasing function of the level of investment in catching capacity. Thus the very act of establishing a QMS may cause the existing level of catching capacity to become excessive even if it were not so previously.

Next note that relative to an increased investment in catching capacity in the deterministic case, a higher catch rate not only shifts the cost curves to the right but also shifts them down. If there were no quota on production, both of these shifts would act to increase resource rents in a bumper year. Similarly, the effect of lower catch rates is to shift the cost curves up <u>and</u> to the left, both of which reduce resource rents in bad years irrespective of whether there is a QMS in operation or not. As a consequence of these multidirectional shifts, the extra resource rent generated in a bumper year will far outweigh the loss of resource rent from a bad year due to an equal but opposite variation in catch rate even in the absence of a QMS to constrain aggregate catch. This fundamental feature of fishing is illustrated in Figure 13, and explains why fishermen attach such importance to their freedom to "cash in" on the occasional good year. The area labelled "LOST RENT" which is the amount by which a QMS reduces resource rents in a bumper year, also may explain the lack of enthusiasm of most fishermen for ITQ's. As can be seen from Figure 13, the imposition of a quota significantly reduces realised resource rents in bumper years without any compensating increase in resource rents in bad years.

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[16]*Again see Fraser (1986), and Lindner and Campbell (1989b).*

This asymmetry in the operation of a QMS in a stochastic environment also has significant implications for prices paid to lease ITQ's on an annual basis because an important characteristic of Individual Transferable Quotas is the temporal subdivision of the entitlement to catch fish into finite term seasons, usually of one years duration. As a corollary, when quota is leased on an annual basis in a variable and uncertain environment, the property right being traded is truncated not only in terms of the size of the catch that can be taken, but also in terms of the time period during which it can be caught. Moreover, the finite term of the lease, and hence of the entitlement to catch fish, is of much shorter duration than the economic life of the capital items which determine catching capacity.

Consequently, even if the industry is in long-run equilibrium in the sense that there is no chronic excess catching capacity as defined above, the nature of ITQ's will lead to short-run or seasonal disequilibrium in any given year, ex post. Specifically, potential aggregate catch (i.e. where $AR^*=MC$) will either exceed or fall short of aggregate entitlement to catch fish as defined by the quota. This seasonal disequilibrium has important ramifications for the evolution of quota leaseprices over the course of the fishing season.

Now consider what would happen to quota prices in the two dichotomous cases delineated above IF actual catch rates were known with certainty prior to commencement of the fishing season. In bad years as illustrated in Figure 12, annual lease price would equal zero at all times because $AR^* < MC$ at Q^*. That is, the supply of quota would exceed demand at any positive price. In bumper years when potential aggregate annual catch would exceed the quota if fishermen were free to make full use of their investment in catching capacity, annual lease price for quota again would be constant throughout the year, but equal to the margin between the port price of fish and marginal catching costs at Q^*. Note that by definition this margin exceeds resource rent per unit of catch.

In practice, knowledge about actual catch rates will be acquired gradually as the fishing season evolves, and will not be complete until the end of the season. Hence it will not be possible to observe the "perfect knowledge" annual lease prices postulated above before the end of the season. In the absence of other influences, annual lease prices during the fishing season can be expected to trend toward one or other of these terminal values.

A stylized picture of the likely evolution of quota annual lease price over the course of a bad season is illustrated in Figure 14. Note that price is depicted as trending toward zero, but not actually reaching zero by the last month of the season. The reasons why the terminal annual lease price is predicted to have some positive finite value are discussed below. Figure 15 illustrates the alternative scenario for the likely time path of annual lease prices as a bumper season unfolds. In this case annual lease prices are depicted as asymptotically approaching port price for the catch on the grounds that the marginal cost of landing over-catch at the end of a fishing season is approximately zero.

In theory, the way in which quota market annual lease prices evolve over the course of a fishing season will follow one of two principal patterns discussed above. As might be expected, the world of practical commerce is not as straight-forward. Nevertheless, these two stylized patterns of price evolution are reasonably well illustrated by quota trading for annual lease of Snapper in area 1.

Figure 16 illustrates how annual lease prices can evolve during a year such as 1987 when catch fell short of total allowable catch by about 20%. It can be seen that annual lease prices did in fact decline toward the end of the fishing season as it became increasingly clear that there would be seasonal quota excess-capacity. Note also that while the entire range of prices fell away as the season progressed, the most marked decline was in upper bound prices.

For most of 1987, this upper bound was $3,300 per tonne of Snapper which was very close, if not equal to the port price for Snapper at that time. Clearly these upper bound prices could only be paid by fishermen with short-run fixed costs which are very high in relation to variable catching costs. The corollary is that these annual lease prices for quota must exceed fishery management rent by a very large margin.

It has been postulated above that any seasonal under or over-capacity becomes progressively more evident as the fishing season evolves. Therefore, some idea of the extent by which quota annual lease prices might over-estimate fishery management rent can be obtained by examining end-of-year trading prices for annual lease of quota in those years when aggregate catch is constrained by the TAC.. The results of such an examination is reported below.

In the 1987/88 fishing year, aggregate catch of Snapper from area 1 actually exceeded the total allowable catch by a small margin. Complete trading data for annual lease of Snapper quota in 1987/88 is illustrated in Figure 17, and it can be seen that more or less the opposite pattern of price movement to 1986/87 was evident. In the first part of the year, very few trades took place at upper bound prices, which in any case fell by about 33% relative to upper bound prices prevailing for the first half of 1987. However, with continuing higher catch rates than for 1986/87, competition in the market for annual lease of quota clearly intensified. As a result, an increasing proportion of trades were transacted at upper bound prices, and the level of these upper bound prices also rose. This pattern of price evolution would have been even more obvious were it not for an increasing proportion of trades recorded as taking place at prices which almost certainly are fictitious.

Finally, there is the question of whether an option premium is a component of quota trading prices. Such a premium could arise as a consequence of the considerable uncertainty faced by fishermen, both about the cost of catching fish, and about the financial returns from doing so. As the act of holding quota does not create any obligation to actually go fishing irrespective of the prospective return from doing so, holding quota is analogous to holding an option in the financial markets to purchase shares at some future date. It is generally accepted that capital markets are efficient in processing available information, so the expected value of future price movements will be zero. However, notwithstanding these expectations, it is common knowledge that a positive price is paid in the market for options to purchase shares. Again it is rational to do so because there is no actual obligation to take up the option if future price movements prove to be unfavourable. Consequently, the positive prices at which such options typically trade provide a partial measure of the cost of market risk.

Likewise, given that holding quota only provides the option to fish, annual willingness to pay for quota by rational fishermen will exceed expected management rent by a premium which is equivalent to option prices in the share market. The size of such an option premium will be equal to the expected value of the avoided losses by not fishing if and when future returns do not cover variable costs. In the long-run, if unfavourable scenarios such as a collapse in fish prices and/or stocks materialise and force quota holders to mothball some or all of their quota, it may be possible to avoid certain semi-fixed costs as well as variable catching costs. Moreover, as more distant future events are typically regarded as more uncertain, this option premium is likely to be larger with respect to long-run decisions than for short-run decisions.

The possible basis for a logical method for estimating these option premiums has already been outlined above. In a certain world, the end of season price for quota when there is seasonal excess-capacity would be zero. It follows that positive end of season annual lease prices for quota given manifest seasonal excess-capacity must be due to the combination of uncertainty and the asymmetric characteristic of the entitlement to catch fish embodied in Individual Transferable Quotas. In other words, when actual catch falls well short of total allowable catch, observed end of season annual lease prices for quota provide an empirical measure of the magnitude of the option premium in the face of residual uncertainty at the end of the fishing season about the possibility of unintended over-catch. As it is almost tautological that uncertainty about annual catch levels will be greater at the commencement of the fishing year than at the end of it, estimates of the option premium based on end of year quota annual lease prices should underestimate the size of the option premium at the beginning of the fishing season.

An examination of annual lease prices for Hoki quota in 1987 revealed that 14 trades were transacted in August at a price of about $20 per tonne when the main fishing season for Hoki had already finished , and when it was clear that catch would fall well short of the TAC. This annual lease price is approximately 4% to 5% of the estimated port price for Hoki.

In 1986/87 when the annual catch of Snapper in area 1 was only about 80% of total allowable catch, annual lease prices for the two Snapper quota trades in August averaged $1150 per tonne, which is about 30% of estimated port price. This is a surprisingly high figure given the existence of considerable quota excess-capacity, and suggests that the market was very poorly informed indeed. This could have occurred either because fishermen with a demand for quota were ignorant of the identity of those with surplus quota, or because they were not aware of the situation in aggregate.

