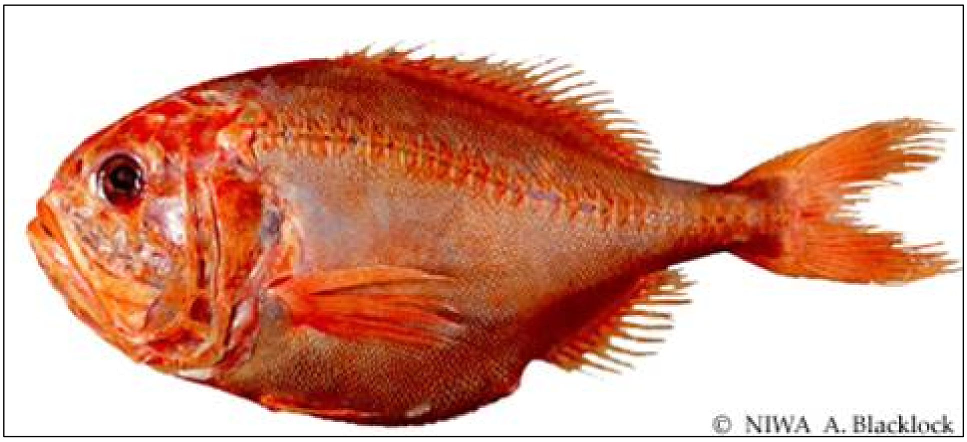
SP-07-SWG-INF-09

Chile
13 May 2009

Information describing orange roughy *Hoplostethus atlanticus* fisheries relating to the South Pacific Regional Fishery Management Organisation



WORKING DRAFT
04 MAY 2007

1. Overview

This species occurs in the north and south Atlantic, in the south-central Indian ocean, in the Tasman sea, on the New Zealand shelf, on seamounts and ridges to the east of New Zealand, and off central and Southern Chile. In the South Pacific, orange roughy aggregates in deep, cold waters over steep continental slopes, canyons, ocean ridges, and underwater topographical features such as seamounts, especially during spawning and feeding.

Orange roughy have very low biological productivity. This is due to a combination of late onset of maturity; low fecundity; low annual growth rate; and high longevity.

Target trawl fisheries for orange roughy have occurred in the South Pacific since the late 1970's to the present day. The Lord Howe Rise and Northwest Challenger Plateau have been the main areas of orange roughy catch in the Tasman Sea outside the New Zealand and Australian EEZs. A fishery on the Norfolk Ridge is a recent development, and the Louisville Ridge fishery to the east of New Zealand continues. Catches peaked in the area in the mid 1990s at around 15,000 t, but in recent years have been 2,000-3,000 t.

Incidental captures of seabirds, through interaction with trawl warps have been reported in some orange roughy trawl fisheries but none have been reported to date by observers on vessels fishing in the Southwest Pacific high seas area.

The main commercial bycatch species when targeting orange roughy on the high seas include: oreos (*Allocyttus niger*, *Pseudocyttus maculatus*, *Neocyttus rhomboidalis*), cardinalfish (*Epigonus telescopus*), ribaldo (*Mora moro*), seal sharks (*Dalatias* spp.), alfonsino (*Beryx splendens*), and rattails. A further 100 plus fish species have been recorded as bycatch from orange roughy fisheries by observers on vessels fishing in the Southwest Pacific high seas area. The mix of species that orange roughy is associated with varies with latitude.

The main method used to catch this species is a high-opening trawl generally fished hard down on the bottom. Trawling for this species on seamounts, knolls and pinnacles has substantial impacts on habitat and benthic invertebrate species, but the reciprocal impact of this on the orange roughy populations or other species is unknown.

There are no regulations regarding limits on catch in international waters of the South Pacific with the exception of the South Tasman Rise region.

There are currently no accepted stock assessments for orange roughy high seas fisheries in the South Pacific and the status of the five known high seas orange roughy stocks (fisheries) in the Southwest Pacific is unknown but likely to range from fully exploited to over exploited.

