

THE AUSTRALIAN CORAL REEF FIN-FISH FISHERY ITQ MARKET

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ABSTRACT

The Australian coral reef fin-fish fishery (CRFFF) on the Great Barrier Reef has been managed under ITQs since 2004. A large number of different reef species (>155) are covered by the management plan, but the primary species in terms of value and volume landed are coral trout and red throat emperor. All remaining species are classified as other species for management purposes. The operational side of the fishery is relatively heterogeneous and distinct sub-divisions exist between participants in terms of individual vessel characteristics and the species and product forms landed. The ITQ system has introduced an additional dimension for heterogeneity between fishers whilst also allowing investors not participating in the fishery to hold and trade quota. This analysis uses data on individual level quota holdings and trades to assess the CRFFF quota market and its evolution through time. Fishery level trends in ownership and trade are determined, and market participants are identified as belonging to one out of a set of seven generalized types. The emergence of groups such as investors and lease dependent fishers is clear. In 2010-11 42% of coral trout quota was owned by participants that did not fish it and 69% of total coral trout landings were made by fishers that owned only 11% of the quota. The incentives faced by the groups within the fishery differ, as do their vulnerabilities and resilience to natural or management related changes in the fishery's situation.

INTRODUCTION

The Australian coral reef fin-fish fishery (CRFFF) on the Great Barrier Reef has been managed under ITQs since the 1st of July 2004. This paper uses information on quota holdings, individual trades and levels of catch to perform a network analysis and map out how lease trade based networks have evolved over the last seven years. We also consider differences in individual standings with respect to factors such as quota held, traded and caught. The paper first provides background information on the whole CRFFF before concentrating on the lease trade network for coral trout, the most significant component in terms of quantity landed and GVP.

The Coral Reef Fin-Fish Fishery

Queensland's Coral Reef Fin-Fish Fishery (CRFFF) is a line based fishery that targets primarily demersal reef-associated fish and operates from the middle to the far north of Australia's east coast. A significant proportion of this area, the Great Barrier Reef Marine Park (GBRMP) is managed by the Great Barrier Reef Marine Park Authority (GBRMPA). The fishery is highly diverse in nature and consists of the commercial reef quota (RQ) fishery, a charter sector, and in some parts of its range a substantial recreational component. It is multi-species in nature and the key commercial species groups include coral trout (CT), red throat emperor (RTE), and other reef species (OS) including cods, groupers, sweetlips, tropical snappers, seaperches, and emperors [1].

Gross values of commercial landings (estimated at ex-vessel prices) for CT, RTE, and OS were approximately AUS\$38m (\$36m live, \$2m dead), \$2m, and \$3m in 2010-11. The market for landings can be divided into two main components, one that is export oriented and one that is domestic. The domestic market consumes mainly dead fish (both fresh and frozen) whilst the export market is predominantly for live coral trout that are sent to Hong Kong. Live fish accounted for 87% of all CT landings in 2010-11. For the financial year 2010-11 average ex-vessel prices of live CT, dead CT, RTE, and OS were AUS\$47/kg, \$17/kg, \$10/kg, and \$7/kg, respectively. Prices for dead fish are believed to have remained relatively stable over the last 5 to 10 years whereas the price of live CT displays

strong seasonality (fluctuating between \$34/kg and 70 \$/kg in the last two years) due to seasonally driven fluctuations in demand in China.

The commercial sector is managed under the Fisheries Regulation 2008, and the Fisheries (Coral Reef Fin Fish) Management Plan 2003. In practice a suite of both input and output oriented controls are applied which include, but are not limited to, measures such as limited entry (licenses), size constraints for vessels and gear, minimum and maximum landing sizes, and total allowable catches (TACs). Other than two 5-day spawning closures, one in October and one in November, the fishery operates year round with seasonal variation due to market and weather-related factors. RQ vessels are also subject to spatial restrictions on where they can operate as part of the GBRMP and Queensland Marine Parks Zoning Plans [2]. On the adoption of commercial TACs on the 1 July 2004 commercial license holders were allocated individual tradable quotas (ITQs) based primarily on the historical catch records associated with the license.

There are three types of RQ quota; coral trout (CT), red throat emperor (RTE), and other species (OS). As the name suggests OS incorporates a number of (approx. 154) other reef fish species, however only a relatively small proportion of these are actively targeted by the commercial fishery. CT quota covers seven separate species of coral trout but the majority of landings consist of the common coral trout (*Plectropomus leopardus*). Under current conditions one quota unit represents one kilogram of fish (live weight equivalent) for all quota types, however there is some capacity for this to be adjusted if specified catch triggers are reached [3]. The available TACs for CT, RTE, and OS are 1,288,156kg, 615,586kg, and 955,604kg, respectively. As legislated, the commercial RQ TACs should not exceed 1350t for CT, 700t for RTE, and 1011t for OS, however following an allocation appeals process the CT TAC was adjusted to ~1423t. The Australian Government Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) subsequently bought back out 135t of CT, 73t of RTE and 109t of OS, in 2004-05, consequently reducing the quantity of quota available to commercial fishers.

