Industry management within the New Zealand quota management system: the Orange Roughy Management Company

G. Clement and R. Wells
Clement and Associates Limited
PO Box 1460
Nelson, New Zealand
clement@fishinfo.co.nz; richard@fishinfo.co.nz

Charmaine Marie Gallagher
AquaMarine Sciences Limited
Nelson, New Zealand
seayaz@mac.com

1. INTRODUCTION

The New Zealand deepwater trawl fisheries, including those for orange roughy, have been co-managed by the Orange Roughy Management Company Limited (ORMC) and the Ministry of Fisheries. Involvement by industry, through ORMC, is a direct consequence of the quota management system (QMS), introduced in 1986, which afforded property rights to the owners of fish quota. Hilborn, Orensanz and Parma (2005) argue that:

> *"the key to successful management of marine resources is the establishment of appropriate institutions for governance that include a reward system, so that the individual welfare of fishermen, managers and scientists is maximized by actions that contribute to a societally desirable outcome."*

The New Zealand QMS, by providing security of tenure to deepwater fishery quota owners, has brought a paradigm shift in the approach to management by those owners. They have combined their interests through the establishment of the ORMC to provide the capability for co-operative engagement in the sustainable management of their fisheries and a strengthened decision-making position in dealings with the Ministry of Fisheries. The ORMC provides a united and professional forum for quota owners to cooperate in managing, developing and researching deepwater fisheries. Through the ORMC, quota owners have allocated effort to specific fishing areas, closed certain areas to allow for stock rebuilding and reduced fishing pressure by using fewer vessels through co-operative catching arrangements. Economic returns from the fishery have improved from co-operative harvesting strategies that deliver premium quality product to markets on a year-round basis. The company has directly contracted research to improve understanding of stocks and stock dynamics.

New Zealand's deepwater (800–1 200 m) fisheries for orange roughy and oreos were developed in the late 1970s, principally through foreign joint venture arrangements. They underwent a rapid transition to an almost entirely domestic operation following the introduction of the QMS. The orange roughy fishery has been one of the highest value fisheries in New Zealand. In the year ending December 2005,

exports were worth $US87.5 million (FOB), equating to 17.2 percent of New Zealand's finfish export earnings (SeaFIC, 2005). New Zealand is the world's largest supplier of orange roughy (Francis and Clark, 2005).

The ORMC has played a major role in creating opportunities and consolidating capital in a highly competitive international fisheries environment. This paper focuses on the development of orange roughy fisheries in New Zealand and the evolution of the ORMC and industry self-management under the QMS from its inception through to 2005. (Since 2005, the ORMC has been involved in a process of integrating its efforts with other offshore New Zealand fishing sectors into the Deepwater Group Limited. This paper does not cover these emerging new relationships.) The development and operation of New Zealand's deepwater fisheries has followed the lifecycle typical of many fisheries (e.g. Caddy, 1984; Smith, 1986; Granger and Garcia, 1996). The Chatham Rise fishery, the oldest and largest orange roughy fishery in the world, is used to illustrate these processes.

2. DEVELOPMENT OF DEEPWATER FISHERIES IN NEW ZEALAND

2.1 Biology

Orange roughy (*Hoplostethus atlanticus)* are deepwater, slow growing, long lived fish, estimated to attain a size of 50 cm and an age of over 130 years (based on otolith counts and radiometric studies by Tracey and Horn [1999]). They are widespread and occur in areas of the continental slope between depths of 500–1 500 m in New Zealand waters (Francis and Clark, 2005). Orange roughy form dense, seasonal spawning aggregations. Feeding aggregations outside of the spawning season are also typical, particularly on underwater topographical features such as hills, knolls and seamounts. Oreos (black oreo [*Allocyttus niger*], smooth oreo [*Pseudocyttus maculatus*] and spiky oreo [*Neocyttus rhomboidalis*]) occur at similar depths and have broadly overlapping distributions. While orange roughy and oreos are largely targeted independently, catches are often mixed. The ratio of orange roughy to oreo in catches varies by region, with oreos being more abundant in southern New Zealand waters.

2.2 The fishery

Japanese and Russian vessels reportedly fished orange roughy off the New Zealand coast as early as 1957 (Johnson and Haworth, 2004). In 1978, the New Zealand government introduced an Exclusive Economic Zone which extended to 200 nautical miles (nm). The government encouraged development in these new offshore areas (i.e. outside the 12 nm territorial sea) through joint ventures by New Zealand fishing companies with partners in Japan, Korea, USSR and other countries. New Zealand companies gained the expertise to catch, process and market orange roughy and oreos using a domestic fleet by the early 1990s. Orange roughy fishing was initially focused on the Chatham Rise, a continental shelf formation east of the South Island. New fisheries areas have been developed continually over the last 30 years. Knowledge of the location and size of orange roughy and oreo populations has unfolded as commercial fishermen and research scientists estimated the apparent size and extent of fishery resources. Two technological advances facilitated the development of these fisheries: 10 kW echo sounders capable of identifying fish marks to 2 000 m and the introduction of global positioning systems (GPS) that enabled discrete fisheries to be located and fished.