2. Taxonomy

2.1 Phylum

Vertebrata

2.2 Class

Actinopterygii

2.3 Order

Beryciformes

2.4 Family

Trachichthyidae

2.5 Genus and species

Hoplostethus atlanticus (Collet, 1889)

2.6 Scientific synonyms

Hoplostethus gilchristi, *Hoplostethus islandicus*

2.7 Common names

Orange roughy, slimehead, atlantischer sagebauch, burfiskur, deep sea perch, degenfisch, granatbarsch, huichidai, kaiserbarsch, olho-de-vidro, orenzi rufi, red roughy, reloj, soldakfisk, l'Empereur

2.8 Molecular (DNA or biochemical) bar coding

Accession DQ108113.1 cytochrome oxidase subunit 1; accession DQ108112.1 cytochrome oxidase subunit 1; accession DQ108111.1 cytochrome oxidase subunit 1; accession DQ108110.1 cytochrome oxidase subunit 1; accession DQ108109.1 cytochrome oxidase subunit 1; accession AM230657 *Hoplostethus atlanticus* microsatellite DNA, locus Hat58; accession AM230656 Hoplostethus atlanticus microsatellite DNA, locus Hat54; accession AM230655 Hoplostethus atlanticus microsatellite DNA, locus Hat25; and, accession AF146639 Hoplostethus atlanticus clone Hat9a microsatellite sequence.

3. <u>Species characteristics</u>

3.1 Global distribution and depth range

Hoplostethus atlanticus has been reported in the North Atlantic from Nova Scotia to Norway, down the eastern South Atlantic to South Africa and across the south-central Indian Ocean to Western Australia. In the Pacific region it occurs along the shelf edge of southern Australia, on ridge and hill features in the Tasman Sea, around the entire New Zealand shelf, on hill features and ridges to the east of New Zealand, and off central and southern Chile (Branch, 2001). It has been recorded from depths of 180 m to at least 1800 m (Kotlyar, 1996), but in the Pacific it is seldom recorded shallower than 500 m and is most common in depths from 700 m -1100 m (Anderson et al. 1998).

3.2 Distribution within South Pacific area

The area in the Southwest Pacific known to be occupied by this fish outside EEZs on the high seas – *based on catch effort data reported to Australia and New Zealand (Clark 2006), scientific observer data and habitat assumptions* – is ~220 000 km2 (See Figure 1 for assumed approximate distribution).

Figure 1: Distribution of orange roughy in the south west Pacific.

3.2.1 Inter-annual and/or seasonal variations in distribution

Spawning occurs in a few specific areas, generally at depths of 700-1000 m, and it is believed that some individuals may migrate distances of 100 km or more to reach a spawning ground (Coburn & Doonan 1994, Francis & Clark, 1998). Time of spawning in the southern hemisphere extends from May to August with differences in the onset of spawning between areas which seems to be consistent from year to year (Pankhurst 1988, Bell et al. 1992, Young et al. 2004).

3.2.2 Other potential areas where the species may be found

Additional area of assumed presence outside EEZs is ~90 km2, mainly on ridges in the mid-Pacific, and the species has been recorded from the East Pacific Rise (reference is required here). Orange roughy is assumed to occur outside the Chilean EEZ on the Nazca ridge, but this has not been confirmed (this last paragraph should be deleted, because the available evidence (extensive Russian research cruises and one Chilean research cruise) don´t register the presence of Orange roughy in Nazca and Sala y Gomez ridges).

3.3 General habitat

In the South Pacific, orange roughy aggregates in deep, cold waters (3-9 ˚C) over steep continental slopes, canyons, ocean ridges, and underwater topographical features such as seamounts, especially during spawning and feeding (Clark et al. 2000). Orange roughy can also be dispersed over smooth bottoms, rough bottoms, and steep, rough grounds. Orange roughy are bentho-pelagic, generally occurring near the bottom but at times ascending to feed or spawn 50-100 m above the seafloor.

3.4 Biological characteristics[1]

Sexes co-occur but are often segregated. Seasonal catch samples from particular grounds are seldom strongly biased to either sex, but samples from individual trawl tows can be strongly biased, indicating some degree of schooling by sex, particularly during spawning.

The fish can reach about 58 cm standard length in the southern oceans, especially off central Chile where on average fish are larger than in New Zealand, Australia, and Namibian grounds; females reach a slightly large size than males. Age and growth of orange roughy from a number of localities have been investigated (Tracey & Horn 1999, Gili et al, 2002). Annual zone formation in the otoliths of juvenile fish has been validated, indicating very slow growth to a length of only 7.6cm after 3 years (Mace et al. 1990). Decay rates of naturally occurring radio-nuclides in otoliths to age fish was first applied to orange roughy by Felton et al. (1991), who concluded that fish 38-40 cm long were 77-149 years old. Additional work by Smith et al. (1995) and Francis (1995a, 1995b) reanalysed the data, and concluded that the longevity of this species probably exceeded 100 years. Radiometric ages were shown to correlate with those derived from counts of zones in otolith thin sections (Smith et al. 1995). Age estimates in excess of 130 years have since been derived using the thin section method (Branch 2001, Gilli et al. 2002), indicating a very slow growth rate for this

[1] It should be noted that most of the reported biology is based on data collected from within EEZs. However, from the data collected on the high seas most of these assumptions about orange roughy biology appear to hold.

species. More recent and sophisticated radiometric ageing have confirmed longevity of 100-150 years (Andrews and Tracey 2003, 2007).

