

OBSERVING RECOVERY: THE ROLE OF IMPLICIT DISCOUNT RATES IN ITQ FISHERIES

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ABSTRACT

This paper discusses the potential application of implicit discount rates (IDR) derived from Individual Transferable Quota (ITQ) trading data as indicators of fishery bio-economic health. The theoretical background is discussed, and in the context of one New Zealand ITQ fishery we analyze the behavior of IDR over ten years of Total Allowable Catches (TACs). We find evidence of convergence of IDR toward the cost of capital over time and a statistically significant inverse relationship between IDR and stock biomass estimates. Further, there is evidence based in the statistical properties of time series of IDR and monthly stock biomass observations of a causal relationship flowing from biomass to IDR. These findings motivate discussion of the role of IDR as an observable condition in fisheries recovery. We note the potential to monitor and compare the progress of fishery recovery using the IDR statistic or derivatives that reflect its time path to long run values associated with the stock management goal. We argue that IDR provide the opportunity to aggregate fishers' tacit knowledge with models of bio-economic optima in understanding the recovery process.

Keywords: ITQ, implicit discount rates, indicator, complex systems

INTRODUCTION

Despite the importance of Individual Transferable Quotas (ITQ) in contemporary fisheries management, few studies exist that examine the problem of developing indicators for measuring the performance of fisheries policy. While a deserving focus is on halting stock declines, there appears to be an opportunity in understanding the progress of the fishery system once a recovery is underway.

In a previous paper we showed the applicability of Ragnar Arnason's minimum information concept [1] to the New Zealand Individual Transferable Share Quota (ITSQ) fisheries management system [2]. This paper considers evidence derived from ITSQ trading data. In a case study of the rock lobster fishery CRA1, time series analysis of monthly average lease and asset prices shows the asset title prices that reflect the long run future of the fishery are growing at a faster rate than the lease title prices that represent the short run. We find evidence of convergence of implicit discount rates (IDR) as revealed through ITSQ trading data toward the real cost of capital. We provide a theoretical foundation for the phenomenon and suggest that the statistic has potential use as a bio-economic management indicator for stock and fishery recovery in rights based management systems.

In 1991 the species rock lobster (*jasus dewardsii*) was introduced to the New Zealand Quota Management System (QMS). The structure of the QMS is an arrangement of entitlements to proportions of a biologically determined available annual harvest that is set by central government and distributed across commercial, non commercial, and indigenous (*tangata whenua*) sectors [3]. These proportional entitlements are tradable, leasable in the commercial sector only. The institutional setting that underpins this allocation involves a consultative process that includes the New Zealand Rock Lobster Management Group, the Ministry of Fisheries, and other stakeholders [4]. Statute requires that harvests are decided that direct the stock biomass toward the biomass that supports maximum sustainable yield.

Quota trading generates price-quantity data that can be used to develop statistics that can reflect the state of the system through the process of revealed preferences. Short run (annual) lease prices give an indication of immediate in-season profitability, long run asset prices are indicative of the future rents available in the fishery.

Theories of renewable resource use link optimal economic harvests outcomes to the cost of capital. High discount rates imply more severe harvesting regimes that favor present consumption over the future. In contrast low discount rates imply the opposite, a higher level of preference for the future over the present. Where natural systems management decisions are framed by the use of bio-economic models the choice of discount rates is crucial to modeling optimal outcomes. There are problems ascertaining the appropriate discount rates to adopt that reflect rates of preference that individuals hold. Rates may vary amongst individuals over time [5] and they may also vary across gender, age cohorts and cultures.

The availability of data detailing rights trading activity gives a view of the revealed preferences of the commercial sector in the New Zealand QMS. This paper considers implicit discount rates derived from ITSQ trading data for one New Zealand rock Lobster Fishery designated CRA1, for the period 1991 to 2001. The fishery has been selected on the merit of commercial harvest by one method, potting, which creates minimal technology externality.

The following section describes the development of our theoretical model which suggests three working hypotheses around behavior of the system as a recovery emerges: first that IDRs converge with the risk mediated cost of capital, second that implicit discount rates are inversely and significantly related to stock biomass levels, and that a causal relationship exists that flows from changes in stock biomass to implicit discount rates. These outcomes have policy applications in that differential rates of change in IDRs across similar (technically, ecologically, geographically) fisheries may be indicative of differing progress toward management goals, and IDRs are linked to stock biomass and are therefore an avenue for triangulation with other fisheries reference data in “diagnostic” processes.

