Appendix 1.

The CRFFF TAC

As legislated, the commercial RQ TACs should not exceed 1350 t for CT, 700 t for RTE, and 1011 t 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 out 135t of CT, 73t of RTE and 109t of OS, in 2004-05, consequently reducing the quantity of quota available to commercial fishers.

Network analysis statistics

The network analysis statistics were derived as follows. 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 (Barabási and Albert 1999).

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

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 (Barabási 2009). 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 (Jackson 2011) 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 (Assenov et al. 2008). The clustering coefficient is a measure of local cohesiveness and for directed networks

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

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 (Watts and Strogatz 1998).

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 can be interpreted as a measure of how fast information may spread between connected nodes in the network (Newman 2003) and is calculated in Cytoscape as the reciprocal of its average shortest path length.

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

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. A high score indicates relatively short paths to other nodes in the network. 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 (2001) algorithm to calculate this:

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

where *j* and *k* are different nodes to *i*, σjk 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 (Brandes 2001).

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.

Table A1.1. Summary characteristics of the coral trout (CT) quota market.

	Coral Trout							
	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Account holders	374	293	298	313	320	326	316	325
Accounts landing fish	165	157	165	172	167	184	173	164
Number of lease trades	285	466	356	485	730	539	554	455
Lease Trades (LT) (000 units)	515.27	872.72	815.64	958.48	1241.837	1157.557	750.21	615.48
Lease trades as % TAC	0.40	0.68	0.63	0.74	0.96	0.90	0.58	0.48
Permanent Trades (PT) (000 units)	369.68	155.77	145.61	48.02	70.08	75.31	91.61	94.88
Perm trades as % TAC	0.29	0.12	0.11	0.04	0.05	0.06	0.07	0.07
% account holders lease trading	0.42	0.61	0.64	0.68	0.80	0.65	0.61	0.59
Gini coefficient	0.66	0.70	0.75	0.77	0.77	0.78	0.78	0.78

Table A1.2. Power law values for CT lease trade degree distributions.

	Coefficient	2004-2005	2008-2009	2011-2012
In-degree	*a*	43.572	41.46	67.825
	γ	-1.747	-1.207	-1.848
	correlation	0.979	0.994	0.994
	R^2	0.937	0.852	0.878
Out-degree	*a*	65.989	44.93	54.295
	γ	-2.224	-1.346	-1.623
	correlation	0.999	0.973	0.992
	R^2	0.932	0.772	0.920

The change in the nature of the networks can also be clearly seen from the γ coefficients set out in Table A1.2, which are lowest in the high trade year indicating that hub-type broker nodes played a greater role in that period (also visible in Fig. 4 in the main text). When $\gamma<3$ the average degree distribution is considered to not be representative (Barabási 2009) as the frequency of very high and very low degree distribution nodes is higher than if the network formed randomly (Jackson 2011) and indicates the prominence of highly connected broker (hub-type) nodes in this system.

Gap analysis

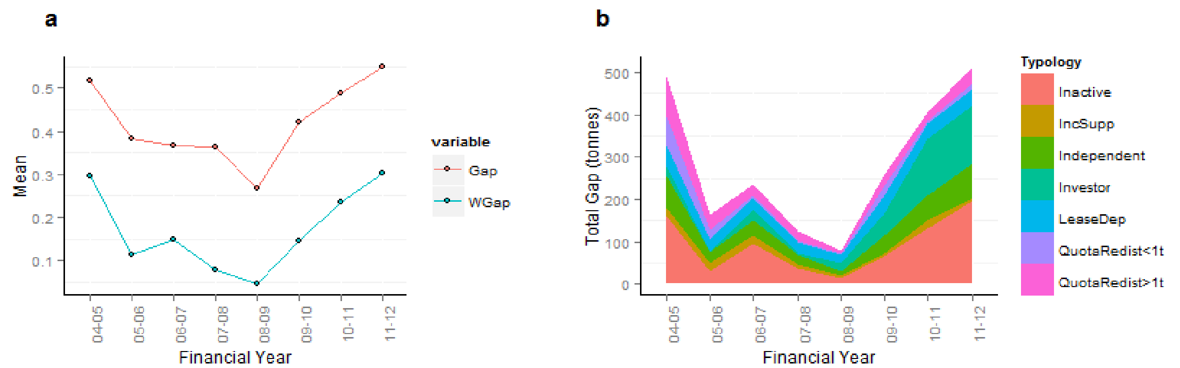
A modified version of gap analysis outlined in Connor and Alden (2001) was undertaken. This approach accounts for the investor component not consuming quota in the traditional sense of landing fish against it.

$$G_{ij\ (non-investor)} = \frac{L_{ij}}{(Q_{ij} + B_{ij} - S_{ij} + I_{ij} - O_{ij})} \qquad \text{(Eq.5)}$$

$$G_{ij\ (investor)} = \frac{O_{ij}}{(Q_{ij} + B_{ij} - S_{ij} + I_{ij})} \qquad \text{(Eq.6)}$$

where *L* are the landings recorded against quota in year *i* by account holder *j*, *Q* is quota owned at the beginning of year *i*, *B* is any quota bought, *S* is quota sold, *I* is quota leased in and *O* is quota leased out. In this way quota held refers to not only the quota they own at the start of the year but also that which may have been bought/sold or leased in/out over the year. As investors do not by definition record catches against the quota they hold, and as such do not 'use' their quota in the same way as other groups, their quota use is defined as the quantity of quota they lease out.

Fig. A1.1. a) evolution of average gap (Gap) and gap weighted by proportion of TAC held (WGap) over time, b) total unused quota at the fishery level in absolute values (tons).



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