Orange roughy are synchronous spawners (Pankhurst 1988, Young et al. 2004). The onset of sexual maturity has been associated to the formation of a transition zone found in the otolith of large fish, where annuli width changes permanently from being wide and opaque to fine and more translucent (Francis & Horn 1997; Horn et al. 1998). On the basis of this assumption Horn et al. (1998) found significant differences in mean size and age at sexual maturity between grounds off Namibia, New Zealand, Tasmania and Hatton Bank southwest of the United Kingdom, with a greater age at onset of maturity found at grounds with a greater modal length of the mature population. In the southwest Pacific, size and age parameters range from 28-34 cm and 23-31 years. Gili et al. (2002) also examined the transition zone and estimated for the Chilean stock fishery in the southeast Pacific that length at onset of maturity was about 33cm at 30 to 32 years. These parameter values are similar to those reported in New Zealand, although modal lengths for mature individuals are bigger for the Chilean grounds.

Spawning occurs in a few specific areas, generally at depths of 700-1000 m, and it is believed that some individuals may migrate up to 100 km to reach a spawning ground (Coburn & Doonan 1994, Francis & Clark 1998). Time of spawning in the southern hemisphere extends from May to August with differences in the onset of spawning between areas which seems to be consistent from year to year (Pankhurst 1988, Bell et al. 1992, Young et al. 2004). Although spawning occurs annually, apparently not all mature fish spawn every year (Bell et al. 1992, Branch 2001). In the Southwest Pacific fecundity is relatively low, ranging from 20 000 – 70 000 eggs per kg of body weight (Pankhurst 1988, Clark et al. 1994, Koslow et al. 1995), while fecundity in the Southeast Pacific is slightly greater, ranging from 16 056 -115 944 egg per kg body weight (Young et al. 2004). Newly fertilised eggs rise in the water column as they develop, but are thought to sink near the end of the development stage to hatch near the bottom about 10-20 days after fertilisation (Bulman & Koslow 1995, Zeldis et al. 1995). The distribution and behaviour of young (<3 years old) orange roughy is poorly known because they are rarely encountered during trawling (Mace et al. 1990), but, they are likely to be demersal from at least 6 months after hatching. Juvenile fish have yet to be found in Chilean waters (Young et al. 2003).

Current productivity parameters used in assessments of New Zealand's orange roughy stocks are: $L\infty$ = 33-38 cm (dependant on sex and area), k = 0.065 yr-1, M= 0.045 yr-1 (Ministry of Fisheries 2006a). Parameters used in assessments of Chilean orange roughy stocks are: females: $L\infty$ = 53.8 cm, k = 0.03 yr-1, M = 0.04 yr-1; males: $L\infty$ = 47.86 cm, k = 0.04 yr-1, M = 0.04 yr-1 (Gilli et al. 2002). Australian productivity parameters vary between populations. For the continental slope populations (St Helens and southern Tasmanian populations); females: $L\infty$ = 31 cm (22-40), k = 0.048yr-1, M = 0.04 yr-1; for males: $L\infty$ = 40 cm (28-52), k = 0.064 yr-1, M = 0.04 yr-1. Fish on the Cascade Plateau are larger and longer-lived with an M of 0.02 (Smith & Waite 2004).

Morphology: four to six dorsal spines, 15-19 soft dorsal rays, three anal spines, and 10-12 soft anal rays; 196-25 ventral scutes. Pale orange through bright brick red in colour, with mouth and gill cavity bluish black.

3.5 Population structure

Separate stocks of orange roughy are recognised on spatial scales that are very small relative to the global distribution of the species, for example in association with small groups of seamounts.