The use of price data from ITQ trading records in the CRA1 fishery is ratified through demonstration of informational efficiency in those markets according to Fama’s Efficient Markets criteria [6]. Estimation of steady state models through time series techniques such as Autoregressive Distributed Lag (ADL) generates long run elasticities between allowable catches and ITQ prices. Fitting linear trends to time series of implicit discount rates from the CRA1 fishery and the cost of capital (rates of return on NZ Treasury 90 Day Bills) in real terms produces evidence of convergence. Estimation of a simple steady state model of the relationship between IDR and stock biomass generates evidence of a robust statistically significant relationship between the two; time series tests of causality show stock biomass Granger causes implicit discount rates.

THEORETICAL BACKGROUND

The starting point for the derivation of models for the economics of renewable resource use is defined in terms the growth rate of stock biomass (B) over time (t) given by,

$$\frac{dB}{dt} = F(B) - H(t) \quad (\text{Eq. 1})$$

where $F(B)$ is an expression for the stock biomass (often a logistic function) and $H(t)$ is the harvest in period t .

The profit maximizing level of stock biomass is derived from the profit maximization objective function of the harvester,

$$PV(\pi) = \int_0^{\infty} [P - C(B)] \left[F(B) - \dot{B} \right] e^{-\delta t} dt \quad (\text{Eq. 2})$$

where P = output price, $C(B)$ is the effect of stock biomass on costs, δ the discount rate, and \dot{B} the rate of growth of the stock. The solution may be expressed in terms of the rate of stock growth and the discount rate held by the harvester,

$$\dot{B} - \frac{C'(B) F(B)}{P - C(B)} = \delta \quad (\text{Eq. 3})$$

The first term in equation (3), \dot{B} , is the rate of growth of the stock biomass. The numerator of the second term, $C'(B) F(B)$, is the marginal stock effect or future effect of the stock on harvest profitability, and the denominator

$P - C(B)$ is the benefit from harvesting in the current period. As \dot{B} tends to zero, $\dot{B} - \frac{C'(B)F(B)}{P - C(B)}$ tends to the cost of capital: δ^* . In a surplus production fishery model with stock biomass less than that which supports maximum sustainable yield $\dot{B} - \frac{C'(B)F(B)}{P - C(B)}$ becomes smaller as the stock grows. This occurs because the level of annual sustainable production is density dependent, the stock growth rate slows, and the flow on externality effect diminishes. Conversely, if the stock level declines $\dot{B} - \frac{C'(B)F(B)}{P - C(B)}$ becomes larger and diverges from δ^* . These aspects form the basis for the expectation that at point of introduction of a species to the QMS the “own rate of interest” of the harvest will be larger than the cost of capital for three reasons. First, the lower stock biomass supports a higher \dot{B} for reasons of density dependence, and secondly the numerator of the second term, $C'(B)F(B)$ will be larger due to stock externalities associated with the prior regime of an input controlled, open access fishery. Lastly, operations financing will require higher rates of return over and above the cost of capital to meet industry risk premiums. There is biological data from the New Zealand rock lobster fisheries that show stock biomass declines have halted and that a recovery of stock levels toward B_{msy} is underway since the introduction of the species to the rights based output managed regime [4]. Accordingly we expect decline in both \dot{B} , the rate of stock biomass growth, and $\frac{C'(B)F(B)}{P - C(B)}$ the marginal stock effect. This should be evidenced by data that shows convergence of the “own rate of interest” associated with harvest toward the cost of capital.

Analytically the central problem associated with demonstrating this is to be able to derive estimates for the harvesters’ “own rate of interest” associated with the various stock biomass levels. This problem can be resolved where stocks are managed under a traded rights regime with a proportional as opposed to absolute rights specification, and where financial information is collected systematically on rights trading. In the context of New Zealand’s rights-based regime the principal functions of fisheries management include monitoring the state of fish stocks, setting the TAC and the total allowable commercial catch (TACC), controls on fishing methods, and administering and enforcing the laws that underpin the management regime [7]. Maximum sustainable yield (MSY) is derived from the use of specialized logistic functions to model the density dependant behavior of fish stocks.

Information generated in quota markets depends *inter alia* on the legal foundations of fisheries policy. In New Zealand’s case, legislation establishes MSY as the reference point for stock management. The central idea behind Arnason’s [8] minimum information system is that quota prices summarize all relevant information about fishers’ current and expected conditions in the fishery. The time path of quota price depends on optimal quota holdings for each firm, the marginal cost of effort, the initial biomass and two exogenous variables, the price of fish p and the discount rate δ . In theory, the problem of discovering optimal holdings is resolved in the market so asset prices represent the present value of future rents in the fishery and lease prices annual profitability.