5. Conclusions

According to conventional wisdom, ITQ prices should measure resource rents generated from the fishery. This view is in conflict with recently available empirical evidence from quota trading data for New Zealand fisheries. At least part of the difference can be explained by a more realistic theory of quota price determination which recognises that the fishing industry is not always in long-run equilibrium, and that account needs to be taken of the interaction between the asymmetric nature of marketing quotas and the stochastic environment facing fishing firms.

Nevertheless a number of puzzles remain, including in particular a strong suggestion that price discovery in the New Zealand quota trading market is being severely hindered by very poorly informed market participants. The reasons for this quite spectacular failure of arbitrage to equilibrate this market should be high on the research agenda for fishery economists. At least in the meantime, no great reliance should be put on quota trading prices as a guide to the size of resource rents generated from the fishery.

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FIGURE 1:
FISHING INDUSTRY COST CURVES
OPEN ACCESS'; TAC ONLY"; & OPTIMAL

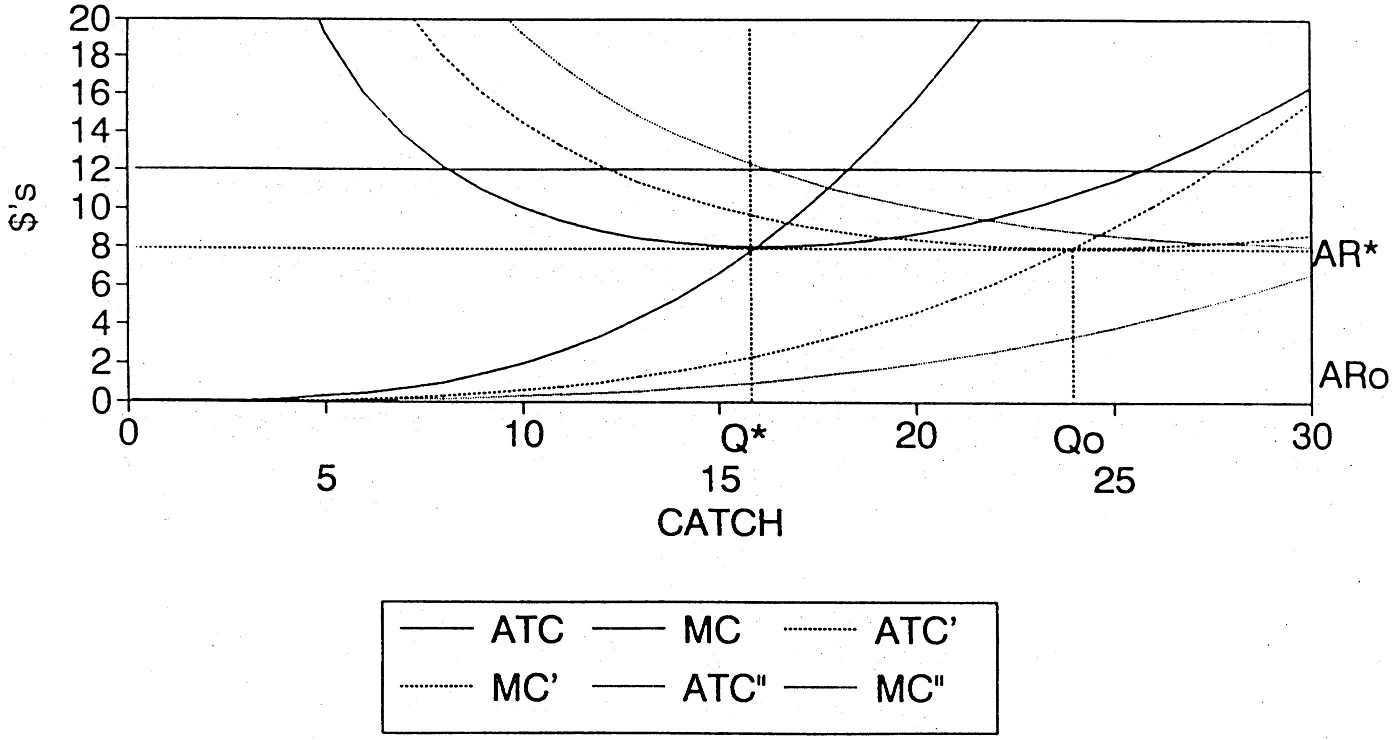

FIGURE 2:
FISHING INDUSTRY COST CURVES
ITQ PRICE = OPTIMAL RESOURCE RENT

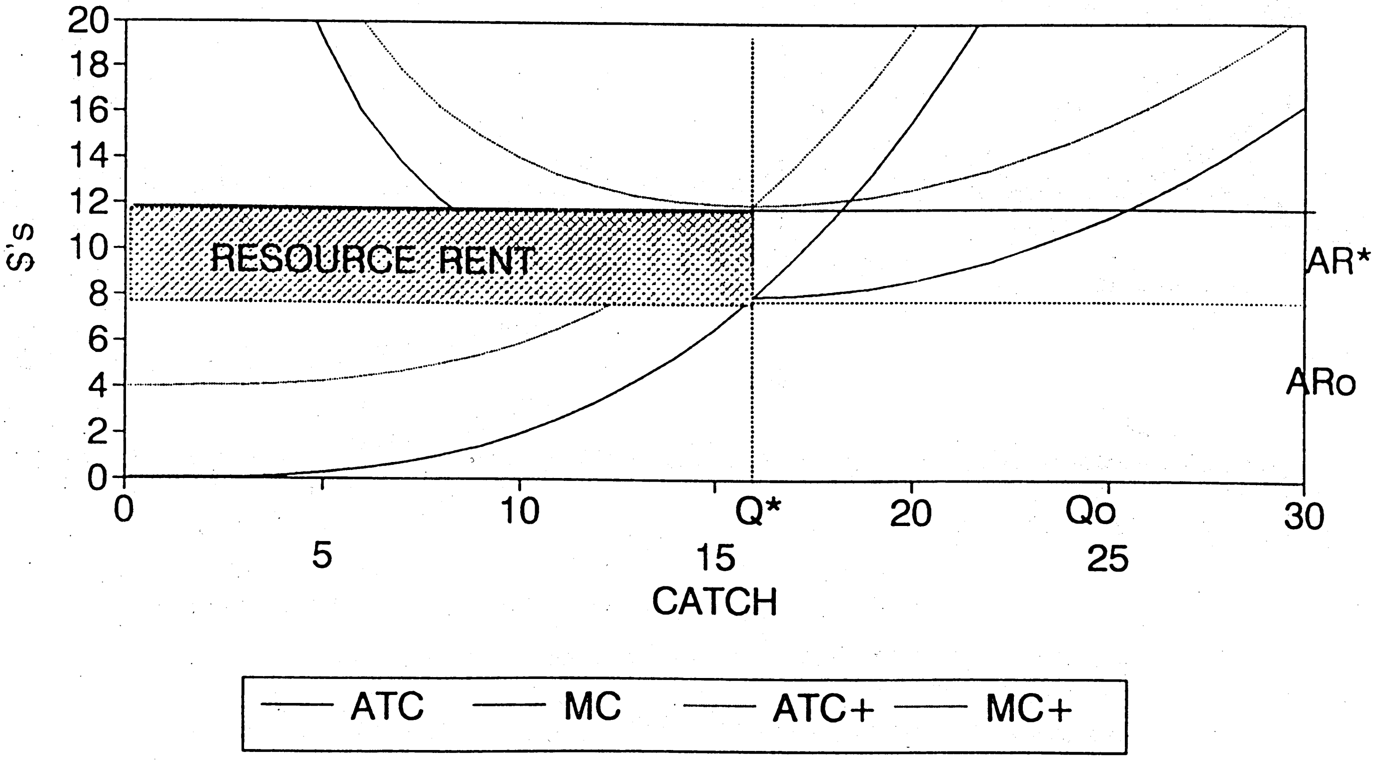

FIGURE 3:
TRADING DATA for SNAPPER #1
MONTHLY PRICES for QUOTA LEASE

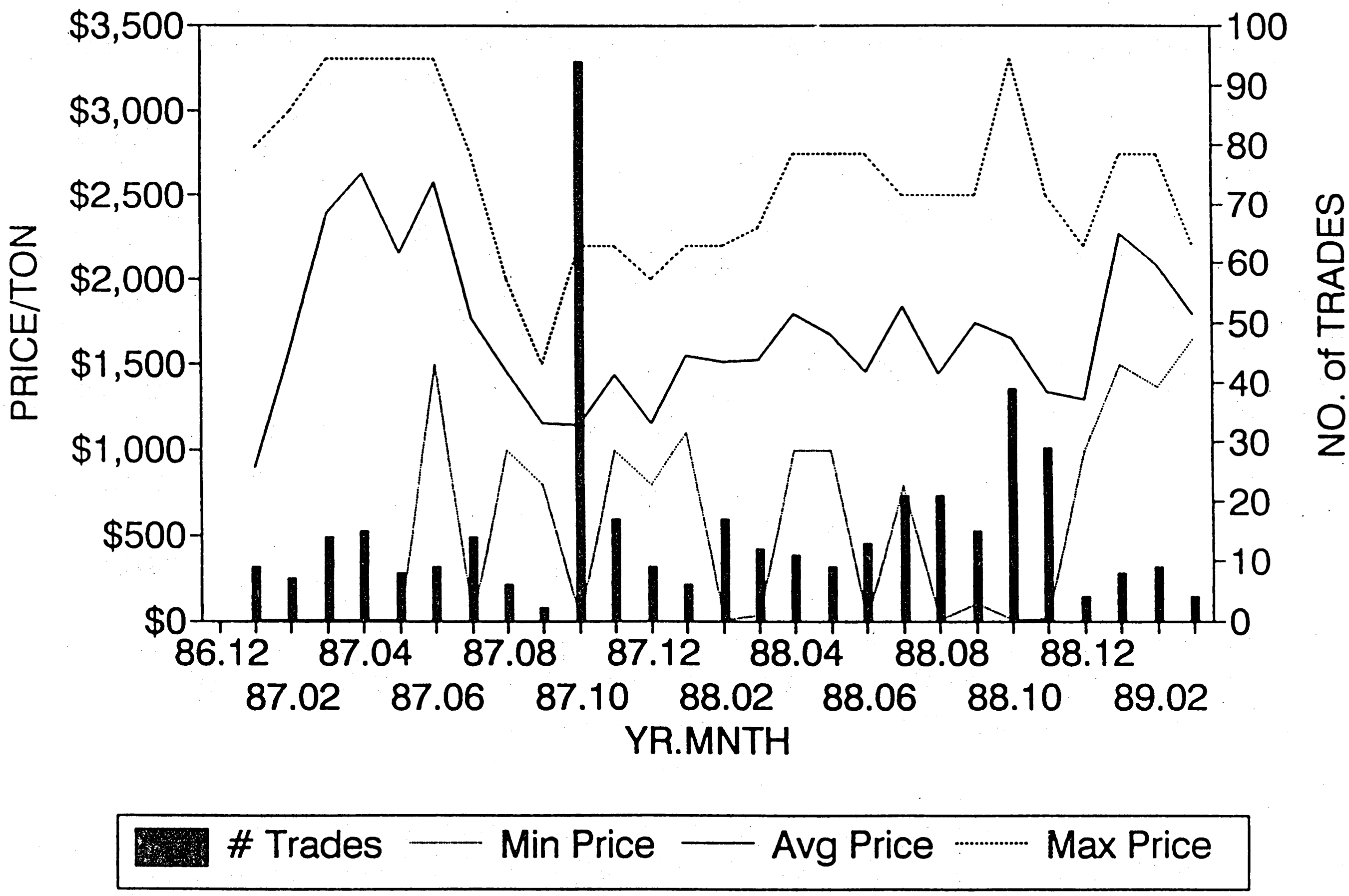

FIGURE 4:

TRADING DATA for SNAPPER #1

MONTHLY PRICES for PERPETUAL QUOTA

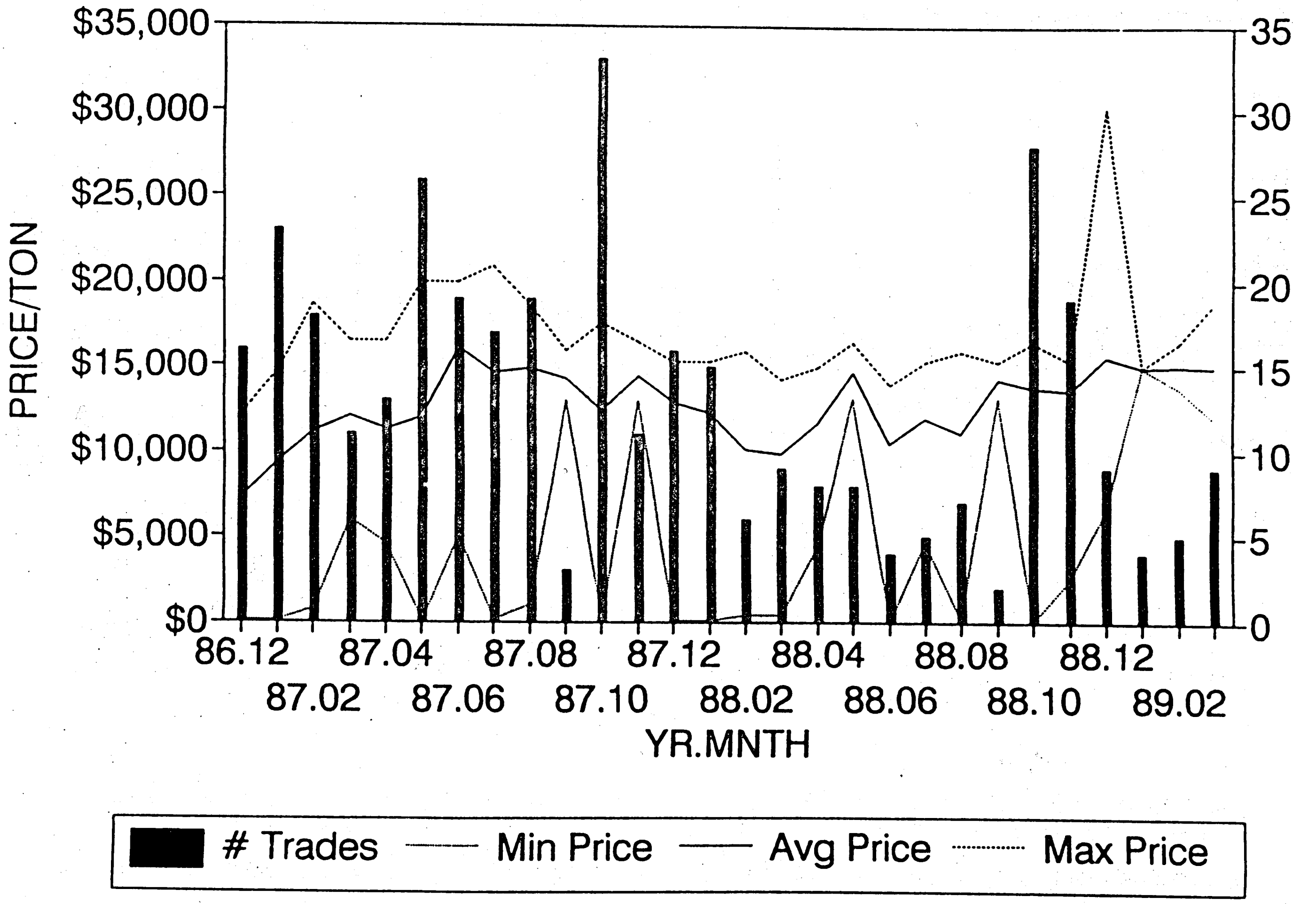

FIGURE 5:

TRADING DATA for HOKI

MONTHLY PRICES for QUOTA LEASE

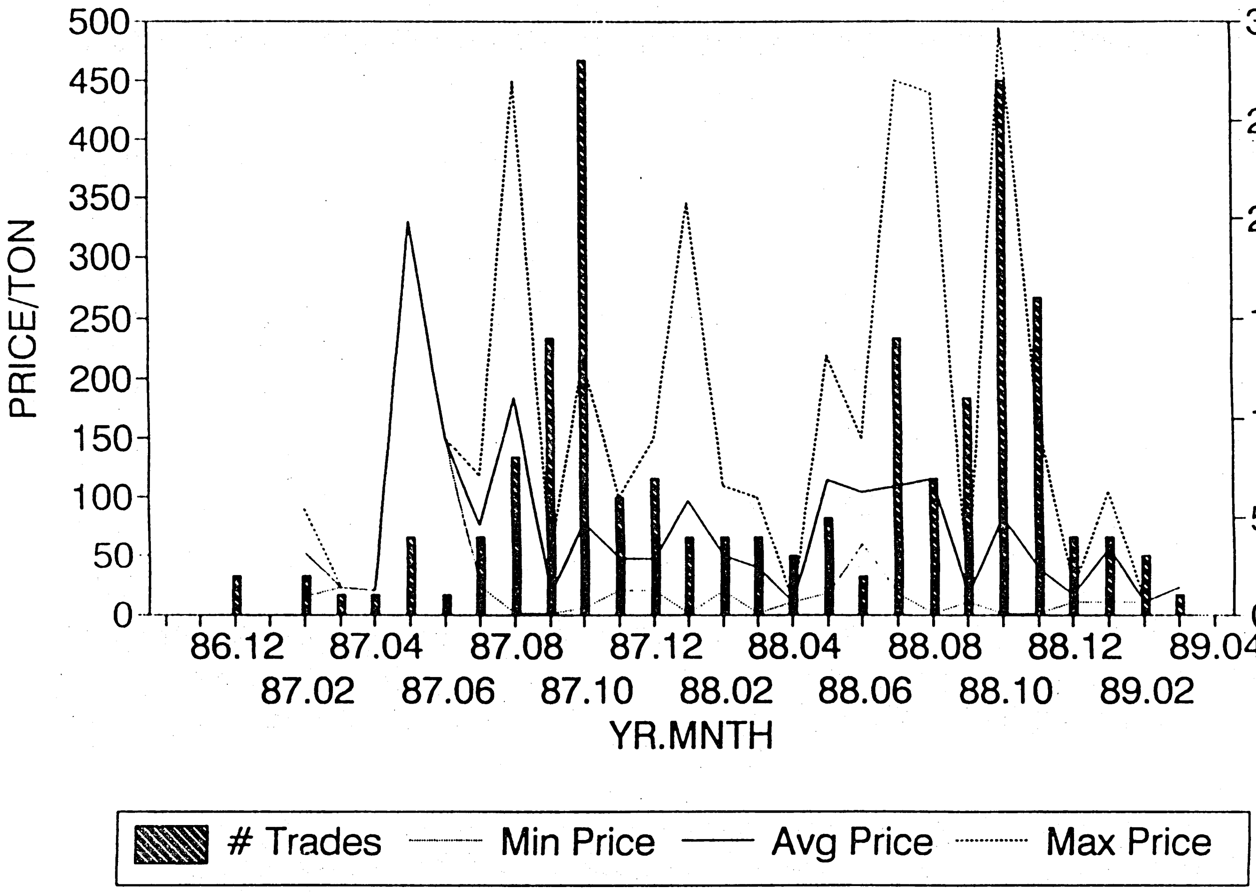

FIGURE 6:

TRADING DATA for HOKI

PERPETUAL QUOTA PRICES : 1986 to 1988

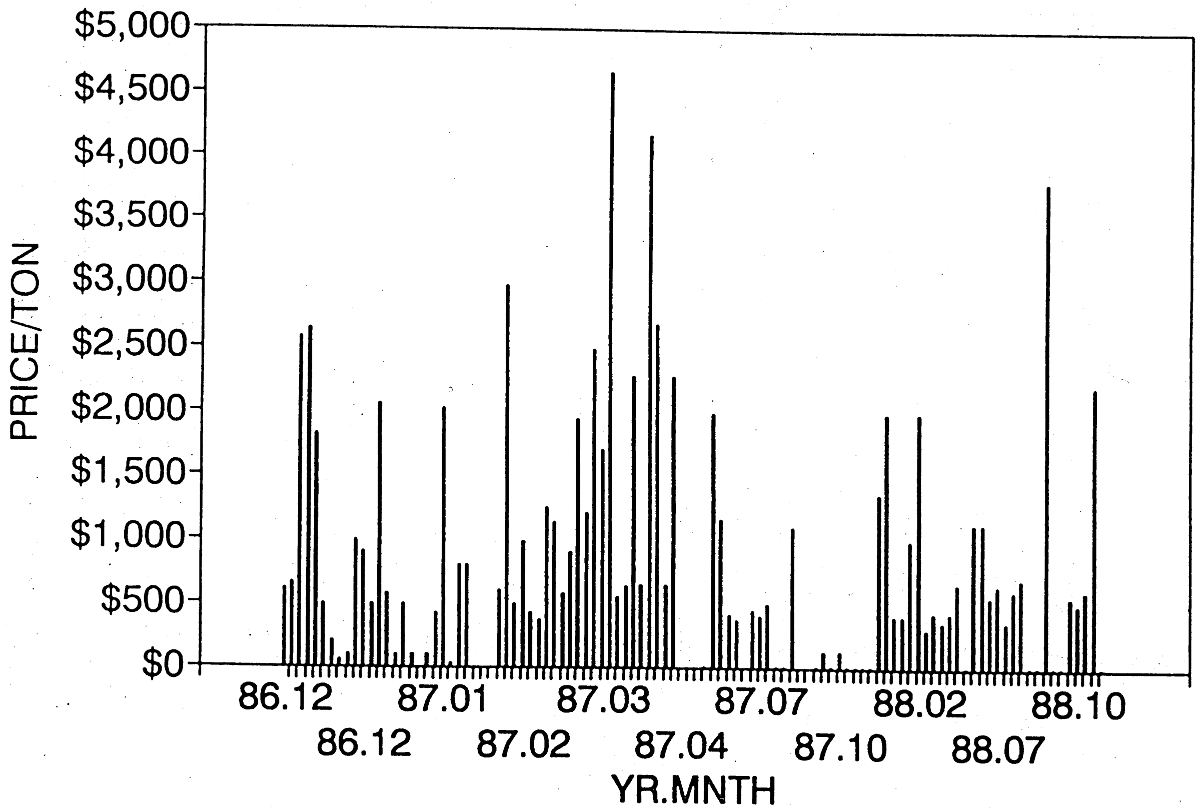

FIGURE 7:

TRADING DATA for TREVALLY #1

ANNUAL LEASE PRICES

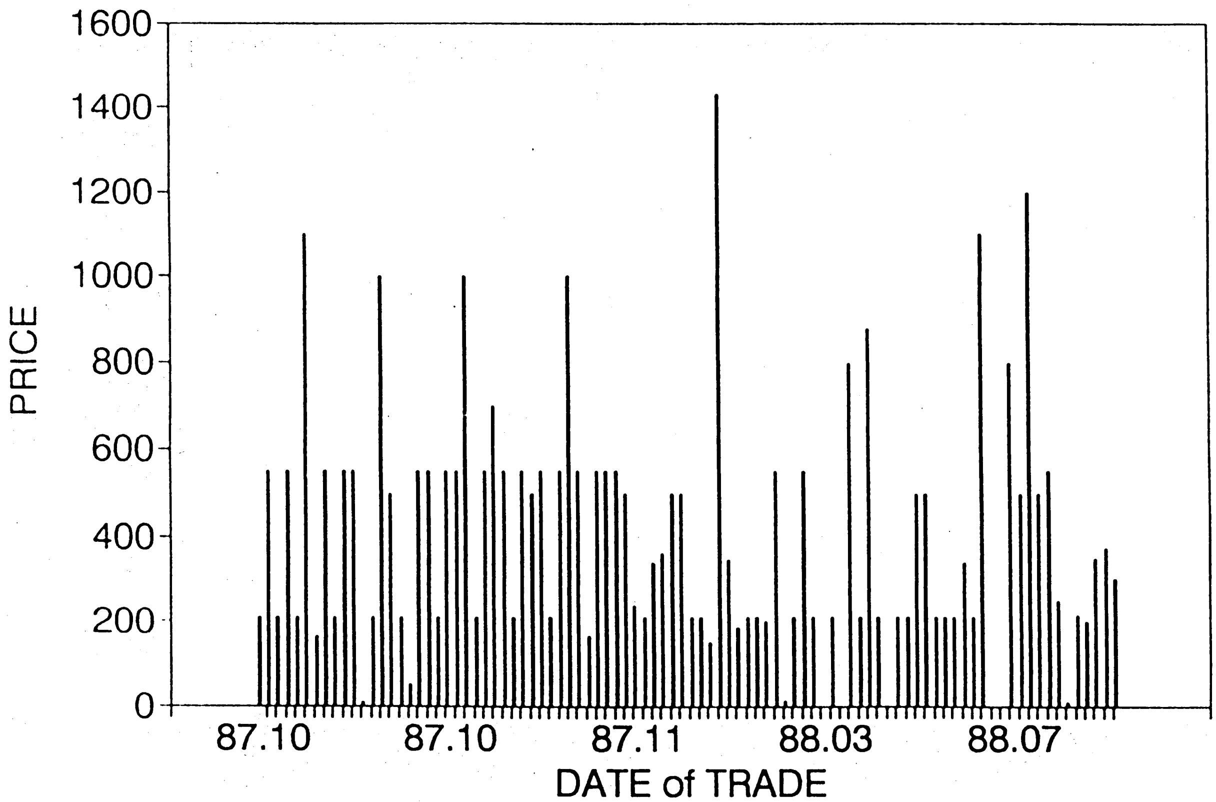

FIGURE 8:

TRADING DATA for SNAPPER #1

1987/88 QUOTA LEASE PRICES

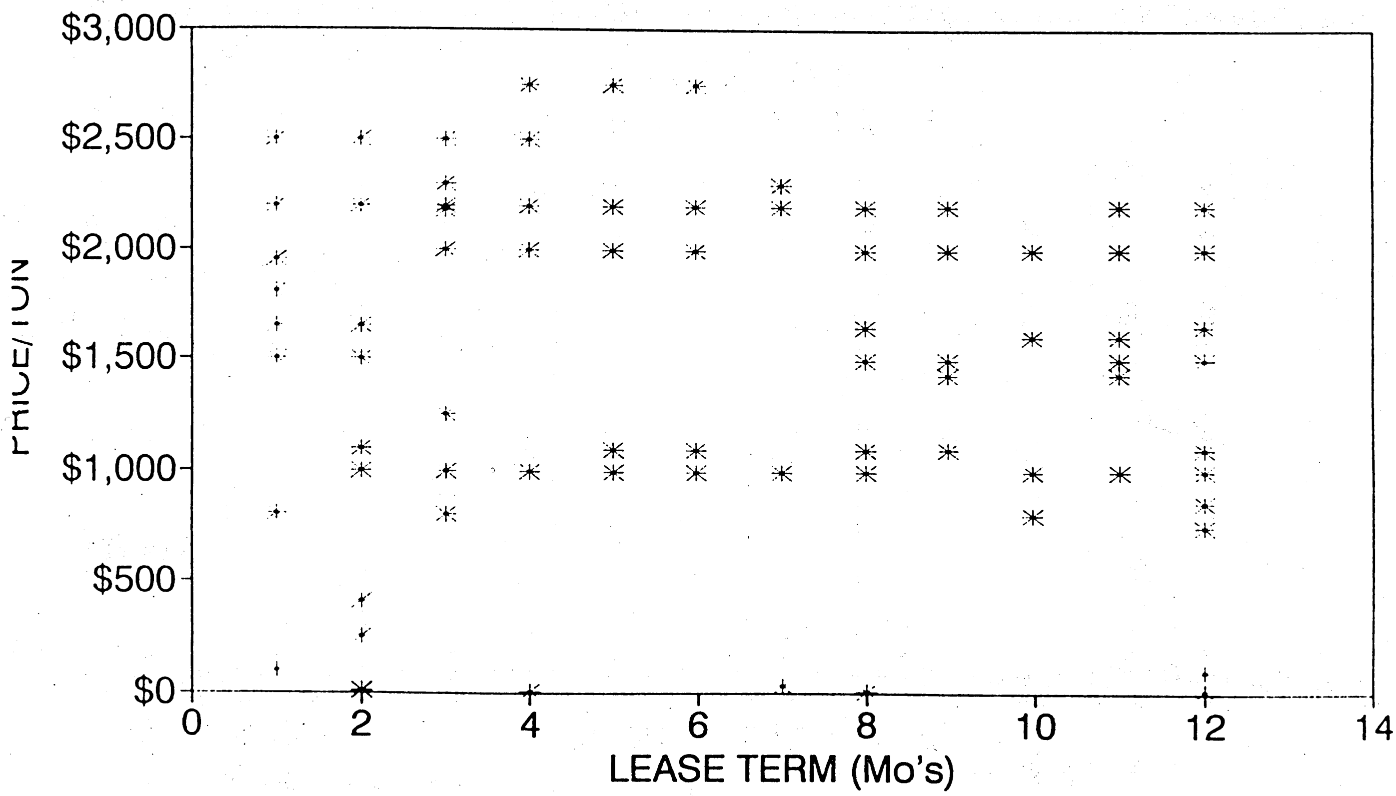

FIGURE 9:

TRADING DATA for SNAPPER #1

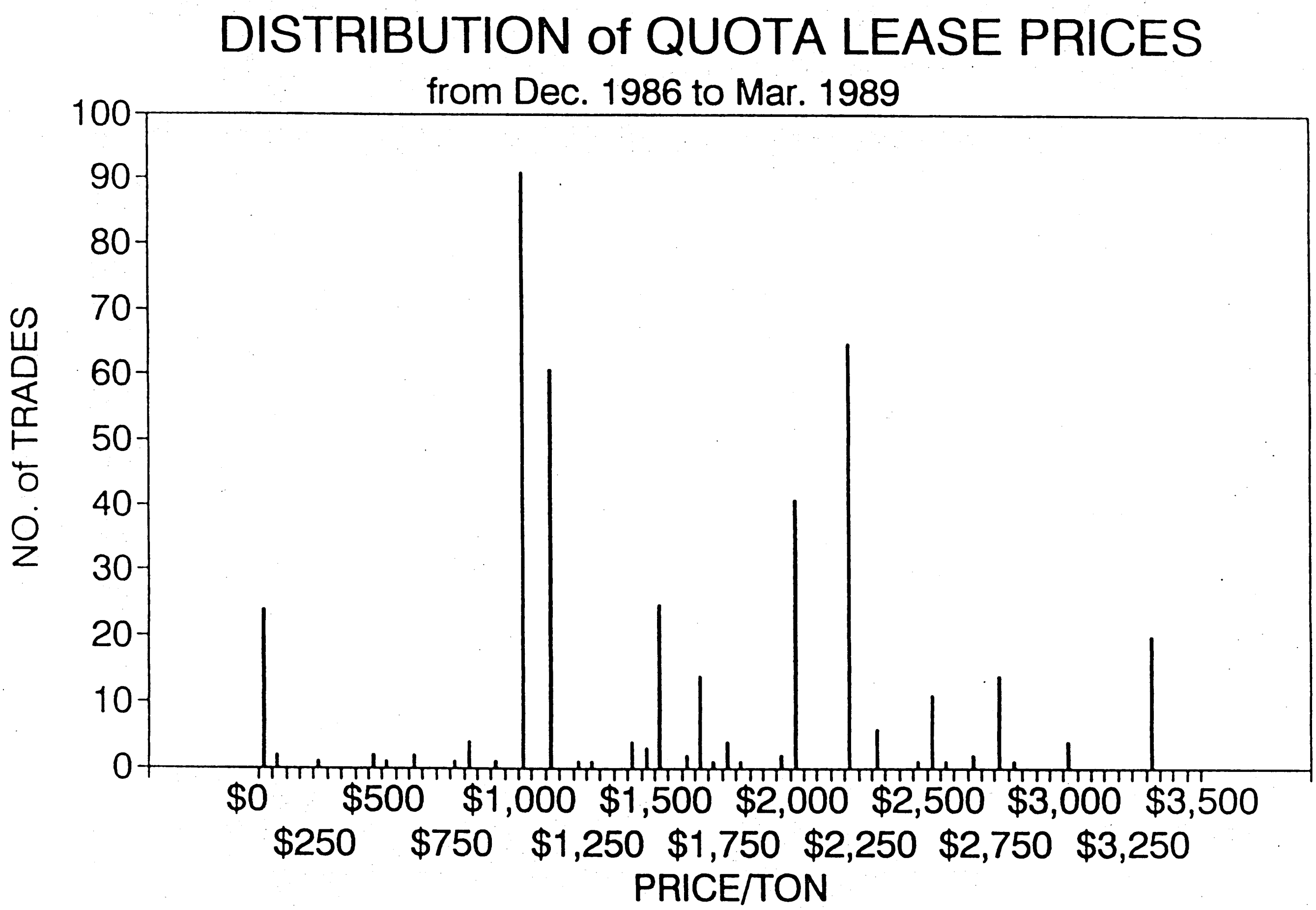

FIGURE 10 : EXCESS CAPACITY
QUOTA PRICING and RESOURCE RENTS

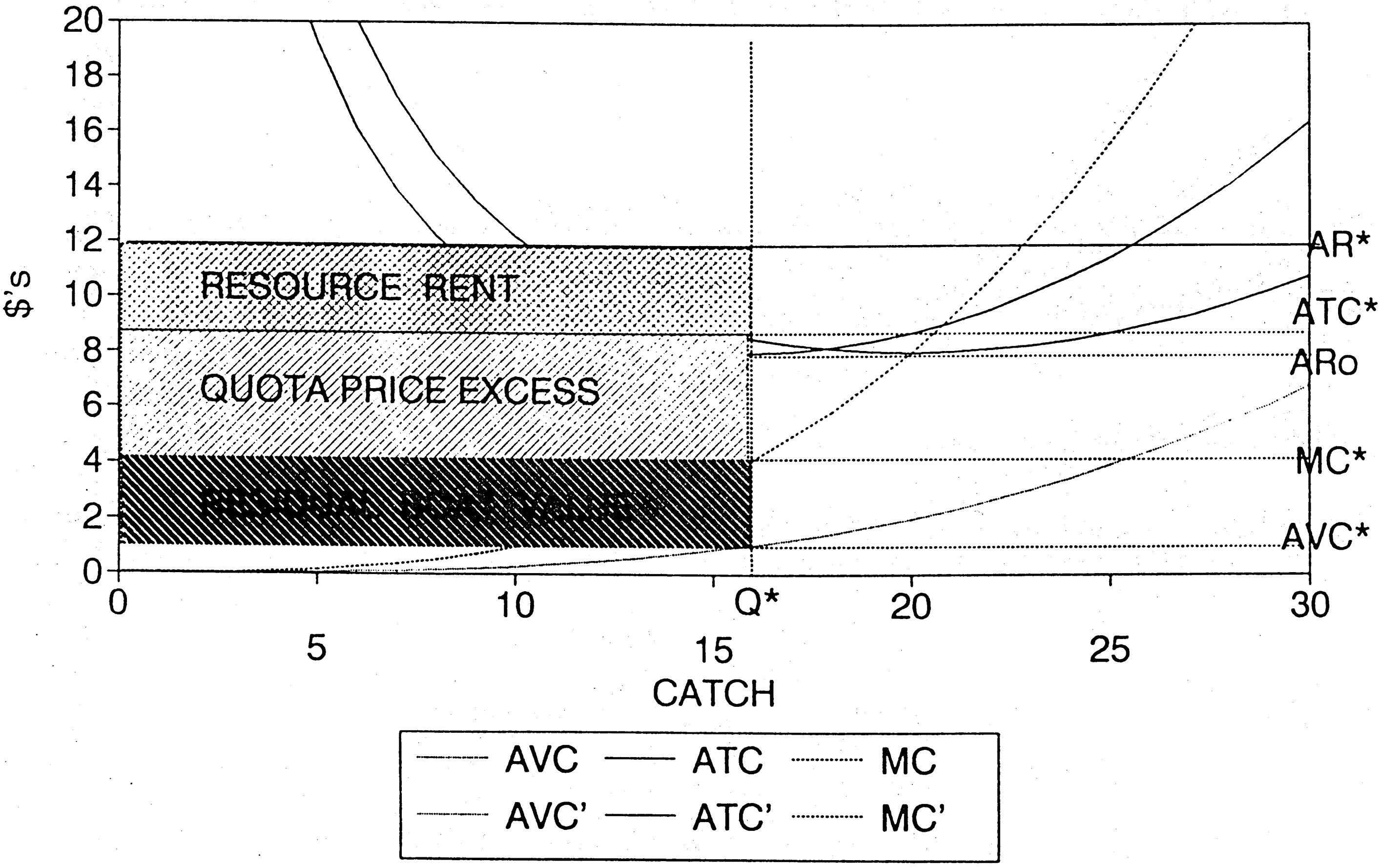

FIGURE 11: UNDER CAPACITY

QUOTA PRICING and RESOURCE RENTS

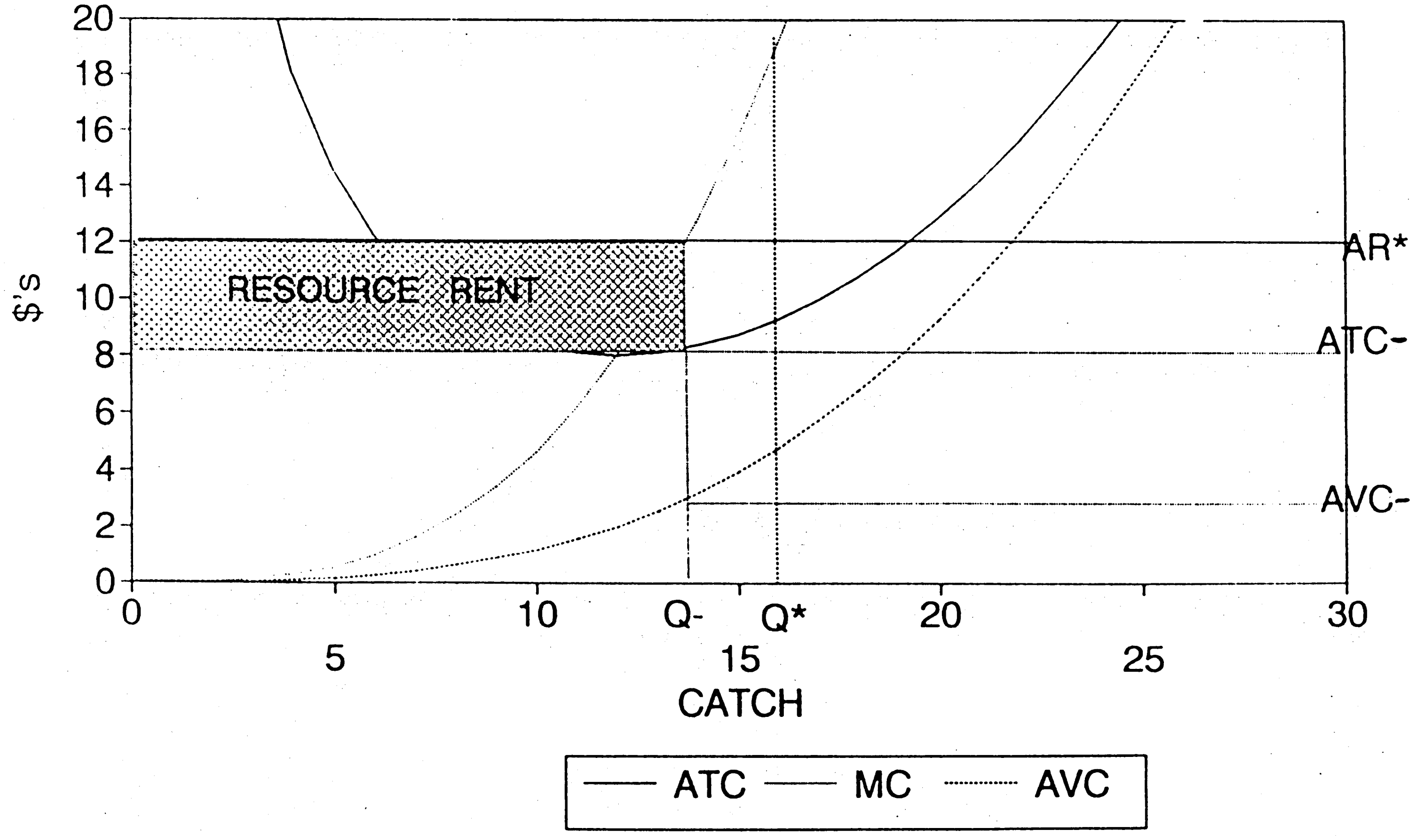