There are genetic and biological differences (maximum size and age at maturity) between populations of orange roughy within the EEZs of Australia and New Zealand (e.g., Lester et al. 1988, Edmonds et al. 1991, Smith et al. 1997, Smith et al. 2002, Ministry of Fisheries, 2006). Genetic studies for the Chilean EEZ fishing grounds using microsatellite and mitochondrial DNA techniques do not support the hypothesis of genetic structure of Chilean orange roughy population (Niklitschek *et al*., 2009). Only parasitic analyses suggest a possible ecological difference in one of the five seamounts studied (*e. g.,* Juan Fernandez 3), although authors do not consider it is evidence strong enough to support population structure. Other studies have shown slight differences in the spawning time (weeks) among seamounts in Juan Fernandez (Niklitschek *et al*., 2005, Young *et al*., 2000).

The five fishing grounds near the New Zealand EEZ boundary (Lord Howe Rise, Northwest Challenger Plateau, Louisville Ridge, South Tasman Rise and West Norfolk) are all regarded and managed as separate stocks (Ministry of Fisheries, 2006) on the basis of geographical separation (Smith 2000) and differences in various stock differentiation factors (Smith *et al*. 2002). Orange roughy on the southwest Challenger Plateau (Westpac Bank) are regarded as a straddling stock with fish inside the New Zealand EEZ (Clark 1991).

The Louisville Ridge is a long seamount chain, and little is known about stock structure within the area. There are several known spawning sites, and it would seem likely that there could be multiple stocks or sub-populations along the ridge based on geographical separation.

Orange roughy on the South Tasman Rise are regarded as a straddling stock with fish inside the Australian EEZ.

3.6 Biological productivity

Orange roughy have very low productivity. This is due to a combination of late onset of maturity; low fecundity; low annual growth rate in relation to size; and high longevity. The proportion of biomass that can be harvested sustainably is very small. These annual harvest values have been estimated to be in the range of 1.0 to 2.0% of virgin biomass (Francis 1992).

3.7 Role of species in the ecosystem

Orange roughy are thought to be opportunistic predators taking advantage of prey often available around underwater features—usually prawns, squid, and small fishes (Rosecchi et al. 1988, Labbé & Arana 2001, Koslow & Bulman 2002). Other prey items include amphipods, mysids, and decapod crustaceans (Rosecchi et al. 1988, Bulman & Koslow 1992). Availability of prey on and around underwater features may explain the non-spawning aggregations observed on some fishing grounds. Juveniles feed mainly on crustaceans, switching to squid and fishes as they grow larger. In the main fishing grounds orange roughy tend to be the dominant large demersal fish biomass in the ecosystem.

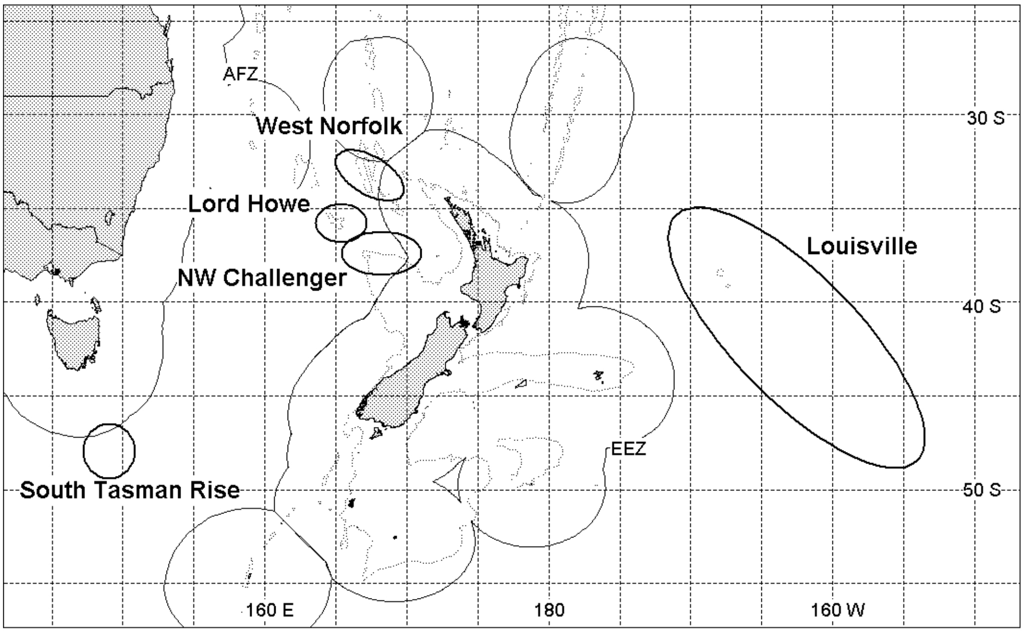
4. Fisheries characterisation

4.1 Distribution of fishing activity

The Lord Howe Rise and Northwest Challenger Plateau have been the main areas of orange roughy catch in the Tasman Sea outside the New Zealand and Australian EEZs. A fishery on the Norfolk Ridge is a recent development, starting in 2001-02. The Louisville Ridge fishery to the east of New Zealand continues.