Batstone & Sharp [2] provide evidence of the applicability of Arnason’s minimum information ideas to a functioning ITSQ system. This system provides a basis for developing three indicators to monitor the outcomes of fisheries policy and guide decision-making, asset (long run) and lease (annual) prices, and the ratio of the two, the implicit discount rate. In theory the optimal decision rule is to harvest (refrain from harvest) the resource until the proportionate rate of growth of the stock (the “own rate of interest”) equals the discount rate. Thus, it is informative to compare the opportunity cost of capital in the economy with the implicit discount rate in the fishery. Implicit discount rates in an ITSQ fishery are revealed by a ratio of annual lease price to the asset price. The implicit discount rate at time t , \hat{r}_t is defined as $\hat{r}_t = \frac{l_t}{a_t}$ where l_t and a_t are asset lease prices respectively.

HYPOTHESES

We specify two linear time trend models accounting for monthly seasonality for two series, implicit discount rates (\hat{r}_t) and real 90 day bill rates (δ_t) as

$$\hat{r}_t = \alpha + \beta T_t + \sum_{i=1}^{i=11} \gamma_i M_i \quad (\text{Eq. 4})$$

$$\delta_t = \kappa + \theta T_t + \sum_{i=1}^{i=11} \xi_i M_i \quad (\text{Eq. 5})$$

Where $\alpha, \beta, \gamma, \kappa, \theta, \xi$ are regression coefficients, T_t a time variable measured in days from the first CRA1 ITQ trade, and $M_{i,t}$ 11 monthly seasonal dummy variables.

At time $t = 0$, the point of introduction of rock lobster fisheries into the QMS we expect $\hat{r}_0 > \delta_0$ because the IDR is inversely related to stock levels and the degree of uncertainty over the operation of the QMS.

For $\hat{r}_0 \rightarrow \delta_0$, either the entire expression or separately, $\frac{C'(B) F(B)}{P - C(B)}$ and or \dot{B} must become smaller.

To demonstrate potential convergence we can econometrically test the following hypothesis:

$$H_0^1: \beta > \theta$$

$$H_A^1: \beta \leq \theta$$

While this test does not demonstrate convergence to the point of some common set of values it may demonstrate initially at least a trend toward convergence.

Confirmation may be obtained by regressing the difference between the \hat{r}_0 and δ_0 series on the time trend and monthly dummy variables:

$$\left(\hat{r}_t - \delta_t \right) = \eta + \phi T_t + \sum_{i=1}^{i=11} \chi_i M_i \quad (\text{Eq. 6})$$

$$H_0^2: \phi < 0$$

$$H_A^2: \phi \geq 0$$

To demonstrate convergence we expect the coefficient on the time trend of the difference between the two series to be statistically significant and negative. This approach to testing for convergence is based in the work of Bernard & Durlauf [9]. In terms of those author's "Definition Two" convergence is defined as the equality of long term forecasts at a fixed time. Two series converge if the long term forecasts for both series are equal at some fixed time t in the future. This definition is conditional upon certain time series properties of the difference series. Specifically, if the difference series contains either non-zero mean or a unit root then the above conditions for convergence are violated. Another perspective [10] nominates a "catching up" process in which there is evidence of a non-zero mean, but absence of evidence of a unit root and the time trend in the deterministic process tends to narrow the gap between the two series without an actual convergence.

Two further testable hypotheses derive from Eq 3. First, that the IDR and stock biomass variables are inversely related, and that the flow of causation in the association is from stock biomass to the IDR. Data are available on three variables that may contribute to an econometric time series model of the IDR: real interest rates as a proxy for costs, stock biomass from stock assessment processes and output prices as a proxy for revenue.

A steady state model of IDR formation in stochastic log form is,

$$idr_t = \alpha_0 + \alpha_1 r_t + \alpha_2 b_t + \alpha_3 p_t + u_t \quad (\text{Eq. 7})$$

α_n are estimated long run elasticities, and $r_t ; b_t ; p_t ; idr_t$ are logs of implicit discount rate, real interest rate, stock biomass and output prices respectively. u_t is the stochastic error term. In order to demonstrate a relationship between idr_t and b_t , the following hypothesis is proposed:

$$H_0^3 : \alpha_2 < 0$$

$$H_A^3 : \alpha_2 \geq 0$$

Granger Causality exists when lagged values of a variable x_t have explanatory power in a regression of a variable y_t on lagged values of y_t and x_t [11]. The last hypothesis to be tested in this analysis is:

$$H_0^4 : b \text{ Granger causes } idr$$

$$H_A^4 : b \text{ does not Granger cause } idr$$

DATA AND ANALYSIS

Figure 1 shows the growth in the New Zealand NSN *jasus edwardsii* stock following QMS implementation in 1991 through time series of annual biomass estimates for the CRA1 fishery.