FIGURE 12: INDUSTRY COST CURVES
EFFECT of BAD and BUMPER YEARS

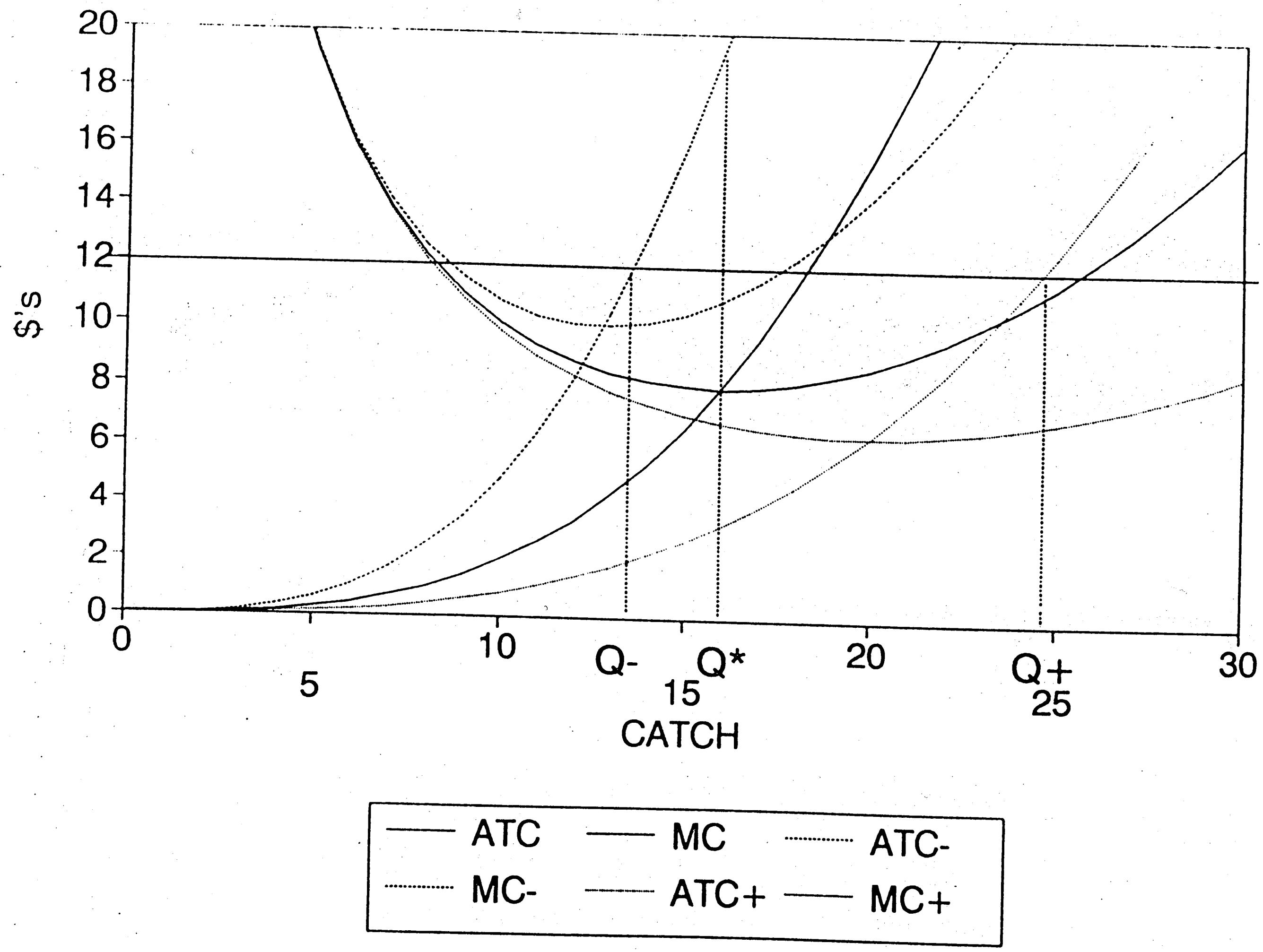

FIGURE 13: ITQ PRICES & RENTS
EFFECT of BAD and BUMPER YEARS

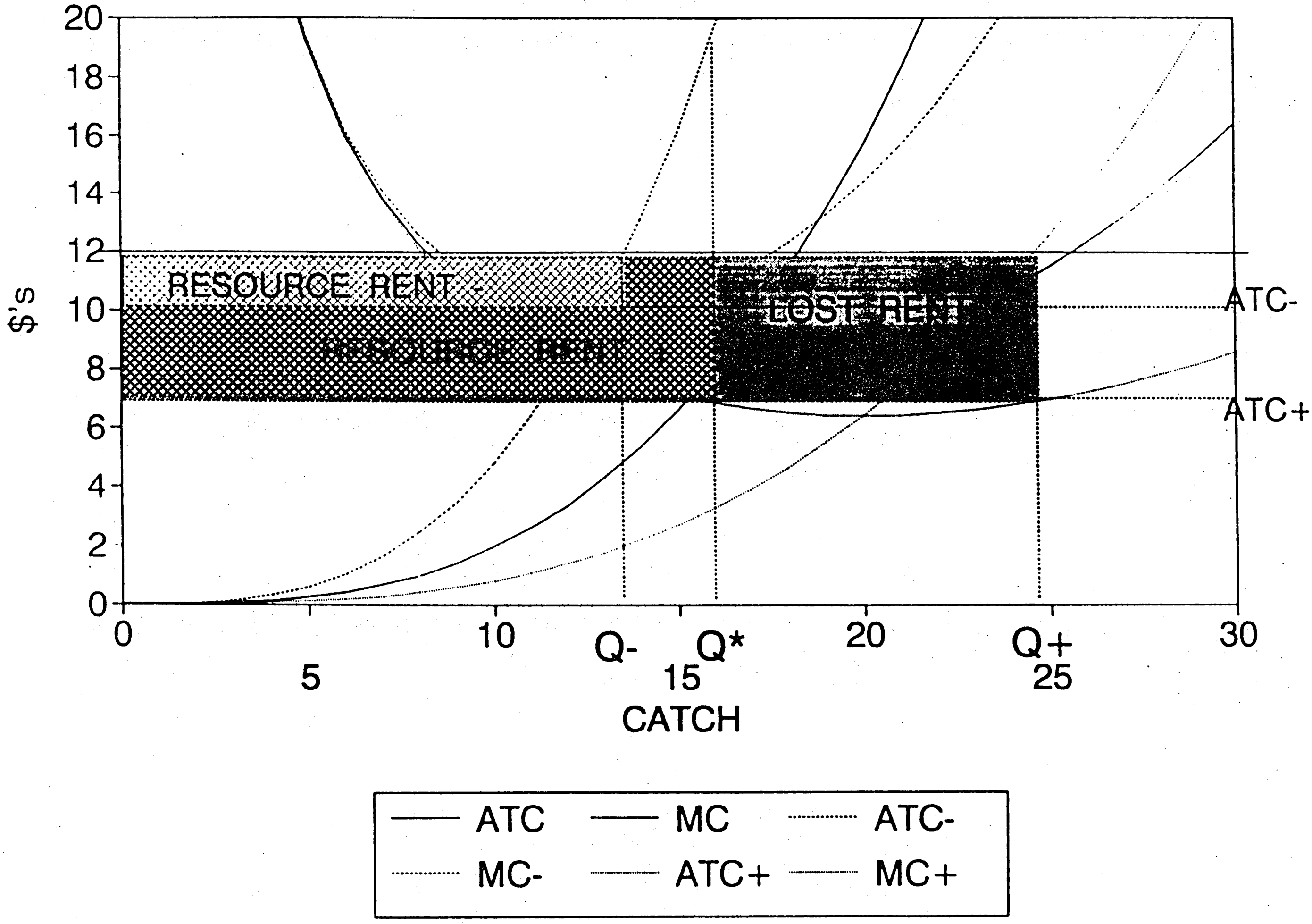

FIGURE 14: QUOTA LEASING PRICES
IN A "BAD YEAR"