Trawlers that target orange roughy now operate as part of the deepwater fleet covering several fisheries including oreo, hoki and squid. Trawlers vary in size between 26 m and 85 m, with a mean length of 43.6 m, a mean tonnage of 793 t, a mean engine power of 1 310 kW and a mean year of construction of 1983. In the 2003/04 fishing year, as many as twenty deepwater vessels caught over 32 000 t of orange roughy. Ten of these vessels capture 70 percent of the annual orange roughy catch, while each of the remaining smaller vessels capture less than 1 000 t per year. Most of the vessels

PHOTO 1
Catch of orange roughy being emptied to processing deck, F.V. San Waitaki

PHOTO 2
Catch of orange roughy being emptied to processing deck, F.V. San Waitaki *East Chatham Rise, July 2006*

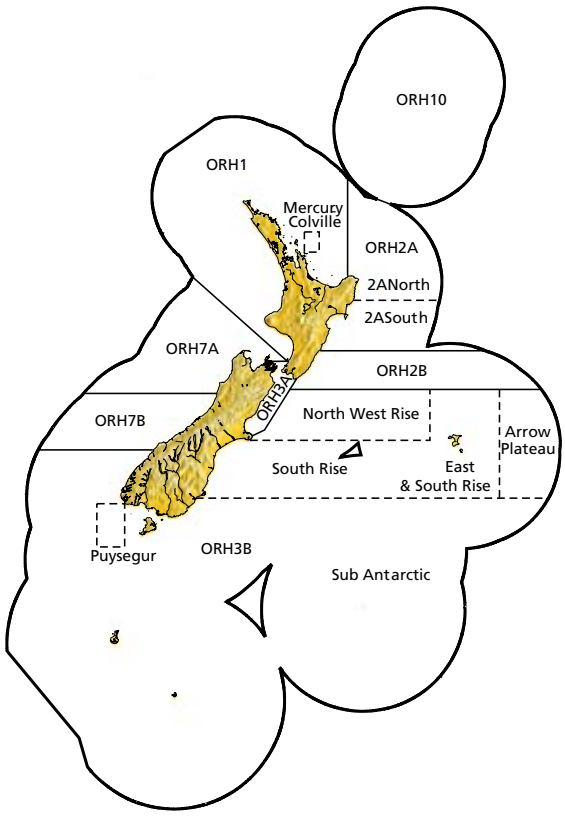
deliver to shore-based processors. Some vessels are freshers that land whole fish on ice as opposed to factory vessels that process at sea. Ice vessels typically make trips of 5–10 days and land their catch as whole fish Large freezer vessels land catch in either headed-and-gutted form (dressed) or as skinless fillets and remain at sea for 5–6 weeks. Photos 1 and 2 show catch and gear handling.

2.3 The Regulatory institution – the QMS

To support the development and management of offshore fisheries, a quota management system was introduced in 1983 for orange roughy, oreos, squid, silver warehou, hake, ling and hoki. Initial allocations of quota were based on an assessment of catch history, investment in vessels and commitment to processing. These deepwater quotas were initially non-transferable. The comprehensive QMS was introduced for 27 fish stocks in 1986. Government and industry agreed to incorporate the seven species under the deepwater quota into the QMS, which provided transferability. New Zealand has acknowledged that quota trading allowed optimization of quota mixes, a reduction in harvesting and processing costs and increased market returns.

In 1985, eight orange roughy Quota Management Areas (QMAs) were established, as seen in Figure 1 (i.e. ORH1, ORH2A, ORH2B, ORH3A, ORH3B, ORH7A, ORH7B and ORH10). There is currently no orange roughy fishing in ORH10. While fishing grounds are distributed about the New Zealand EEZ along the 1 000 m contour, the QMA boundaries serve to broadly separate the known fisheries for stock assessment and management purposes. As knowledge about the

FIGURE 1
Orange Roughy Quota Management Areas (solid lines) and designated sub-areas (dotted lines)



stocks has developed, several QMAs have been subdivided to better align management with recognized, discrete fisheries. These discrete fishery sub-areas have separate catch limits under the TACC, which are managed by quota owners in co-operation with the Ministry of Fisheries. Designated sub-areas on the Chatham Rise are the Northwest Chatham Rise, the East Chatham Rise (incorporating the "spawn box" fishery) and the Arrow Plateau. The South Rise, a subset of the East Chatham Rise, was created in 1991. The region south of 46° S, the Sub-Antarctic sub-area, is considered an exploratory region and a series of smaller orange roughy fisheries there are managed by individual topographic feature.

The objective of the QMS is to maintain biomass (B) at or above B_{MSY}, the stock size that will produce the maximum sustainable yield (MSY). For orange roughy, MSY is interpreted as the catch level that will maintain the biomass above 20 percent of the initial unfished biomass (B_0) more than 90 percent of the time (Francis, 1992). A target reference point of 30 percent B_0 and a limit reference point of 20 percent B_0 have been used for orange roughy stocks (Annala *et al.*, 2004). In New Zealand, two interpretations of MSY have been considered: maximum average yield (MAY), an estimate that assumes a constant proportion of the stock is harvested each year, or a Maximum Constant Yield (MCY), an estimate from modeling the maximum constant catch available with consideration for stock size fluctuations. In the simulation modelling, the above risk probabilities are applied in calculating these yields. Under an MAY strategy, B_{MSY} is estimated to be around 30 percent B_0 and the catch to be around 5–6 percent of the stock size (Annala, *et al.* 2005; Hilborn, Orensanz and Parma 2005). Under an MCY harvest strategy, B_{MSY} is estimated to be around 44 percent B_0.