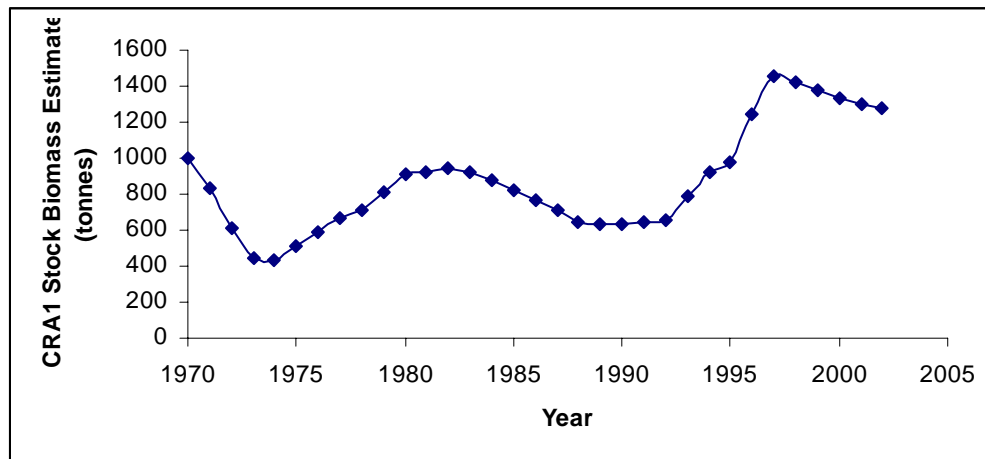


Figure 1: CRA 1 Estimated Stock Biomass 1970 – 2004 (Source: NIWA, NZ [12])

On this basis we make the assumption that the stock decline has been halted and the fishery is making steps toward recovery. As stock recovery strategies take effect harvest costs decline and the value of ITQ rights should increase. Since stock abundance is increasing, the slope of the surplus production function decreases as stock biomass increases. In turn, we would expect IDR to decline.

ITQ trading data echoes these sentiments. Figure 2 describes CRA1 ITQ monthly average prices in 1990 NZ\$ terms for the period June 1990 to April 2001 for the months where trades in both lease and asset markets are evident. The underlying individual transaction series are integrated of order 1 (I1), and there is evidence of cointegration between lease and asset prices series (Johansen quadratic trend, $p < 0.05$). De-trending and de-seasonalizing lease and asset prices confirms the relationship between asset and lease prices. In terms of price determination irregularities arising from market illiquidity issues, two of Fama's [6] three market efficiency characteristics are present: prices follow random walks and there exists evidence of an underlying relationship between an asset and its return.

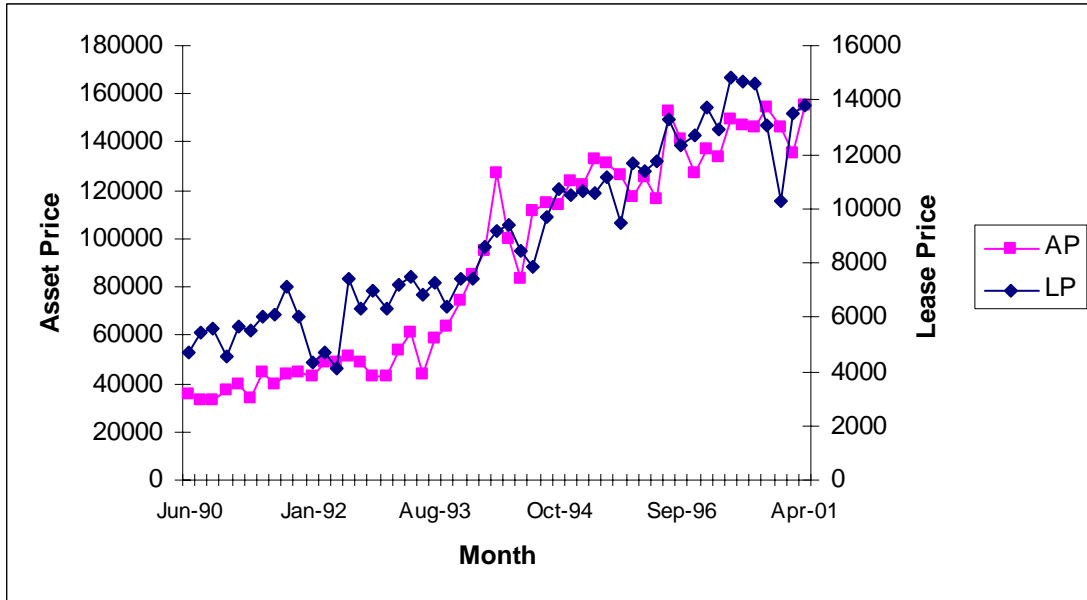


Figure 2: CRA1 ITQ monthly average prices in 1990 NZ\$ terms for the period June 1990 to April 2001 (Source data: NZ Ministry of Fisheries)

Gathering further data on output prices enables estimation of the system elasticities through time series multivariate modeling [2]. In this market system the elasticity between TACC and asset price is of the order of -1.4% ($p < 0.05$) and lease and asset prices of the order of $+0.64\%$ ($p < 0.05$) measured with asset price as the response variable.