The Lord Howe Rise extends from the north-western margin of the Challenger Plateau, off the west coast of New Zealand, out to Lord Howe Island in the western Tasman Sea. The ridge is mostly in international waters, although it does extend into both the Australian and New Zealand EEZs. A major fishery for orange roughy developed on the Lord Howe Rise in 1988, and has progressively shifted to the Northwest Challenger Plateau (Figure 2). A number of countries fished the area in the late 1980s; however, during the 1990s New Zealand and Australian vessels were dominating the fishery.

Figure 2: The New Zealand/Australia region, showing location of major fisheries for orange roughy outside New Zealand and Australian EEZs (1000 m depth contour shown around New Zealand) (from Clark 2006).



New fishing grounds have been developed on the West Norfolk Ridge, which runs northwest from the North Island of New Zealand towards New Caledonia. This comprises a chain of ridge peaks and underwater topographical features (including some seamounts and knolls) both within and beyond the New Zealand EEZ.

The Louisville Ridge is a chain of seamount and guyot features extending southeast for over 4 000 km from the Kermadec Ridge. It is a “hotspot” chain of more than 60 volcanoes, most of which rise to peaks of 200–500 m from the surrounding seafloor at depths around 4 000 m. The Louisville Ridge is on the high seas to the east of New Zealand. The Louisville Ridge fishery dates from 1994.

The South Tasman Rise is a prominent ridge extending south from Tasmania into the Southern Ocean. It has a series of small peaks near its main summit at about 900 m just outside the Australian 200 mile Fishing Zone. In 1997 a fishery developed for orange roughy over the South Tasman Rise. This was fished mainly by Australian and New Zealand vessels, but recently fishing activity has diminished to very low levels.

Fishing also occurs within the New Zealand and Australian EEZs. The main fishing grounds within the New Zealand EEZ are the Chatham Rise off the east coast of New Zealand, although major fisheries have also occurred in the past on the Challenger Plateau and off the east coast of the North Island. In Australia the main fishing grounds are the East and south of Tasmania, with historically a large fishery based on spawning at St Helens seamount, and non-spawning fish on hills to the south of Tasmania. The Cascade Plateau has also had moderate catches. Fishing in the South east Pacific occurs only within the Chilean EEZ around 33°S to 34°S on the Bajo O'Higgins and Juan Fernandez Islands seamounts. Fishing began in 1999, and commercial fishing activities have been suspended from 2006 for research purposes.

4.2 Fishing technology

The characteristics of vessels fishing orange roughy differ between areas. They range from relatively small (20–30 m length) trawlers that return their catch to shore whole on ice, however the majority of catch is taken by factory trawlers (up to 70–80 m) that process the catch onboard to head-and-gut or fillet form. Trawl gear has developed over the duration of the fishery, and is designed to cope with rough seafloor (use of bobbin and rockhopper ground gear) and large catches. Electronics have also developed extensively in the last 2 decades, with, for example, echosounders, GPS, and net-monitoring equipment making deep fishing much more efficient and effective.

A large number of New Zealand (or NZ-registered) vessels have been involved over time in the orange roughy fisheries outside the New Zealand EEZ. These total 127 individual vessels, although many have not been involved for more than a few years, or only carried out a small number of tows. Numbers have varied by fishery, with 54 for the Lord Howe Rise, 65 for the Northwest Challenger, 8 in the West Norfolk Ridge, 55 in the Louisville Ridge, and 17 in the South Tasman Rise fishery. The number of vessels has generally decreased in all fisheries in recent years, and in 2006 numbers were 6, 8, 6, 5 and 0 in the respective areas.

In the New Zealand EEZ between the years 1979 and 2006 there have been about 260 vessels reported as fishing for or catching orange roughy.

In the Chilean EEZ, between years 2000 and 2003, there were 5 fishing boats targeting orange roughy on a regular basis that share a significant part of the annual total catch. In 2004 and 2005, fleet size dropped to 3 and 2 boats respectively, one of which was a factory trawler that entered the fishery as part of the acoustic survey financed by the industry in 2003 and by a research grant in cooperation with the industry in 2004.