RQ effort and landings fell sharply in 2004-05 (Figure 1) following the introduction of TACs and implementation of the GBRMPA Representative Areas Program. The latter increased the area of no-take zones in the GBRMP from <5% to >33% and was accompanied by a statewide fisheries buyback program. Landings have since remained low when compared to the pre-quota era and to-date, the TACs have not been met, so cannot currently be considered to actively constrain the RQ fishery’s level of output. The only quota group to have come close is CT in the year 2008-09 when approximately 96% of the TAC was landed. In more recent years two significant cyclone events, Hamish in March 2009 and Yasi in February 2010, have also contributed to a decline in effort and landings across the whole fishery. Historic landings and the TAC (horizontal black dashed line) for each RQ group are shown in Figure 1.

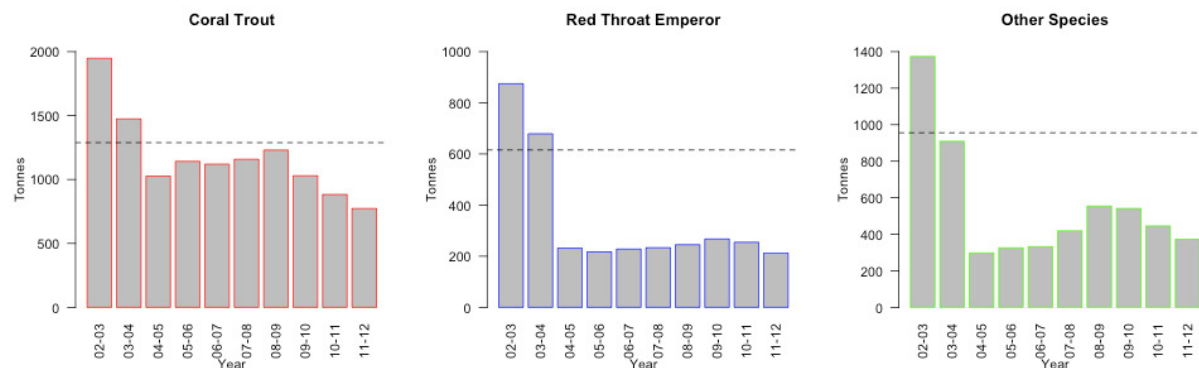


Figure 1. RQ landings over time for CT RTE OS with the TAC shown as a horizontal black line

The aim of the paper is to determine how trade patterns for quota have developed over time.

MATERIALS AND METHODS

Data

The Queensland Department of Agriculture Fisheries and Forestry (QDAFF) holds data at the individual trade level for all quota types, along with the quantity of quota held and fished against separate quota account in each year. The analysis presented in this paper is based on an anonymised version of this data. The dataset covers the period since ITQs were first introduced on the 1st of July 2004 up to the end of the 2010-11 financial year (30th of June in Australia). Data relating to the years 2006-07 and 2007-08 were partially incomplete so are not included in the analysis presented here. As is common in many fisheries managed under ITQs there is no requirement to report the \$ value of quota transactions along with the quantity traded, meaning that quota trade prices, and how these have evolved over time, are not directly available.

Account holder typologies

The relative positions people occupy in the quota market can strongly affect the incentive structures they face in terms of individual trading and fishing behavior. Following van Putten and Gardner [4] we used information relating to individual lease trading behavior and quantities of CT landed annually to assign each quota account holder to one out of 7 groups (Table 1).

Table 1: Account holder typology definitions

Typology	CT catch	Lease in	Lease out
Income supplementer	>0	0	>0
Independent	>0	0	0
Investor	0	0	>0
Lease dependent	>0	>0	0
Quota redistributor <1t	<1t	>0	>0
Quota redistributor >1t	>1t	>0	>0
Inactive	0	0	0

Quota redistributors were split into those that land over one tonne of fish and those that land less in order to distinguish between those that are relatively active fishers and those that are not.

Network analysis

Social network analysis [5-7] is the mapping and quantification of relationships between individual entities. Based upon the principals of network theory [8, 9], network maps and statistical measures are used to illustrate and mathematically assess a network's properties and indicate how these may have changed over time. In context of the CRFFF, network analysis has been used to formally identify the existence and nature of trading relationships between anonymous account holders in the market for RQ quota, specifically short-term lease trades for CT. We used the open source platform Cytoscape¹ to visualize and analyze the networks but a number of alternatives, such as the SNA package in R, are also available.

This methodology has been widely applied and used to analyze social networks such as the world wide web and citations in research [8]. In a fisheries context the significance of social networks has been established with respect to compliance [10], viability during resource scarcity [11], and relationships between fish traders [12]. To the best of our knowledge a study of the Tasmanian rock lobster ITQ market [13] is the only previous example of this technique being used to assess such markets in the context of fisheries. This provides some useful points of reference, allowing comparisons to be made between a number of key indicators.