Fitting linear trends to the data shows that asset prices are growing at a faster rate than lease price prices (Figure 3). Prices that reflect the long term future of the fishery are growing at a faster rate than those that reflect short term (annual) profitability. The implication is that the IDR will converge or co-integrate with the cost of capital as the high risk premium and required rates of return associated with open access fisheries are replaced by risk reduction enabled by stock recovery strategies derived and refined in multi-sector consultative processes of the NZ Rock Lobster Management Group.

Implicit discount rates for the CRA1 fishery are described in Figure 4 along with real rates of return on NZ Treasury 90 day bills. Linear trends have been fitted whose slope coefficients are of magnitude -0.0014 and -0.0005 respectively. The long run trend in both in these series is for decline; with the fishery IDR declining at a rate faster than the return on 90 day bank bills.

Other avenues to modeling the relationship between IDR and real interest rates are described in (Eq. 4) and (Eq. 5). The outcomes of estimating those equations are presented in Tables I and II. The two coefficients of interest are those on the time trend (T) variable in each estimation. β , the coefficient on the time trend the implicit discount rate equation is negative and statistically significant, while θ , the coefficient on the time trend variable in the 90 day bill rate equation is negative, and not statistically significant. On this basis we are unable to reject $H_A^1 \beta \leq \theta$ ($p < 0.05$), so turn to confirmation by estimating (Eq. 6). Table III describes the outcomes.