The Minister of Fisheries sets the annual total allowable commercial catch (TACC) for each QMA based on the best available scientific and fisheries information. The setting and enforcement of TACCs provides for sustainable utilization. Annual catch entitlements (ACE) are generated on quota ownership and afford the right to harvest in a QMA for a single fishing year (i.e. 1 October through 30 September). Financial penalties (deemed values) are paid to the Government when catches exceed ACE owned by an operator. Deemed values are set above the net economic returns from the catch to encourage catches to be balanced within available ACE. Deemed values are set on an increasing scale, so that a vessel pays higher deemed value rates a tonne as the vessel increases the percentage amount by which it exceeds its ACE.

TACC setting is based on a scientific stock assessment program. Industry and government collaborate in a scientific working group to establish the information needs for appropriate fishery management. Scientific research and quota/ACE registry services are cost recovered for each fishery from quota owners, who are levied in proportion to their share of the TACC. The New Zealand fishing industry receives no subsidies from the government.

2.4 Orange roughy fishery management

New fisheries under a B_{MSY} strategy will be managed through three stages: development, fish-down and sustainable management. If a stock falls below the level that will provide MSY, then a fourth stage of rebuilding may be required. New fisheries on long-lived species such as orange roughy have a large, non-sustainable surplus during the development phase of a fishery (Hilborn, Orensanz and Parma, 2005). The fish-down phase, to harvest this surplus biomass, is characterized by a period of high catches until the stock is reduced to the management target. Once B_{MSY} is attained, lower catch levels are set to maintain stocks at or above B_{MSY} in the long-term. For orange roughy, fishery biomass is managed to decline to around 30 percent of the unfished biomass (B_0).

FIGURE 2
Hypothetical fish-down of an orange roughy fishery

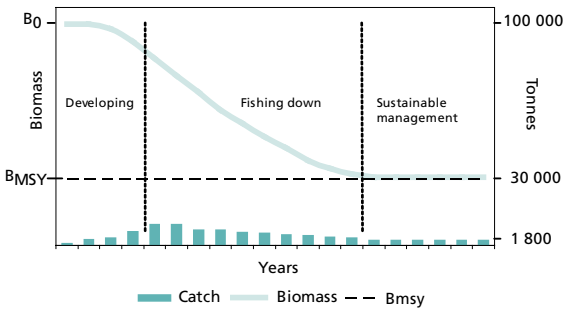
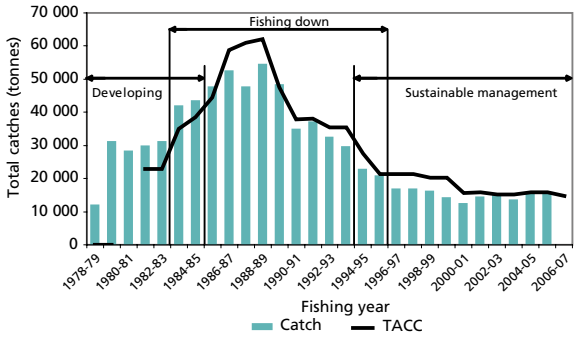


FIGURE 3
Historical total catch and TACC (tonnes) for New Zealand orange roughy fisheries and the associated fishery stages



The life-cycle of a hypothetical orange roughy fishery is illustrated in Figure 2. Assuming the unfished biomass (B_0) is estimated at 100 000 t, a target biomass of 30 percent B_0 or 30 000 t will produce the maximum sustainable yield (MSY). The transition from the unfished level to B_{MSY} provides an opportunity to remove 70 000 t of "surplus" biomass during the fish-down period. This 70 000 t catch could be taken at different rates over time. For example, the TACC could be set at 10 000 t/year for 7 years or 7 000 t/year for 10 years. Managers can select between a "hard-landing" (i.e. large changes in TACC at the end of the fish-down, once B_{MSY} is reached) or a "soft-landing" (i.e. progressive TACC reductions). Once the B_{MSY} target of 30 000 t is reached, the catch must be reduced to a level that maintains the population at or above B_{MSY}. At B_{MSY}, the long term yields are estimated to be 5–6 percent of current biomass, or 1 500–1 800 t in this example.

Early years in the orange roughy fishery were characterised by high catches and high catch rates, some at over 50 t a tow (Annala *et al.*, 2005) and were followed by declines in catch, as TACCs were subsequently reduced. The fish-down and sustainability phases of orange roughy fisheries have been the subject of considerable scientific scrutiny (Clark and O'Driscoll, 2003; Francis and Clark, 2005; Koslow *et al.*, 2000). However, TACC adjustments (by QMA) and catch limits for areas under industry governance over this time have reflected reductions in biomass as stocks have been fished down towards B_{MSY} (Figure 3). Most New Zealand orange roughy management measures use progressive reductions in TACC (i.e. soft-landings).