The structure of networks, the associated descriptive statistics, and how these all change over time indicate how information is likely to pass through networks, the ability of one business entity to interact with another, and the relative degree of control each individual may exert over exchanges in the network. Individual entities within a

network are typically referred to as nodes and connections between these nodes are called edges. From a theoretical perspective, the structural distribution of these edges, can range from being either purely random to completely regular. Early work in the area assumed random connectivity [14] but more recently it has been shown that real life networks, especially those in the social / economic domain often display markedly non-random, so called “scale-free”, properties [15, 16].

The number of other nodes any single node is directly connected with is its degree d . A network is said to be scale-free when its degree distribution, conforms to that of a power distribution [15].

$$P(d)=cd^{-\gamma}, \quad (\text{Eq. 1})$$

where $P(d)$ is the probability P that a node has degree d , c is a normalizing constant, and γ is an unknown parameter. For $\gamma < 3$ the average degree distribution is considered not representative and the network is deemed to be scale-free [16]. Under a power distribution the frequency of very high and very low degree distribution nodes is higher than would be expected had the network formed purely at random [17] and indicates the prominence of high degree nodes acting as hubs.

Several additional statistical measures are also used to assess the networks and are computed using the NetworkAnalyser component of Cytoscape [18]. The clustering coefficient is a measure of local cohesiveness and for directed networks

$$C_i = e_i / (d_i (d_i - 1)), \quad (\text{Eq. 2})$$

where d_i is the number of neighbors of i and e_i is the number of connected pairs between all neighbors of i and $0 < C_i < 1$. The average clustering coefficient gives an overall indication of the level of clustering in the network as a whole and it has been shown that real world social networks can display high levels of clustering when compared to purely random networks [19].

The network diameter indicates the maximum length of shortest paths between two nodes, in terms of the number of edges d between them. The characteristic path length of a network is the average shortest path length between nodes in the network, the shortest path length being $L(i,j)$, where i and j are two separate nodes. A high characteristic path length relative to the number of nodes in the network implies the network is becoming similar to a linear chain whereas a relatively low characteristic path length indicates the network is compact.

Characteristics of the nodes themselves are assessed using measures of closeness centrality and betweenness centrality. The closeness centrality of a node is a measure of how fast information can spread between connected nodes in the network [20] and is calculated in Cytoscape as the reciprocal of its average shortest path length.

$$Cc(i) = 1 / \text{avg}(L(i,j)), \quad (\text{Eq. 3})$$

where $L(i,j)$ is the length of the shortest path between two nodes i and j , and $0 < Cc < 1$ and zero indicates the node is isolated. The betweenness centrality of a node provides an indication of the amount of control exerted by this individual node on interactions in the network, Cytoscape uses the Brandes [21] algorithm to calculate this:

$$Cb(i) = \sum_{j \neq i} \sum_{k \neq i} (\sigma_{jk}(i) / \sigma_{jk}), \quad (\text{Eq. 4})$$

where j and k are different nodes to i , σ_{jk} is the number of shortest paths from j to k , and $\sigma_{jk}(i)$ the number of shortest paths from j to k that i lies on [21].

In the context of trade networks, properties such as those described in this section bear direct relation with the ability of information to spread between groups, and have implications for overall market efficiency.

Determinants of position in the market

Finally, basic linear regression models were estimated in R in order to investigate whether and the extent to which the type of connectivity individual account holders have in the market place (as measured by in / out degree or edge counts) could be explained as a function of their typological group (Table 1) as well as quantitative measures of their involvement in CT fishing and CT quota trading (e.g. lease in/out quantities, quota owned and used).

RESULTS

Market dynamics

The greatest change in number of market participants was seen between 2004-05 and 2005-06 for all quota groups. CT, RTE and OS market participant numbers fell by 21%, 19%, and 13% respectively. This is believed to be mainly a result of license owners selling the entitlements they were awarded in the initial year, and is supported by the exceptionally high volume of permanent trades observed in this period. Permanent trades in the first year were seen to be in the region of 30-35% of the TAC whereas all subsequent years fall between 5-10% of TAC.

A summary of selected market characteristics and how these have evolved over time for the three quota types is set out in Table 2. Three years are reported, the year that ITQs were first introduced into the RQ fishery (2004-05), what is considered to be the ‘peak’ catch year since the introduction of ITQs (2008-09), and the last year for which complete records are available (2010-11).