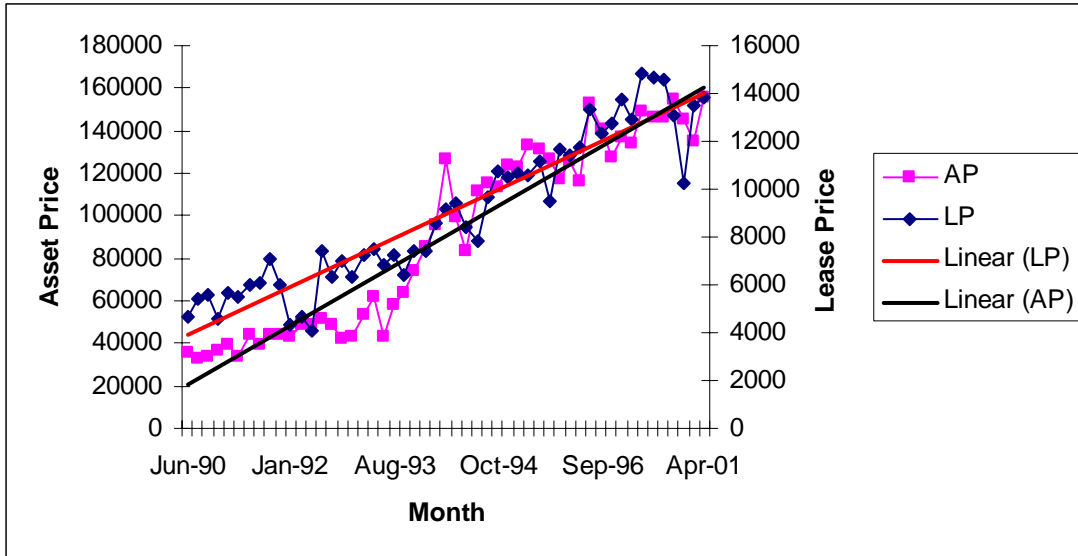


Figure 3: Linear Trends CRA1 ITQ Prices

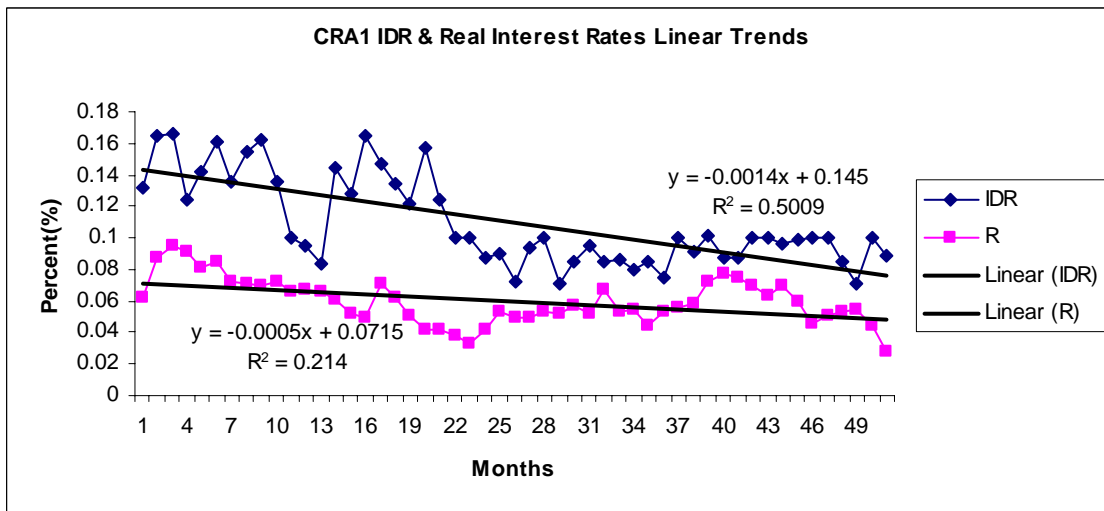


Figure 4: CRA1 IDR & Real Interest Rates Linear Trends

The estimate of ϕ is negative and statistically significant ($p < 0.05$). The interpretation is that the difference between the two series $\left(\hat{r}_t - \delta_t \right)$ grows smaller at an estimated linear rate of 0.00112 percent per calendar day.

Accordingly we can reject $H_A^2 : \phi \geq 0$ and accept $H_0^2 : \phi < 0$ as evidence of convergence of the two series.

Although there is evidence as to convergence of the two series, the coefficient on the time trend associated with the difference series is very small, suggesting convergence many years in the future. This artifact brings us to test these findings in terms of Bernard & Durlauf's [9] Proposition Two.

Table I: $\hat{r}_t = \alpha + \beta T_t + \sum_{i=1}^{i=11} \gamma_i M_i$ Estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
T	-1.49E-05	5.75E-06	-2.582748	0.0137
JAN	0.122171	0.023474	5.204567	0.0000
FEB	0.112189	0.026446	4.242186	0.0001
MAR	0.116806	0.019510	5.986881	0.0000
APR	0.143427	0.018102	7.923082	0.0000
MAY	0.128112	0.021780	5.882029	0.0000
JUN	0.131277	0.017222	7.622752	0.0000
JUL	0.137981	0.016205	8.514781	0.0000
AUG	0.132700	0.018746	7.078945	0.0000
SEPT	0.116628	0.021880	5.330319	0.0000
OCT	0.142297	0.017617	8.077355	0.0000
NOV	0.134573	0.025920	5.191949	0.0000
R-squared	0.640424	Durbin-Watson stat		1.663448
N	51			

We are able to reject the presence of a unit root in the log of the difference series ($p=0.03$, trend model) but note that in two other models of the Augmented Dickey Fuller (ADF) test we are unable to reject the hypothesis of a unit root. Further, the difference series has a non zero mean. Estimation of (Eq. 7) is reported in Table IV. While explanatory power is low, the coefficient on the stock biomass variable is negative and statistically significant. The coefficient on the real interest rate variable is close to significance and positive in sign. There is no evidence of a connection between

Table II: $\hat{\delta}_t = \kappa + \theta T_t + \sum_{i=1}^{i=11} \xi_i M_i$ Estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
T	-3.68E-06	3.50E-06	-1.048996	0.3006
JAN	0.061571	0.014295	4.307324	0.0001
FEB	0.053650	0.016105	3.331377	0.0019
MAR	0.062401	0.011881	5.252204	0.0000
APR	0.065405	0.011024	5.933190	0.0000
MAY	0.064789	0.013263	4.884879	0.0000
JUN	0.059011	0.010487	5.626902	0.0000
JUL	0.065991	0.009868	6.687298	0.0000
AUG	0.065187	0.011415	5.710517	0.0000
SEPT	0.063749	0.013324	4.784509	0.0000
OCT	0.067526	0.010728	6.294447	0.0000
NOV	0.082463	0.015784	5.224519	0.0000
R-squared	0.806398	Mean dependent var		0.059670
N	51	Durbin-Watson stat		1.338610

output price and IDR. The low value of the DW statistic implies serial correlation in the error term, accordingly the robustness of the model is tested by estimation with AR1 errors as reported in Table V.

Table III: $\left(\hat{r}_t - \delta_t \right) = \eta + \phi T_t + \sum_{i=1}^{i=11} \chi_i M_i$ Estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
T	-1.12E-05	4.17E-06	-2.684756	0.0106
JAN	0.060600	0.016997	3.565383	0.0010
FEB	0.058539	0.019149	3.057048	0.0040
MAR	0.054405	0.014127	3.851159	0.0004
APR	0.078022	0.013107	5.952485	0.0000
MAY	0.063323	0.015770	4.015277	0.0003
JUN	0.072266	0.012470	5.795299	0.0000
JUL	0.071990	0.011734	6.135451	0.0000
AUG	0.067512	0.013573	4.973937	0.0000
SEPT	0.052879	0.015843	3.337736	0.0019
OCT	0.074771	0.012756	5.861724	0.0000
NOV	0.052110	0.018768	2.776579	0.0084
R-squared	0.172447	Mean dependent var		0.049956
Adjusted R-squared	-0.060966	S.D. dependent var		0.025704
S.E. of regression	0.026476	Akaike info criterion		- 4.222847
Sum squared resid	0.027338	Schwarz criterion		- 3.768300
Log likelihood	119.6826	Durbin-Watson stat		1.128418