Research on orange roughy presents challenges. Research trawl surveys, egg surveys and CPUE indices have proven useful during the fish-down phase, during which the management objective is to reduce the population size to the B_{MSY} level. Signals in the data are strong and the resulting relative biomass estimate series prove useful for tracking population changes. Once the fish-down to B_{MSY} is complete and the annual TACC or catch limit has been scaled down to a level that will produce sustainable catches in the long-term, the stock size is expected to display little variability. Problematically, changes in biomass detected by subsequent surveys are usually so small that they fall

within the margin of error of the estimates. The measures that had been used during the fish-down phase are not precise enough to be informative for management purposes. Precise estimates of biomass are therefore required and absolute estimates are preferred over relative estimates. This is a technical and scientific challenge that is yet to be resolved.

As a consequence, orange roughy management has experienced sustainability issues associated with limited information. Scientists now acknowledge that stock assessment information was over-optimistic (Annala *et al.*, 2005). Biomass and yield estimates in the 1980s overestimated the resilience of stocks and inadequately reduced TACCs once stocks had been fished down to B_{MSY}. Annala *et al.* (2005) review over 20 years of orange roughy stock assessment research and management in New Zealand. They conclude that there were difficulties in determining catch limits that would result in an orderly fish-down to the target biomass (i.e. B_{MSY}) and that as many as 7 of the 9 major stocks had been reduced below $B_{MSY.}$

2.5 Management costs

For 2007, the levies on the Orange Roughy areas covered by the fisheries described here are NZ$1 573 845. This levy is paid to the government treasury and is a "cost recovery" in the sense that the Ministry of Fisheries has a budget that is not specifically dependent on the levy. The government decides on the Ministry budget and then some of the incurred costs are repaid to the treasury.

The industry must purchase some services directly from Fish Serve. FishServe has a per-transaction fee schedule, which is posted at: http://www.fishserve.co.nz/information/fees. The total budget for FishServe is about $4 million per year, but the orange roughy fleet would pay a relatively small part of this because they are a limited number of members and they deal in relatively large blocks of fish and so would not have many transactions.

3. FORMATION AND OPERATIONS OF THE ORMC

3.1 The ORMC cooperation

The development of the ORMC began with successful cooperative actions by ORH3B quota owners to develop and provide scientific research for new fisheries in unexplored areas. The consequent improvement in fisheries management measures led to an agreement with the Minister of Fisheries in 1991 and the formation of the Exploratory Fishing Company (ORH3B) Ltd. In 1994, quota owners extended the activities of the Company to cover all orange roughy and oreo fisheries (excluding ORH1) and renamed it the Orange Roughy Management Company (ORMC). The objective of the management company is to maximize the value of New Zealand's EEZ fisheries through improved research and improved co-operation with the government. The ORMC's vision is to maximize the long-term value of orange roughy and oreo fisheries in world markets by ensuring a consistent supply of high quality product.

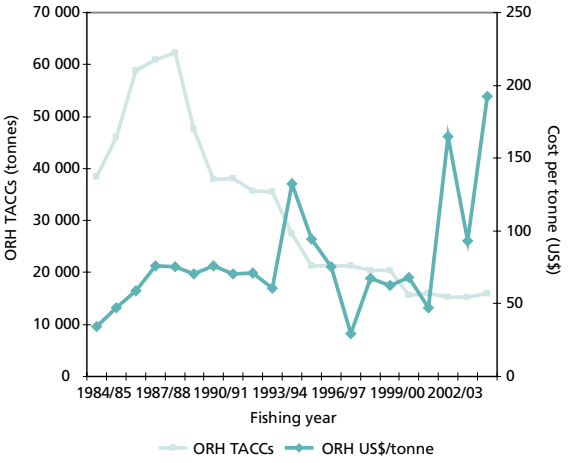
As of 2004, there were 6 to 15 quota owners in each orange roughy QMA, with 86–100 percent of the quota in individual QMAs owned by six companies or individuals. The number of quota owners participating in cooperative management in the ORH3B QMA has declined as consolidation and rationalization of quota has progressed through the fishery phases. In 1994 when the ORMC was formed, all but one quota owner participated. As of 2005, the ORMC represents the owners of over 95 percent of the deepwater quota.

3.2 ORMC scientific involvement

Quota-based management of orange roughy is information intensive. Collection of biological data from the deepwater fleet has become an important component in the assessment and management of fisheries. The ORMC has established a programme to collect biological information from the commercial fleet on new and developing fisheries that uses independent expertise, trained industry personnel and quality assured processes. This work is supplemented by fishery-independent research managed by the Ministry of Fisheries.