Table 2: Summary of quota lease trade markets for each RQ group in the financial years 2004-05, 2008-09, and 2010-11

	Coral Trout			Other Species			Red Throat Emperor		
	2004-05	2008-09	2010-11	2004-05	2008-09	2010-11	2004-05	2008-09	2010-11
Account holders	367	322	320	359	375	374	358	351	354
Accounts landing fish	165	168	175	194	223	219	158	158	160
Number of lease trades	284	730	554	96	210	281	112	357	377
Lease Trades (LT) (000 units)	511.98	1,241.83	750.21	237.50	615.14	480.24	134.28	220.13	244.42
LT / TAC (%)	0.40	0.96	0.58	0.25	0.64	0.50	0.22	0.36	0.40
Permanent Trades (PT) (000 units)	373.97	70.08	95.39	312.90	49.55	49.83	199.62	28.38	59.17
PT / TAC (%)	0.29	0.05	0.07	0.33	0.05	0.05	0.32	0.05	0.10
% account holders with no LT	0.57	0.20	0.44	0.74	0.43	0.45	0.76	0.60	0.54
Gini Coefficient	0.656	0.787	0.792	0.534	0.711	0.726	0.636	0.768	0.777

The proportion of account holders participating in the lease market, the overall volume of quota leased, and the numbers of temporary trades undertaken were lowest in the first year of ITQs for all quota types. For CT these measures of participation and trade peak with landings in 2008-09 before falling to levels more similar to those seen in 2005-06. Measures of lease trade and participation for RTE and OS quota do not peak until a year later in 2009-10, when landings were also highest since the introduction of ITQs for RTE and amongst the highest for OS. These quota groups also differ from CT in the way that trades and levels of participation in their markets remain relatively flat after peaking, rather than falling. The proportion of account holders that participate in the associated lease trade markets are generally lower for OS and RTE categories when compared to CT for all years other than the most recent when CT participation fell close to that of OS (56%). Concentration of quota ownership was tested for by calculating the Gini index² for each quota group in each year; the indices indicate that the market was relatively concentrated for all groups in 2004-05 and has become increasingly concentrated over time. The rate of concentration was greatest between the first year of ITQs and 2008-09.

Over the whole period observed, annual numbers of individual lease transactions increased by 95%, 193%, and 237% for CT, RTE and OS. The quantity of units leased also increased, by 47%, 82%, and 102% for CT, RTE and

OS respectively. These are generally substantially larger increases than the 47% increase in number of trades and 60% increase in volume of trades seen over a comparable period of time in the Tasmanian rock lobster fishery [13]. As the total quantity of units leased (kg) increased proportionally less than the number of lease trades, the average size of these trades has fallen over time and by 2010-11 average CT lease trades were 25% smaller than in 2004-05, RTE 38%, and OS 40%.

Changes in the distribution of quota account types

Proportional ownership and use of CT quota by the alternative groups of quota accounts is illustrated in Figure 2. At the group level investors have consistently owned the greatest proportion of quota for the whole period observed (536,643 units in 2010-11), whilst lease dependent fishers have accounted for the greatest proportion of landings (606 tonnes in 2010-11). The role of investors as ‘owners’ and lease dependent fishers as ‘catchers’ has been consistently developing over time with investor holdings increasing from 10% of the CT TAC in 2004-05 to 42% in 2010-11, and proportion of landings CT taken by lease dependent fishers going from 40% in 2004-05 to 69% in 2010-11. The role of quota redistributors that also land over one tonne of CT per year has diminished, both in terms of ownership and use, with the proportion of landings taken by this group falling sharply from 37% to 10%, almost exactly the same amount lease dependent landings have increased by. Ownership of quota by redistributors that landed less than one tonne of CT increased and then decreased as landings did the same.

Of the 367 businesses present in the first year of ITQs 176 of these were seen to still be present in some form by 2010-11. A significant proportion (38%) of businesses was inactive in 2004-05, meaning that quota owners neither leased nor caught any part of their quota during that year. This proportion was still 24% of the total in 2010-11, but decreased to 14% in 2008-09. Of the 139 inactive businesses seen in 2004-05, 103 left the system by 2010-11 (these businesses could be assumed to have sold out), 20 were still inactive, 3 had become independent (indicating that they had started fishing on their quota), 8 had become investors (so were now leasing their quota out), and 2 had become quota redistributors<1t (so were now leasing quota in and out, and catching CT). The 46 accounts classified as inactive in 2008-09 held a total of 33,787 CT quota units (~3% of TAC) (range of 0 to 12,292)