While the R^2 has improved and the new value of ρ is encouraging, the coefficient on the interest rate term is no longer significant. However the coefficient on the biomass term remains significant and negative in sign. On this basis it is possible to reject $H_A^3 : \alpha_2 \geq 0$ and accept $H_0^3 : \alpha_2 < 0$, demonstrating the required evidence of a statistically significant inverse relationship between the IDR and stock biomass.

The question of causation remains. Table VI describes the outcomes of two way Granger Causality tests on the log variables of IDR and stock biomass. On the basis of the table above it is possible to reject $H_A^4 : b$ does not Granger cause idr, and to accept $H_0^4 : b$ Granger causes idr.

In this section of the paper we reported the outcomes of econometric analysis of time series data with a view to testing hypotheses around the motivation and behavior of implicit discount rates – derived from ITQ trading data – over the period 1991 – 2001 for the New Zealand CRA1 rock lobster fishery. We have demonstrated convergence of the IDR toward the cost of capital and that a reliable inverse relationship exists between the IDR and estimates of stock biomass. There is evidence of a flow of causation from stock biomass to implicit discount rates.

Table IV: Estimation $idr_t = \alpha_0 + \alpha_1 r_t + \alpha_2 b_t + \alpha_3 p_t + u_t$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
r_t	0.107728	0.062002	1.737494	0.0847
b_t	-0.287135	0.029968	-9.581310	0.0000
p_t	0.011825	0.084370	0.140152	0.8888
R-squared	0.417211	Mean dependent var		-2.247452
Adjusted R-squared	0.408245	S.D. dependent var		0.232028
S.E. of regression	0.178489	Akaike info criterion		-0.586284
Sum squared resid	4.141572	Schwarz criterion		-0.521088
Log likelihood	41.98788	Durbin-Watson stat		0.397995

Table V: AR1 Estimation $idr_t = \alpha_0 + \alpha_1 r_t + \alpha_2 b_t + \alpha_3 p_t + u_t$

Variable	Estimated Coefficient	Standard Error	T-Ratio 128 Df	P-Value
r_t	0.58387e-01	0.8507e-01	0.6864	0.494
b_t	-0.44243	0.1276	-3.468	0.001
p_t	-0.72761e-01	0.8599e-01	-0.8462	0.399
Constant	1.2436	0.8666	1.435	0.154
Durbin-Watson = 2.1216		Rho = -0.06334		
R-Square Between Observed And Predicted = 0.7941		Modified For Auto Order=1		

Table VI: Biomass – IDR Grainger Causality Outcomes

Null Hypothesis:	Obs	F-Statistic	Probability
Log (Biomass) does not Granger Cause Log(IDR)	131	3.42909	0.03547
Log(IDR) does not Granger Cause Log (Biomass)		1.49189	0.22889

DISCUSSION

Fisheries systems may be defined in the widest sense as spanning bio-physical and socioeconomic subsystems. There have been calls in the scientific literature for some measure of integration of the various approaches that the disciplines have adopted to fisheries. Ecologists note the limitations of mathematical models in assessing complex ecological relationships. The requirement to take account of social and economic factors is consistent with developments in the field of environmental effects assessments which emphasize the interconnected nature of socio-economic and biophysical systems and the role of interaction, feedback and accumulation processes in the assessment of state, pressure and responsiveness in natural systems.

Much of the fisheries literature concentrates on the problem of halting stock declines. Once this goal is achieved an ensuing set of problems emerges. How fast should stocks be rebuilt toward a management target, how are the dividends of rebuilds distributed, and how can management agencies incorporate economic information in their decision making process? Sophisticated fishery bioeconomic models have been designed to answer these questions by incorporating one of a number of variants of biological stock models with an economic model. The economic sub-model usually combines catches, cost and output price data in a net present value model to generate rent estimations. However that treatment ignores the problems associated with applying such a model: data fouling through harvesters' perceptions of a need for commercial confidentiality, discount rate selection issues, and the potentially high cost of assembling the required inputs.