While fundamental biological and fishery parameters are estimated through modelling, these estimates depend on the underlying assumptions of natural mortality, fishing mortality, age and recruitment and these are not well established for orange roughy (Francis and Clark, 2005). Quota owners need to know the sustainable yields of the stocks to ensure that their investments in quota, vessels, onshore plants and markets are underpinned by sustainable management. It is in the best interests of quota owners to ensure this information is made available by conducting the necessary fishery research commensurate with the status of the fishery (i.e. developing, fishing down, sustainable or rebuilding phases). As fisheries have matured and TACCs have been adjusted to lower, long-term catch levels, revenues have declined. Consequently, the industry has faced increasing assessments per tonne for research and management costs over 1984–2005 (see Figure 4). Research assessments in 1984 were $US 34.37/t and have risen in 2005 to $US 159.91/t. (Note that in Figure 4, data for 2003/04 and 2004/05 are net of government repayment settlements.)

FIGURE 4
Orange roughy management costs vs. TACC, 1984–2004



Note: 1984 value: $US 34.37/mt and 2005 value $US 159.91/mt. Government repayment settlements given in 2003/04 and 2004/05 reduced levies for those years.

3.3 The ORMC's refined fisheries governance of Chatham Rise and exploratory fisheries

Prior to 1991, the government managed the ORH3B QMA as a single stock with a research focus on a single spawning aggregation on the Northeast Chatham Rise. The industry thought that there are multiple spawning sites on the Chatham Rise and elsewhere in the large ORH3B QMA. The industry believed that management of ORH3B should be based on more than one distinct fishery or stock. Research indicated that the 16 000 to 20 000 t catch from the Northeast Chatham Rise, taken mostly over flat ground during the spawning season, was not sustainable and recommended a revised annual catch of around 6 000–8 000 t (Annala *et al.*, 2005). The ORMC responded by agreeing to the cessation of fishing there to provide rebuilding and to spread catches to other areas within the large ORH3B management areas. To bring this into effect, the ORMC reached an agreement with the Minister of Fisheries in 1991 to establish several discrete fisheries within the ORH3B QMA (shown in Figure 1).

i. Northwest Chatham Rise;
ii. Northeast and South Chatham Rise;
iii. Arrow Plateau (an exploratory fishery area to the east of the Chatham Rise);
iv. Puysegur (a discrete fishery off the southwest coast of New Zealand); and
v. Sub-Antarctic (a large exploratory fishery area south of 46° S latitude).

These designated sub-areas and their associated catch limits were managed with an industry Deed of Agreement signed by all ORH3B quota owners. Since 1991, catch limits have been set for each designated sub-area. Each fishing year, quota owners partition their ORH3B annual catch entitlements (ACE) into the separate sub-areas. Quota owners trade ACE and report sub-area catches to the ORMC monthly and the ORMC manages the designated sub-area catches to the catch limits. The Deepwater Deed of Agreement is annually reviewed and updated to reflect changes in orange roughy (and oreo) TACC, quota ownership, compliance agreements, reporting requirements, notifications of quota and ACE transactions, species restrictions and specific area restrictions. Quota owners cooperate and communicate to ensure that catches from fishery sub-areas are within agreed limits. In some areas, catch limits have subsequently been set at zero by industry to maximize the rebuild rates where populations have been assessed to be below $B_{MSY.}$ For example, the Puysegur fishery was closed from 1 October 1997 and remains closed.

4. EVALUATION OF INDUSTRY CO-MANAGEMENT

4.1 ORMC management leadership

The QMS provides a platform for industry self-governance. The QMS has removed competitive fishing and allowed quota owners to adjust their species mixes, fleet composition and harvest plans to provide a consistent year-round supply of high quality product. The ORMC leadership has brought about further improvements through cost reductions, better stock management and co-operative actions, including resource development. A quota owners' management company, such as the ORMC, provides independent expertise and resources to improve the sustainable management and utilisation of fisheries. The ORMC acts on its shareholder's behalf to

i. implement a range of initiatives to improve the management of deepwater fisheries (e.g. fisheries research, strategic and fisheries planning, dispute resolution and relations with other stakeholders);
ii. provide a united and credible voice on all matters concerning the sustainable management and utilization of New Zealand's deepwater fisheries; and
iii. provide and maintain a direct dialogue with government and, in particular, the Minister of Fisheries.

The ORMC has taken on greater responsibility for managing fisheries by representing quota owner interests with other industry organizations and with government agencies. Agreements, through civil contracts between the ORMC, quota owners and the government, have resulted in self-regulatory management controls that include

i. closing areas to fishing;
ii. establishing and maintaining sub-areas and associated catch limits within large quota management areas;
iii. voluntarily reducing catches through the setting aside of quota;
iv. managing catches from discrete topographic features such as seamounts, hills and knolls within the exploratory fishery sub-areas where science-based stock assessment information is lacking (i.e. to spread fishing effort); and
v. supporting or promoting TACC changes based on the best available scientific information. In some instances, this included basing quotas on more conservative assumptions than the consensus recommendations of scientists.