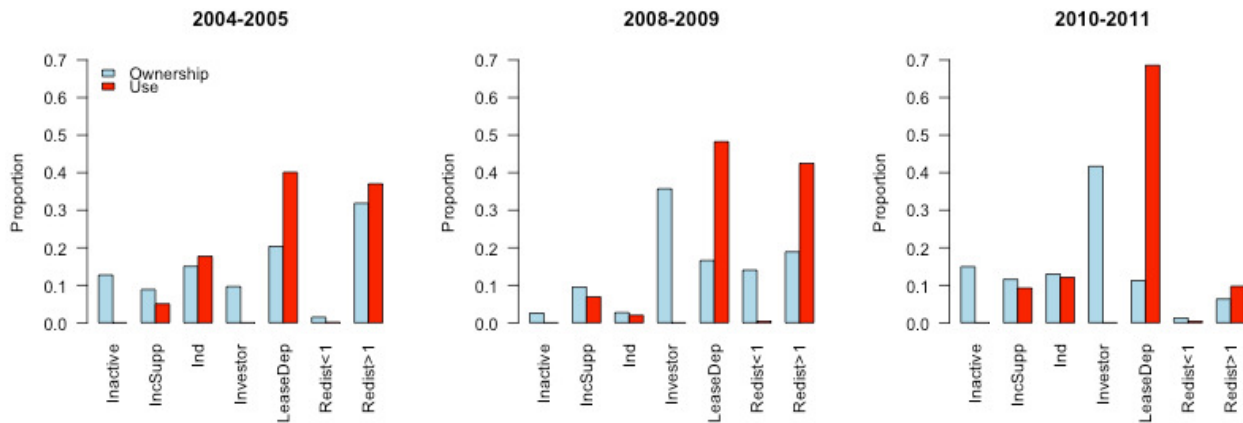


Figure 2. Evolution of CT quota ownership and use for alternative typologies as a proportion of the total (SEWPaC holdings excluded)

The number of independent operators fell as CT fishery conditions were such that the TAC was nearly taken in 2008-09, but once again increased as the gap between total fishery catches and the TAC increased. The quantity of account holders deemed to be inactive (use = 0, lease in/out = 0) almost doubled over the period observed from 46 in 2008-09 to 75 in 2010-11, however the volume of quota owned by this group increased six fold from just under 33 tonnes in 2008-09 to almost 193 tonnes in 2010-11, such that in 2010-11 15% of the TAC for CT was not fished or traded.

Network analysis results

The plots in Figure 3 depict the CT lease trade market network in each financial year, and how it has changed over time. The circular nodes each represent an individual quota account that held or traded CT in that year. The lines joining nodes, edges, represent the existence of a direct lease trading relationship between those quota account holders in that financial year. The size of connected nodes reflects the total volume of trade it is involved in over the year in terms of number of quota units traded (both in and out). The completely unconnected nodes that sit at the bottom of each network are the quota holders that do not undertake any lease trade activity in that year, and as such their size is not related to level of trade. These businesses are a combination of those classified as either independent or inactive in Table 1.

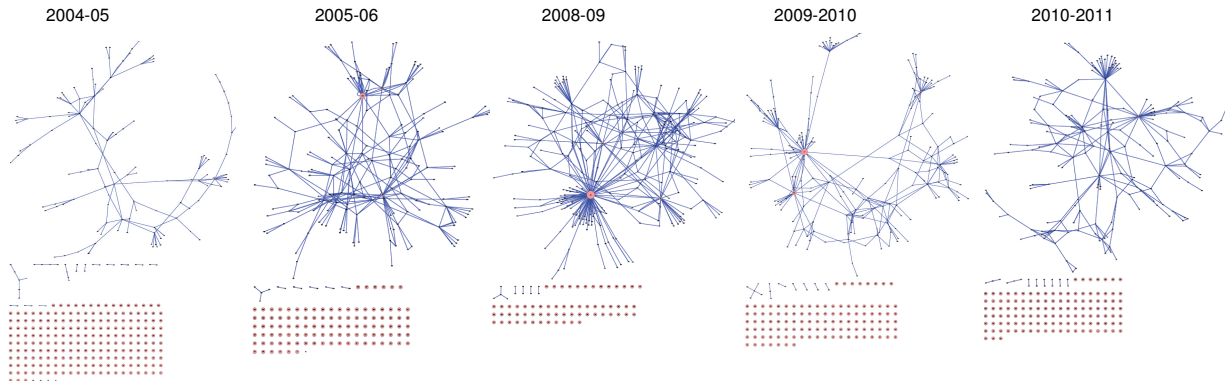


Figure 3. CT lease trade network maps

The network maps clearly demonstrate how CT lease market connections have evolved; with high numbers of unconnected non-traders in the first year (2004-05) the network then builds up, incorporating more and more participants, to a peak in 2008-09 before reverting to some extent by 2010-11. In a directed network such as the one considered here, where relationships are not necessarily symmetrical (i.e. trader A may lease to trader B but B does not lease to A), the degree distribution can be assessed in terms of either its inbound connections (in-degree) or its outbound connections (out-degree) as the numbers for each will vary. Degree distributions of both forms are plotted on a log scale in Figure 4 for the CT lease trade network and the parameter values for the power law (equation 1) are reported in Table 3.