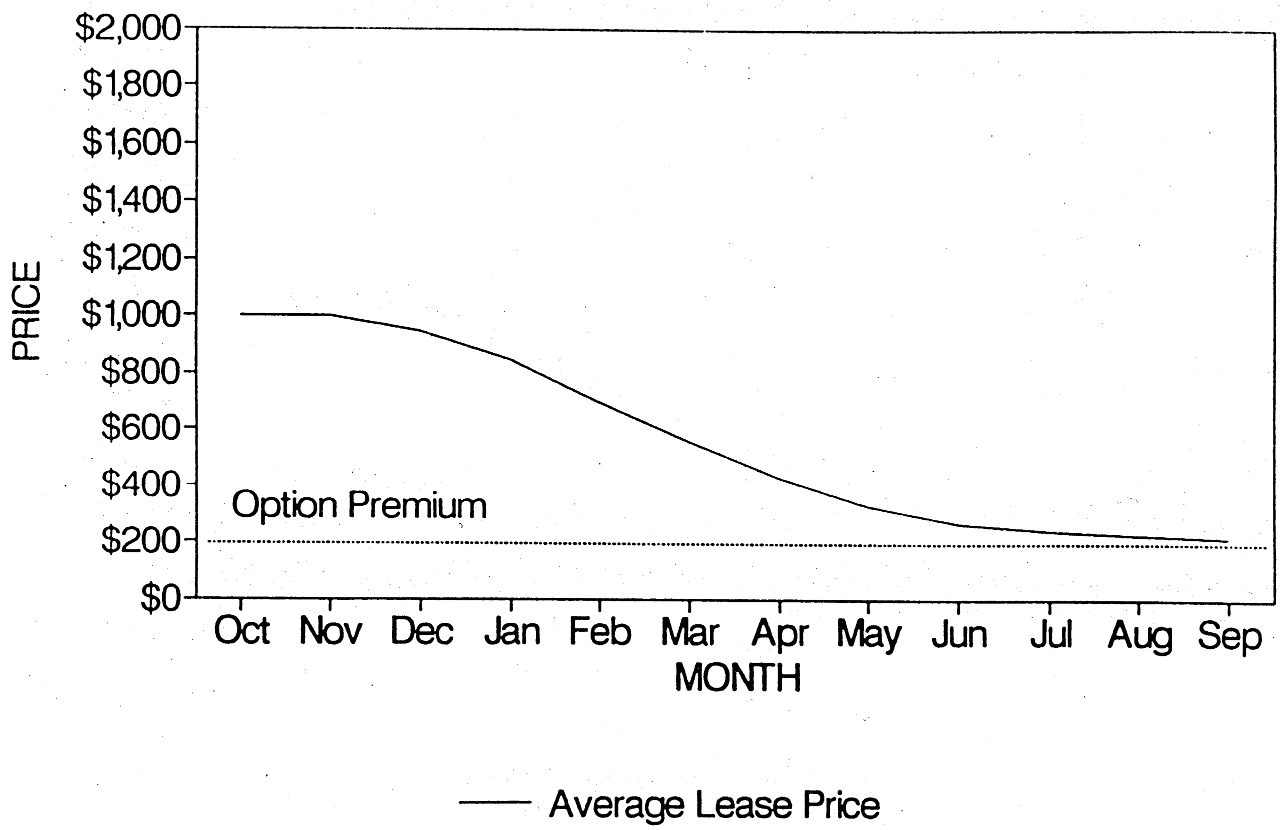

FIGURE 15: QUOTA LEASING PRICES
IN A "BUMPER YEAR"

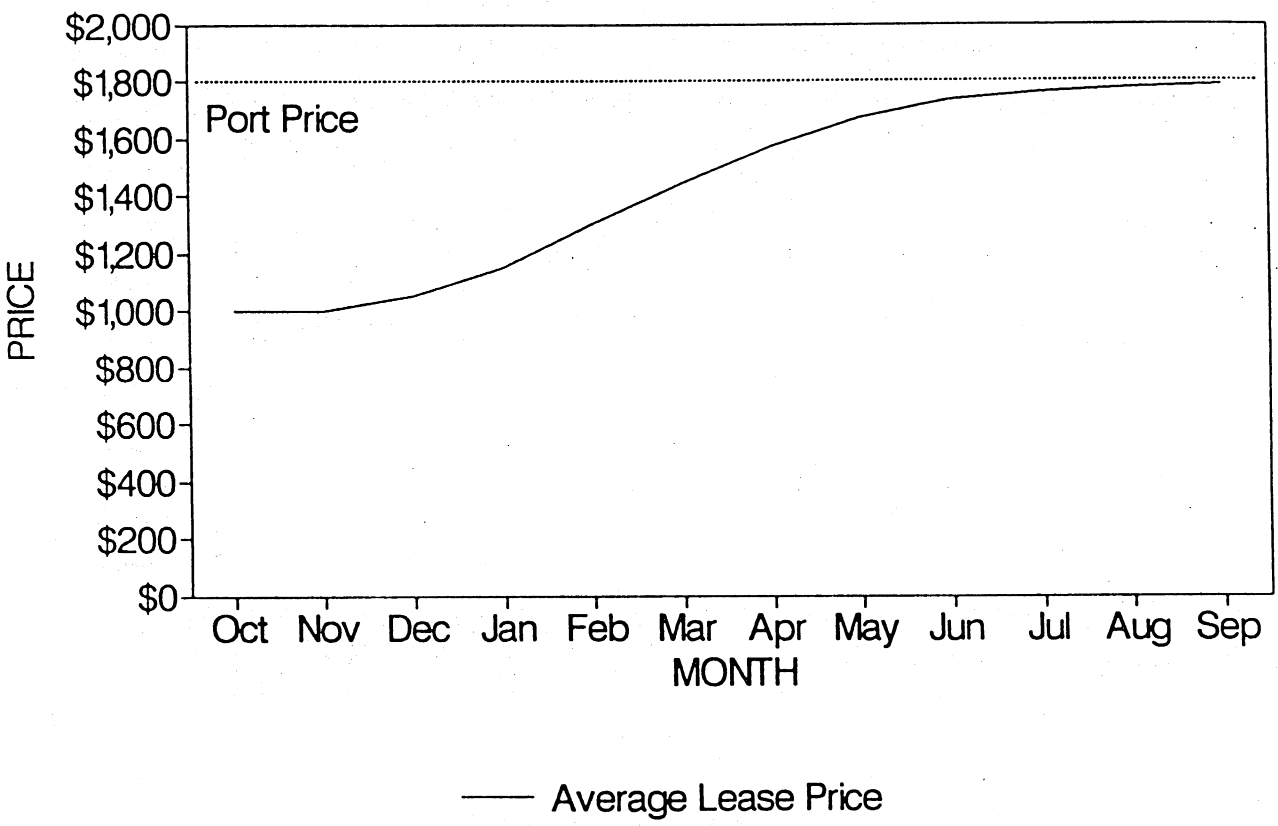

FIGURE 16:

TRADING DATA for SNAPPER #1

1987 QUOTA LEASE PRICES

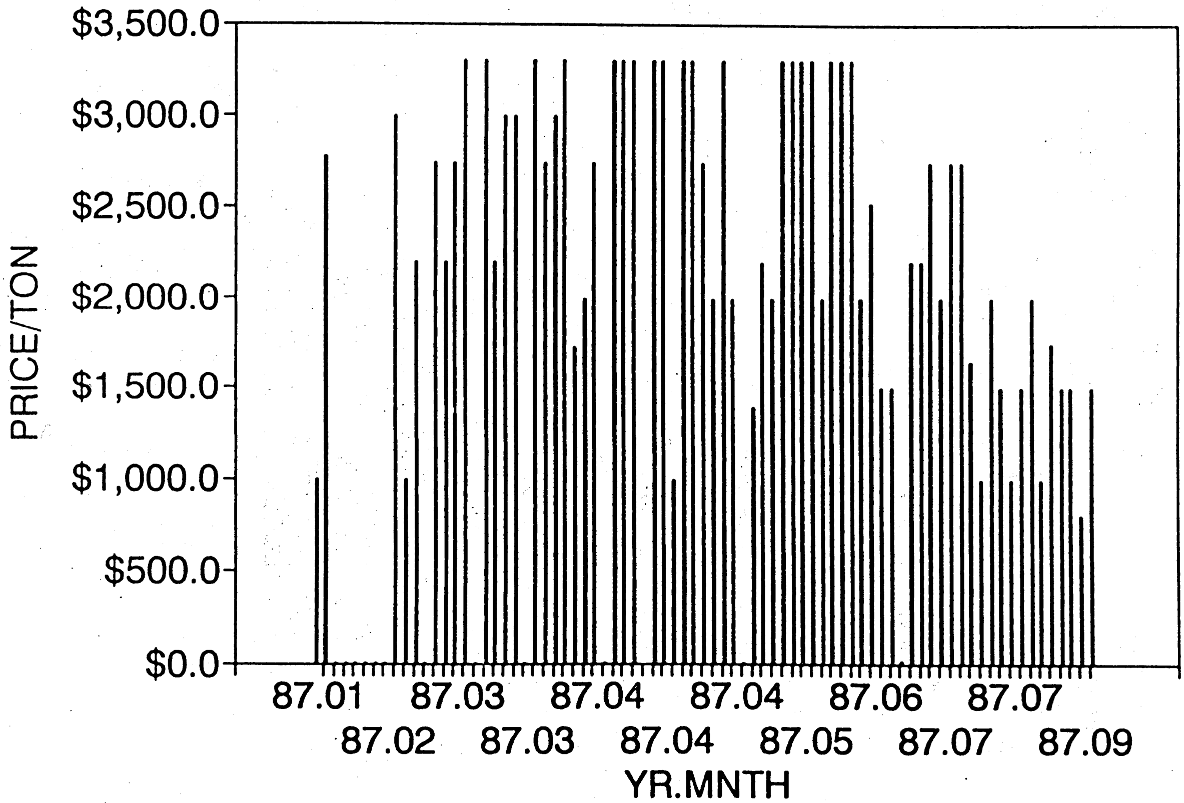

FIGURE 17:
TRADING DATA for SNAPPER #1
1987/88 QUOTA LEASE PRICES