4.2 The ORH3B industry governance – Chatham Rise and exploratory fisheries

The significance of these industry steps to manage quotas in sub-areas is well illustrated in the ORH3B QMA, which the ORMC manages at three distinct levels. The first is at the QMA level, where ORMC manages the overall catch to ensure it does not exceed

TABLE 1
Catch and catch limits (t) by designated sub-area within ORH3B

Year	Northwest Rise		South & East Rise		Pusegur		Arrow Exploratory		Sub Antarctic/ Exploratory	
	Catch mt	Limit mt	Catch mt	Limit mt	Catch mt	Limit mt	Catch mt	Limit mt	Catch mt	Limit mt
1992–93	3800	3500	10200	10800	4280	5000	10	*	360	2000
1993–94	3500	3500	10000	10800	2410	5000	470	*	260	2000
1994–95	2400	2500	5600	5500	1260	2000	750	3000	900	1000
1995–96	2400	2250	5100	4950	730	1000	170	*	3460	4500
1996–97	2200	2250	5000	4950	490	500	280	*	900	5000
1997–98	2300	2250	6300	4950	0	0	330	1500	850	4000
1998–99	2700	2250	4800	4950	0	0	730	1500	780	4000
1999–00	2100	2250	5700	4950	0	0	290	1500	470	4000
2000–01	2600	2250	5200	4950	0	0	190	1500	1320	4000
2001–02	2200	2000	7800	8400	0	0	70	1000	1200	1300
2002–03	2200	2000	8600	8400	0	0	220	1000	1160	1300
2003–04	2000	2000	8300	8400	0	0	140	1000	760	1300
2004–05	1600	1500	8800	8650	100**	0	60	1000	1680	1300

Notes: East Rise includes the Spawning Box, closed between 1992–93 and 1994–95 and the non-spawn fishery.
* Arrow Plateau included in Sub-Antarctic.
**Puysegur research catch 2004–05.

the TACC. The second is at the designated sub-area level, where the ORMC manages catch limits for each discrete fishery. These fisheries are managed as separate fish stocks. ACE is traded, catch is counted and fleets are managed by designated sub-area. ACE may not be moved between designated sub-areas. The third level involves the management of catch from individual topographic features in the exploratory sub-areas, where 500 t limits apply. A topographic feature is declared closed once the 500 t limit has been taken. An individual feature is managed as an area with a radius of 10 nm around its centre. The ORMC sub-area management paradigm is recognized and supported by the New Zealand Minister of Fisheries. The agreed designated sub-area catches have been well managed and annual catches have by-and-large matched the agreed catch limits (Table 1).

Although the ORH3B TACC has remained at 12 700 t for 10 years (Figure 5), sub-area catch limits within this QMA have undergone periodic changes. This is illustrated in Figure 6 and 7, which show that the catch limit for the Northwest Chatham Rise has declined during this period while the East and South Chatham Rise catch limit has increased. A portion of the ORH3B TACC (250 t) is set aside to cover research survey catches by commercial vessels, when these occur.

FIGURE 5
Catches and TACCs for the orange roughy ORH3B fishery, 1979–2005

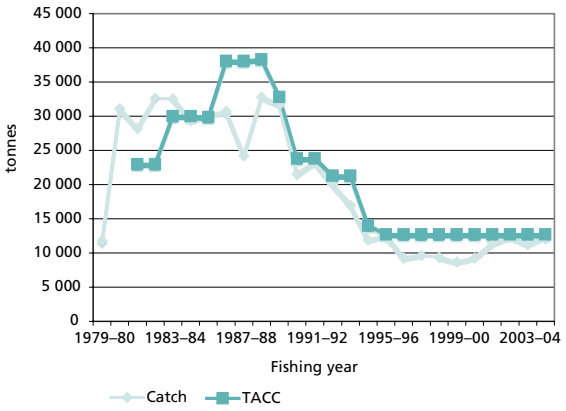


FIGURE 6
Catches and catch limits for Northwest Chatham Rise orange roughy fishery, 1979–2005

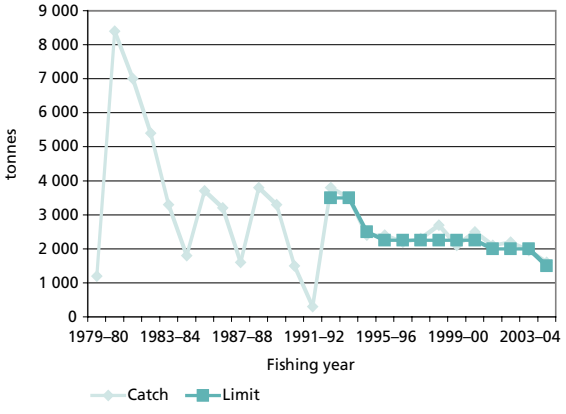
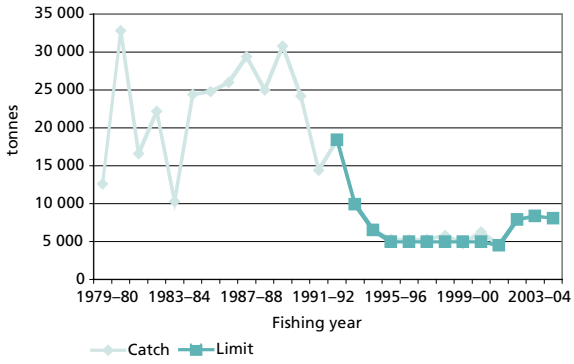


FIGURE 7
Catches and catch limits for the East Chatham Rise orange roughy fishery, 1979–2005



4.3 Improved research from industry involvement

The ORMC quota holders have invested an estimated $US 84.5 million in research since 1983 through direct purchase and through government levies. Both the Ministry of Fisheries and the ORMC have contracted research by independent organisations with international expertise in the following areas:

i. biomass surveys,
ii. stock discrimination (including genetic and morphometric techniques),
iii. age and growth investigations and validations,
iv. biological sampling of commercial catches for stock assessment, and
v. environmental studies on benthic habitats and impacts from fishing.