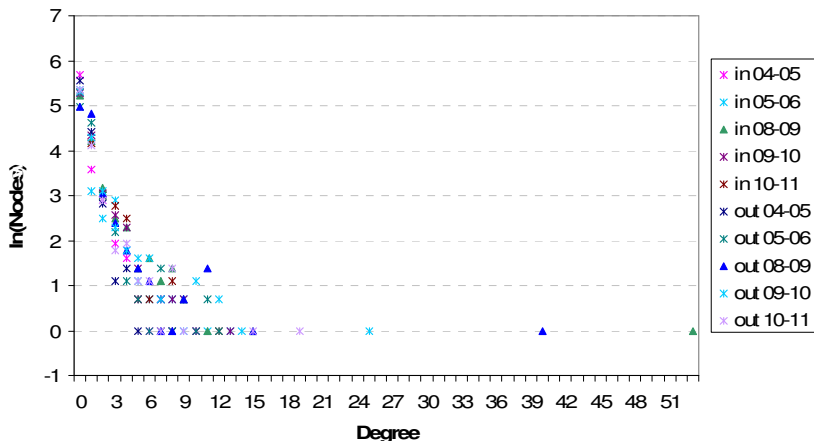


Figure 4. Annual level degree distributions (log scale, in- and out-) for the CT lease trade market

The general shape of the degree distributions in Figure 3 is similar across all years and relationship directions. This illustrates that the majority of market participants were connected to relatively few (one or less) other participants

for the years observed. In 2004-05 80% of account holders had an in-degree of zero, implying no inbound connections, and 70% had out-degree measures of zero. In the same period 10% and 22% of account holder respectively had in- and out-degree measures of only one (indicating lease trading relationships with only one other account holder). Account holders with no lease trading relationships (i.e. degree distribution of zero) always formed the largest group in each year. The proportion of account holders with degree distributions of zero (for both in and out) were observed to be at their smallest in 08-09 when they accounted for 58% and 45% of account holders respectively, implying that nearly half the account holders leased quota in, while more than half the account holders leased quota out in that year.

All of the degree distributions satisfy the power-law (Table 3), indicating that all the networks have scale-free properties. The change in the network’s nature can also be clearly seen in these indicators, with the γ coefficient being lowest in the high trade year indicating that hub type components play a greater role in that year (also visible in figure 3). Results for the initial year may be harder to interpret as the high levels of permanent trading that occurred concurrently in this and the following year is likely to have confounded the measure for these periods.

Table 3: Power law values for CT lease trade degree distributions

	Coefficient	2004-5	2008-9	2010-11
<i>In-degree</i>	<i>a</i>	43.572	41.968	70.603
	γ	-1.747	-1.211	-1.719
	<i>correlation</i>	0.979	0.994	0.989
	R^2	0.937	0.853	0.891
<i>Out-degree</i>	<i>a</i>	65.989	44.432	42.082
	γ	-2.224	-1.339	-1.453
	<i>correlation</i>	0.999	0.972	0.993
	R^2	0.932	0.762	0.870

The major differences between degree distributions in Figure 4 are seen in the size of the distribution’s tail each year. In its initial years (2004-05 and 2005-06) the network has relatively short tails, with the maximum number of trading relationships any one market participant had being 10 in 2004-05 and 14 in 2005-06 (both out-degree). By 2008-09 (solid triangular points) the maximum had increased to 53 and 40 (for in- and out-degree respectively), the highest levels observed in any period, resulting in much fatter tails. In 2009-10 and 2010-11 the maximum number of inward oriented trading relationships dropped to 13 and 12 respectively. Outward oriented relationships dropped to 25 and 19 respectively.

The proportion of account holders with a degree greater than or equal to 4 never exceeds 10% of the total number of account holders. In the years with unusually high maximum levels of degree distribution, primarily 2008-09, this effect is all the more pronounced (Table 4). By removing the account holder with the highest level of degree distribution in each year the gap between these individuals with exceptionally high levels of degree distribution and the remainder of the network becomes apparent (Table 4).

Table 4: Minimum and maximum levels of degree distribution within the CT lease trade market

	2004-05	2005-06	2008-09	2009-10	2010-11	Mean	Sd.
Max:							
<i>in-degree</i>	10	14	53	13	12	20.4	18.3
<i>out-degree</i>	8	12	40	25	19	20.8	12.6
Max after account holder with highest degree distribution removed:							
<i>in-degree</i>	8	13	15	10	8	10.8	3.1
<i>Out-degree</i>	7	11	15	12	15	12	3.3

The network clustering coefficient is consistently close to zero, as in the Tasmanian rock lobster (RL) case [13]³ and indicates low levels of clustering at the network level. Measures of network diameter were generally lower in the CT market (from 3 to 8) when compared to values observed in Rock Lobster study (4 to 11). The peak of 8 occurs in 2008-09 and the value subsequently falls to 6 in 2010-11. This indicates a relatively less complex network and more

direct routes between the furthest apart agents in the market. These differences with the Tasmanian rock lobster case are possibly related to the fact that rules regarding quota ownership and trade differ between the two fisheries, with QLD regulations allowing for broker-type activity to develop, as well as concentration of ownership⁴.

Not accounting for the initial year (2004-05), due to the relatively small number of nodes taking part in the market, the characteristic path length of the network has steadily fallen over time, from 3.37 in 2005-06 to 2.32 in 2010-11, indicating that the average trading connection between any two agents fell in this period. The initial increase from 1.45 to 3.37 between 2004-05 and 2005-06 is likely to be a result of the increase in the number of market participants over the same period, in the absence of broker type nodes that reduce the average path length between nodes. A similar magnitude increase in the characteristic path length was observed in the RL fishery and attributed to increasing numbers of quota owners having high number of connections.