Harvesters hold – albeit not in a "scientific" format - much of the information necessary to solve fisheries management problems. Lack of the appropriate format makes it difficult to operationalise this information to solve sustainability problems which are understood in terms of the fisheries science / economics paradigm. This situation does not exist in isolation. For example there are parallels with the long held appreciation of the medicinal properties of plants of indigenous peoples. An interesting corollary is the idea that harvesters, because of the frequency of their interaction with the marine system are often the first to become aware of important changes to the system. Where fisheries are managed under an ITQ system, particularly an ITSQ system the potential exists for that knowledge to be revealed through the investment and disinvestment decisions of firms. Central to the application of that knowledge are the ideas that implicit discount rates are revealed in rights markets transactions, and, through time series analysis of transaction in rights markets system, relationships may be revealed as elasticities.

Arnason [1,8] proposes that harvesters, through their activity hold information as to the biological state of fish stocks and that this information is reflected in their investment and disinvestment decisions that in turn are reflected in ITSQ rights transaction prices. This information may be used to reveal IDRs - where markets are liquid - and to replace the collection of financial information from harvesters in bioeconomic models for the estimation of fishery economic rent. Thus, given reasonably efficient markets, policy makers should be able to unravel the influences on price formation in ITSQ markets, and therefore be able to interpret the health of a fishery through the decentralized decisions of harvesting firms [3].

This approach may be useful in that it offers an avenue to integrate harvesters' assessments of the progression of stock rebuilds with scientific and catch and effort data. The result is a high level indicator that may have utility in understanding rapidly fluctuating multi-species systems. Problems with the use of ITQ trading data have been noted however. For example Hatcher [13] questions the reliability of minimum information approaches under conditions of non-compliance. Other aspects are the realities that often rights design does not take account of the need to configure rights so that markets of sufficient liquidity are created, or that differential rights specifications are evident across differing harvest sectors, creating differing sets of incentives, and in turn behavior, amongst stakeholders.

CONCLUSION

The paper has discussed the potential application of IDRs derived from ITQ trading data as indicators of fishery bio-economic health. We have argued that harvesters' rates of returns, while not directly observable, may be inferred from ITSQ trading data. We have shown the theoretical foundation for the dynamic behavior of harvesters' "own rate of interest" as stock declines are halted and new issues confront fisheries managers that may need additional information to resolve. In the context of one New Zealand fishery, we have demonstrated evidence of convergence of IDR toward the cost of capital over time, a statistically significant inverse relationship between IDR and stock biomass estimates, and, evidence based in the statistical properties of time series of IDR and monthly stock biomass observations of a causal relationship flowing from biomass to IDR. These findings motivate discussion of the role of IDR as an observable condition in fisheries recovery. Within constraints imposed by the design of the institutional context we suggest that IDR provide the opportunity to aggregate fishers' tacit knowledge with other models of bio-economic optima in understanding the recovery process in complex environments.

REFERENCES

1. Arnason, R., 1990, Minimum Information Management In Fisheries, *Canadian Journal Of Economics*, 23(3), 630-653.
2. Batstone C.J., and Sharp, B.M.H; 2003, Minimum Information Systems and Fisheries Management, *Journal of Environmental Economics and Management*, 45 (2003) 492-501.
3. Batstone, C.J., and Sharp, B.M.H., 1998, New Zealand's Quota Management System: The First Ten Years, *Marine Policy*, (23): 2, 177 – 190.
4. Sullivan, K., 2004, Report from the Mid Year Fishery Assessment Plenary, November 2004: stock assessments and yield estimates, Science Group, New Zealand Ministry of Fisheries.
5. Chichilnisky, G., 1997, What is Sustainable Development? *Land Economics*, 73(4) 467-91.
6. Fama, E.F. 1970, Efficient Capital Markets: A Review Of Theory And Empirical Evidence, *Journal of Finance*, 25:383-417.
7. Tuck, W. 1997. Towards Better Management of New Zealand's Commercial Fisheries: a Discussion Paper on Proposals to Reform Management of New Zealand Commercial Fisheries. Ministry of Fisheries, Wellington.
8. Arnason, R., 1993, ITQ Based Fisheries Management, in Risk Evaluation and Biological Reference Points for Fisheries Management, (eds) S.J.Smith, J.J.Hunt, and D.Rivard, *Canadian Special Publication Fisheries and Aquatic Science*, pp 345-356.
9. Bernard, A.B., and Durlauf, S.N., 1996, Interpreting tests of the convergence hypothesis, *Journal of Econometrics*, 71, 161 -174.
10. Greasley, D., and Oxley, L., 2000, Outside the Club: New Zealand's economic growth 1870-1993, *International Journal of Applied Economics*, (14) 2 ,173-192.
11. Greene, W.H., 1993, *Econometric Analysis*, 2nd Edition, Macmillan, New York, 791p.
12. National Institute of Water and Atmospheric Research, Data Source in personal communication.
13. Hatcher, A., 2005, Non-compliance and the quota price in an ITQ fishery, *Journal of Environmental Economics and Management*, 49(3) 427 – 436.