The transition from government-only to industry-and-government and now towards industry-only purchased research, has been an inevitable and desirable outcome of the ITQ system. There is a greater need by quota owners for information on the state of the stocks to improve management and to ensure sustainable utilization. In the direct purchase of research information, quota owners recognise the need for all research to be independent and to be peer reviewed.

The ORMC has invested in leading edge technologies such as swath mapping, which acoustically maps the ocean floor in swaths up to 12 km wide at orange roughy depths. The data can be digitally enhanced to produce a range of products, including acoustic images of the seafloor. Swath mapping enables a much clearer understanding of these deepwater habitats through refined bathymetric outputs. New Zealand leads the world in this field and the ORMC has now mapped the deepwater fishery areas throughout New Zealand's EEZ. This information is critical in improving the management of these fisheries, particularly for assessing and managing the possible environmental effects of fishing.

The integration of industry research and management strategy is well illustrated by developments in the Chatham Rise fishery. The Chatham Rise fishery initially focused on spawning aggregations of orange roughy between June and August and was steadily fished down. By 1992, this fishery was assessed to be below the management target (i.e. below B_{MSY} or 30 percent B_0) and the quota owners' response was to close the area known as the "Spawn Box" and to support further research to determine the stock size. The "Spawn Box" closure from 1992–93 to 1994–95 resulted in the development of new fisheries within eastern and southern parts of ORH3B, a move to year-round fishing and a reduced dependency on fishing spawning aggregations.

A research trawl survey of the "Spawn Box", undertaken in 1994 by the Ministry of Fisheries, provided a higher estimate of current biomass than the previous surveys, but with greater uncertainty (i.e. a coefficient of variation of 70 percent). Industry expressed concerns about the merits of demersal trawl surveys to estimate the biomass during the spawning season, as aggregations of orange roughy occur in "plumes" rising up to 200 m into the mid-water. The 1994 survey highlighted the inadequacy of this method for assessing highly aggregated orange roughy and trawl surveys were abandoned. Industry challenged scientists to develop alternative methods and turned to acoustic techniques.

To date, the ORMC has invested over $US 4 million in the development of acoustic technology for the biomass assessment. Counting orange roughy acoustically is extremely challenging. Orange roughy have a very low backscattering cross section,

are found at depths greater than 1 000 m, form dense aggregations, are often found over sloping ground and are close to the sea bottom. The first acoustic surveys were undertaken on the Chatham Rise stock in 1998. Further acoustic surveys have subsequently been completed by the ORMC on the East Chatham Rise spawning plume annually in 2002, and annually to, and including, 2006.

The acoustic research subsequent to 1994 established that the biomass on the East Chatham Rise was much higher than previously estimated. Subsequent stock assessments were undertaken by a consortium of international scientists from the University of Washington, the Australian Commonwealth Scientific Research Organisation (CSIRO), the New Zealand Seafood Industry Council (SeaFIC) and the National Institute of Water and Atmospheric Research (NIWA). The results of these assessments indicate that the current biomass in the most important sub-areas may to be around 50 percent B_0 (i.e. well above B_{MSY}). Industry acknowledge there is uncertainty around the model outputs and have chosen to harvest at a rate substantially below the 2001 stock assessment recommendation.

The southern portion of New Zealand's 200 nm zone remains relatively unexplored but hosts a number of discrete orange roughy fisheries. Exploration of deepwater fisheries is expensive, difficult and dangerous, but ORH3B quota owners continue to explore these areas. Industry-initiated exploratory surveys in the early 1990s resulted in new fisheries being developed here. An example is the Puysegur fishery, discovered in 1991 that produced a total catch of around 15 000 t over six years before being voluntarily closed by industry from 1 October 1997 to promote stock re-building.

4.4 The ORMC self-management of fishery sub-areas

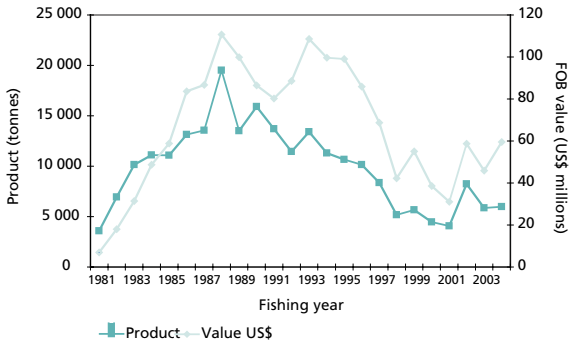
The ORMC has established and managed designated sub-areas within the ORH3B QMA for 15 years. Since its inception, the designated sub-areas have been carefully constructed based on the TACC for the overall QMA. The ORMC has been successful in the management of sub-area catch limits by way of an annual Deepwater Fisheries Management Agreement among quota holders that sets out the available quota and ACE for each designated sub-area. Industry management avoids the administrative costs associated with government responsibility to monitor and enforce sub-area catch limits.