Figure 5 plots the proportion of account holders with centrality values greater than zero over time. The proportion of individuals with a closeness centrality greater than zero in the CT market (Figure 5) is initially much higher than that observed for RL, but steadily decreases over time, which would indicate a fragmentation of the network into sub-components. This may be regionally defined, in relation to spatial constraints. The betweenness centrality for CT slightly increased in 2008-09 but then fell back close to its initial level, a level comparable to that observed in early years of RL quota trading.

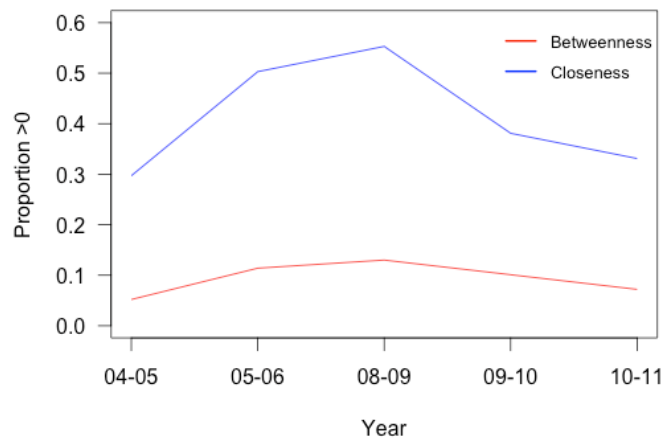


Figure 5. Proportion of nodes with betweenness and closeness centrality >0 for the CT lease market

Position of account groups in the network

Values for quantities of CT quota leased in and leased out were found to be highly correlated hence only the information for leasing out is used in the models reported here (Table 5). The three models presented all relate to 2010-11 and show that whilst the quantitative measures detailing how much CT quota an individual owns, catches, or leases out are in all cases significant, the magnitude of their influence is very small. The typological groups however are also highly significant where we would expect them to be and have greater influence on the magnitude of account holders in- / out- degree or edge count. As expected, parameter values for the independent group are not significantly different to zero in all models as the measures of degree for these individuals are always zero. Lease dependent status is significant with respect to the probability of having a high in-degree, whilst not significant with respect to out-degree, again conforming to expectations as this group will have predominantly incoming relationships within the network.

Table 5: LR models for CT quota lease market participants in 2010-11

Explanatory variables	<i>In-degree</i>			<i>Out-degree</i>			<i>EdgeCount</i>		
	Estimate	Std.	Sig	Estimate	Std.	Sig	Estimate	Std.	Sig
Constant	0.207	0.110	.	0.094	0.148		0.301	0.219	
CT quota owned	0.000	0.000	***	0.000	0.000	**	0.000	0.000	***
CT catch	0.000	0.000	***	0.000	0.000	**	0.000	0.000	***
LeaseOut	0.000	0.000	***	0.000	0.000	***	0.000	0.000	***
Investor	-0.255	0.169		0.999	0.227	***	0.744	0.337	*
Independent	-0.153	0.171		-0.056	0.230		-0.209	0.341	
IncomeSupp	-0.366	0.312		0.961	0.418	*	0.595	0.621	
LeaseDependent	1.310	0.164	***	-0.308	0.220		1.002	0.327	**
QuotaRedistL1t	1.651	0.278	***	2.134	0.373	***	3.785	0.553	***
QuotaRedistG1t	1.721	0.279	***	1.425	0.375	***	3.146	0.556	***
Adjusted R2		0.621			0.600			0.590	

(Significance codes: . 0.05, *0.01, **0.001, ***0)

DISCUSSION AND CONCLUSIONS

From inception up to the 2008-09 peak in CT catch, network indicators for the CT ITQ component of the CRFFF fishery are generally consistent with those observed in the Tasmanian rock lobster fishery [13], and with those of a growing and maturing marketplace. As the fishery came closer to reaching its TAC temporary trade activity increased substantially and the role of well connected “hub” nodes grew. Yet, despite the networks all displaying scale-free properties, the typically assumed trend towards increasing scalefreeness as networks evolve [8] is not consistently observed in this case, with the opposite actually being observed to some degree as the gap between total landings and TAC subsequently grew between 2008-09 and 2010-11.

The observation that after the peak of 2008-09 the γ coefficient for in-degree distribution was seen to increase again, back to 2004-05 levels, also suggests a strong reduction in the role of well connected nodes as leasers in of quota from multiple other traders. Whilst the CT lease trade network has reverted to some degree since 2008-09, this has not occurred in a symmetrical manner as certain features of the peak period remain. However, and interestingly, the out-degree γ coefficient remained close to the level observed in 2008-09, suggesting that their role as a supplier of quota (with many outward connections) to the network has persisted. One possible explanation for this is that over time such account holders have undertaken permanent transfers to acquire sufficient quota that their need to lease quota in just to satisfy demand has diminished, especially as demand for CT quota is far lower in 2010-11. Concentration in the ownership of quota was observed for CT, lending weight to this explanation. This points to a need for permanent and temporary trades to be considered jointly in the analysis.

The other striking result is the proportion of nodes that are disconnected. The disconnected nodes seen in Figure 3 are a combination of businesses deemed either inactive or independent in Figure 5 and the pattern of disconnected nodes becoming less prevalent in better years is linked with the general increase in the level of lease market participation seen at that time (Table 1). For the independent component, when catches were higher, businesses whose quota holdings had previously been sufficient to cover their catches, and allow them to exist outside of the lease market, needed to source additional quota and consequently entered the market in order to lease it in (becoming ‘lease dependent’ in the process). This situation was also reflected in the inactive component whose numbers were substantially lower in the peak period (falling from 139 in 2004-05 to 13 in 2008-09) as they either sold out (99), began leasing their quota out (19 became investors), fished it themselves (4 became independent), fished it and leased it out (2 became income supplementers), fished it and leased in (1 became lease dependent), or leased in and leased out (1 became a quota redistributor<1t. These numbers were similar by 2010-11, the main exception being those that were investors falling by half with most of these having sold out.

The observation that some degree of inactivity persisted throughout the whole period (quota holders that did nothing with their quota) is an interesting and somewhat counterintuitive situation. In addition to the opportunity cost of not

using it in some way (fish, lease out), the ownership of quota incurs annual fees that are levied independent of whether it is fished. Inactivity also results in the loss of associated catch history, potentially another cost to the account holder should management conditions change. Without more information logical explanations for this situation are that imperfect exchange of information is forming barriers to trade or that the transaction costs associated with leasing out are simply too great and exceed the benefits. At the fishery level this withheld quota has potential implications with respect to the lease price in times of high demand and is effectively a source of inefficiency.

As broker nodes are not stable it is likely that the flow of information through the network will be asymmetrical, leading to inefficiency. Further, if individual entities each only hold low quantities of quota it is quite possible that the transaction costs involved with leasing it out, especially in periods of thin demand, prevent this from happening. However, in 2010-11 inactive nodes held an average of just over 2.5t of quota.

If the most likely point of entry to the network for a disconnected node is via a broker node [15] this will also result in connected nodes becoming increasingly connected in periods with increased lease market participation. It was anticipated that being highly connected may also provide an advantage to these account holders in times of low demand and facilitate the leasing out of their quota ahead of less connected account holders, however the data does not support this.

The results demonstrate that as catches increased to the point that the TAC for CT was close to being taken, there was a clear emergence of very highly connected broker type entities. These then fell away again to some extent in years where quota uptake was lower. It appears evident that under conditions of high demand (and thinning supply) instead of many individuals forming lease trade relationships with many other individuals, a likely inefficient situation if the result is high numbers of small trades with multiple quota owners (and relatively high transaction costs), these account holders instead form relationships with the same singular or few individuals (broker nodes) depicted in figure 3.

When demand for quota fell as a result of lower landings at the fishery level the necessity for individuals to source quota in excess of their norm – resulting in interactions and trade with account holders outside of their usual range – the role of broker nodes, especially as leasers in, abated. This is likely to be because at lower levels of demand fishers are able to satisfy their trade requirements via existing (possibly more local) networks at the port level, or within their social network. Only once demand increases to the point that these familiar connections are not sufficient, will brokers who are able to facilitate trades of the size and nature wanted become more attractive due to the likely lower transaction costs associated with dealing with one as opposed to many smaller holders. The extent to which hubs play an important role as brokers seems to vary with the circumstances of the fishery. In a slack market, people may know enough about potential supply and demand of quota immediately around them to satisfy their needs. In a tighter market, this may not be enough, and recourse to brokerage type services might develop, increasing the importance of certain key nodes.

The regression analysis suggests there is some connection between an account holders characteristics (both typological and quantitative) and the role they end up playing in a trade network in terms of their connectivity (in-degree, out-degree). The typology was seen to be the strongest indicators of the number and type of connections an account holder will have and further validate the explanatory robustness of the typologies themselves. This paper presents only an initial overview of the CT lease trade network and further work is needed to better investigate aspects such as the other quota groups, concurrent permanent trades, the influence and importance of sub-networks, and how initial allocations and position in the market influence long term survival and market efficiency.

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¹ www.cytoscape.org/

² The Gini index measures the level of inequality among values, the index is can have a value of between zero and one where zero is perfect equality and one perfect inequality (i.e. where one person owns all quota).

³ This is to be expected in a market where agents trade to maximize profit, there is heterogeneity in preferences / utilities derived from owning / leasing quota and lack of concentration of ownership of quota in only a few agents.

⁴ The Tasmanian rock lobster fishery has restrictions on the ownership of quota.