To provide for credible fishery management and a transparent collaborative management arrangement between the Ministry of Fisheries and Industry, the ORMC focuses on an essential auditing and monitoring role of the catch spreading agreements including:

i. annual Deepwater Fisheries Management Agreement Schedule;
ii. monthly reports detailing estimated catch, landings, location and effort data for orange roughy in ORH 3B;
iii. quarterly comparison of QMA catches, reported to the ORMC by sub-area, with the overall QMA catches as reported by ACE-holders to the Ministry of Fisheries;
iv. quarterly audit of Sub-Antarctic feature catches reported to the ORMC against those reported by ACE-holders to the Ministry of Fisheries (i.e. analysis of catches by latitude and longitude); and
v. correspondence to ACE-holders, relating to area closures as sub-area and feature catches reach 80 percent and 100 percent of the catch limits.

The ORMC reporting framework assists in ensuring the robustness of the catch limits in the Sub-Antarctic Fisheries. The Sub-Antarctic exploratory region is not managed with a current annual yield (CAY) policy and has only limited assessment information as the basis for determining whether current or proposed catch limits are sustainable.

FIGURE 8
Orange roughy landings and export value (US$), 1981–2004



5. DISCUSSION

5.1 Economic benefits

ITQs have provided incentives for efficient operators to invest in additional quota, new vessels, improved harvesting and processing capabilities and market development. As management has become more complex, with the introduction of smaller multiple fisheries, large quota owners have undertaken to lease the quota owned by smaller operators. This has resulted in improved utilization of vessels, rationalization of the fleet and processing capabilities and substantially less fishing pressure.

Security of catch access allows quota owners to focus on market needs. Quality of fish products has improved substantially. The industry has moved away from bulk fishing during spawning seasons towards year-round fishing with smaller amounts in each tow to maintain fish quality. Today, less than 30 percent of the Chatham Rise catch is taken during the spawning season. The majority is taken throughout the year by a fleet of less than ten vessels, with fish quality optimized through small catches, targeting of non-spawning fish and, in many cases, processing onboard to produce frozen-at-sea consumer-ready products. There are now fewer than five factory trawlers targeting orange roughy in New Zealand's waters.

Annual export revenues from orange roughy have averaged about $US60 million in recent years. The main markets are the USA and Australia, with additional exports to China, Canada and France. New Zealand supplies over 60 percent of the orange roughy imports into the USA, 18 percent of China's imports and 17 percent of Australia's imports. Since 1985, the value of orange roughy export has grown faster than export volumes (Figure 8). Overall, the value of New Zealand orange roughy and oreo fisheries, as represented by the market value of the quotas, had grown to $350 million (Statistics New Zealand, 2007).

5.2 The new sustainability management paradigm

The difficulties with biological assessment and consequent stock reductions below B_{MSY} in some fisheries necessitated re-building strategies and fishery closures. The slow population recovery rates by deepwater stocks (Koslow *et al.*, 2000), together with global pressure from non-government organizations around the perceived impact of deepwater trawling on benthic habitats, caused scientists to advocate a shift to more conservative assessment assumptions. This more conservative sustainability paradigm, the associated higher target biomass levels and consideration of ecosystem-based environmental management is well understood by the ORMC, which has already taken steps to:

i. reduce fishing effort through catch consolidation;
ii. improve efficiency and catch rates through fleet rationalization;
iii. spatially manage areas where stocks show vulnerability; and
iv. implement benthic protection areas (BPAs) that exclude bottom trawling in 30 percent of the New Zealand EEZ.

5.3 The ORMC now and in the future

The Orange Roughy Management Company, through cooperative arrangements and civil contracts, has successfully transformed competitive quota owners into a sophisticated, co-operative group that participates in science, policy and management decisions. Several factors made this cooperative approach possible, including:

i. a small number of participants;
ii. leadership by quota owners who recognized the improved business environment under the QMS;
iii. a relatively new fishery with little political interference;
iv. a simple fishery with no competing users of the resource;
v. a fishery focused on a high value, high market demand species; and
vi. a fishery requiring close management and facing challenges to estimate stock size.

Industry leadership and participation in the management of these deepwater fisheries has contributed to the international recognition, of the success of the New Zealand QMS. Quota holders, although strongly independent, acknowledge that their best interest is to cooperate on stewardship of the limited natural resources. This cooperation continues to evolve. Two major initiatives from the fishing industry since the year 2005 are: (a) consolidation of multiple deepwater and middle depth fisheries to create The Deepwater Group Limited (DWG) and (b), initiation of benthic protection areas (BPAs). The structure of the industry has also seen some significant change as a large number of small quota holders resulted from the distribution of Maori quota previously managed by the Te Ohu Kai Moana Trust to individual Iwi (local Maori groups and organizations) under terms established by the Treaty of Waitangi Fisheries Commission. Together with the New Zealand Government, the ORMC has successfully evolved through the lifecycle of deepwater fisheries and is well positioned to take on the challenges of the 21st century.

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