*****Note that Australian information and information from other countries fishing on the high seas still needs to be incorporated here. Abstract from Document SWG 24***

4.3 Catch history

Orange roughy has been target-fished by trawl off New Zealand since 1979, off Australia since 1985, and off Chile since 1999. Southwest Pacific landings peaked in 1990 and have been declining since then. Southeast landings peaked in 2001 and steadily declined after that time. Reported landings from FAO data in the South Pacific are provided in Table 1, but, note that the data contain catches from within EEZs and on the high seas. Further, some of the catches reported appear to include double counting resulting from flag states fishing within other states EEZ under foreign license or charter arrangements reporting catches which are also reported by the coastal state.

Globally, most orange roughy catches have come from the southern hemisphere (Figure 3) and have been declining in all areas since the mid 1990s.

Catches (t) for New Zealand taken outside EEZs in the South Pacific region are given in Table 2. The Lord Howe fishery has been fished by other states including Australia and the catches in Table 2 represent approximately 34% of the total known catch from the fishery.

Table 1: Reported landings (t) of orange roughy by country, FAO area and year from 1977 to 2004.

Flagged vessel	FAO area(s)	1977	1978	1979	1980	1981	1982	1983
New Zealand	81	-	-	5 000	26 027	24 060	29 592	41 759
Un. Sov. Soc. Rep.	81	319	-	1 251	17 300	14 076	8 860	7 229
Total reported South Pacific region catch	71,81,87	319	-	6 251	43 327	38 136	38 452	48 988
Total reported catch outside the South Pacific	27,47,51,57	0	0	0	0	0	0	0
Total world reported catch	71,81,87, 27,47,51,57	319	0	6 251	43 327	38 136	38 452	48 988
Flagged vessel	FAO area(s)	1984	1985	1986	1987	1988	1989	1990
Australia	81	-	-	2 600	5 400	6 900	13 542	37 901
New Zealand	81	37 271	39 999	44 609	49 014	55 361	51 538	48 379
Norway	81	-	-	-	-	-	1 153	3 450
Russian Federation	81	-	-	-	-	991	1 132	36
Un. Sov. Soc. Rep.	81	4 028	4 306	2 475	130	-	-	-
Total reported South Pacific region catch	71,81,87	41 299	44 305	47 084	49 144	56 352	67 365	89 766
Total reported catch outside the South Pacific	27,47,51,57	0	0	0	0	0	1966	1 712
Total world reported catch	71,81,87, 27,47,51,57	41 299	44 305	47 084	49 144	56 352	69 331	91 478
Flagged vessel	FAO area(s)	1991	1992	1993	1994	1995	1996	1997
Australia	81	33 111	18 187	12 050	9 977	7 070	4 526	3 129
New Zealand	81	35 819	36 568	29 681	31 718	33 077	28 639	20 545
Norway	81	82	2	1 602	665	1	5	12
Russian Federation	81	506	-	-	-	-	-	-
Ukraine	81	4	-	-	-	-	-	-
Total reported South Pacific region catch	71,81,87	69 522	54 757	43 333	42 360	40 148	33 170	23 686
Total reported catch outside the South Pacific	27,47,51,57	1 424	5 059	3 368	3 054	8 400	15 818	20 859
Total world reported catch	71,81,87, 27,47,51,57	70 946	59 816	46 701	45 414	48 548	48 988	44 545
Flagged vessel	FAO area(s)	1998	1999	2000	2001	2002	2003	2004
Australia	71	-	-	717	872	326	764	818
Australia	81	3 207	28	26	17	14	54	56
China	81	-	-	-	-	547	338	-
Korea, Republic of	81	-	230	-	47	-	-	-
New Zealand	81	21 485	23 780	17 879	14 044	17 954	17 778	17 829
Norway	81	3	-	-	-	-	-	-
Ukraine	81	-	-	102	195	-	176	272
Chile	87	2	779	1 482	1 868	1 514	1 249	1 262
Total reported South Pacific region catch	71,81,87	24 695	24 817	20 206	17 043	20 355	20 359	20 237
Total reported catch outside the South	27,47,51,57	17 725	12 886	9 248	11 437	11 606	7 436	5 644

Figure 3: FAO data of orange roughy catch (t) in the South Pacific from 1977 to 2004 compared to global catch of the species.

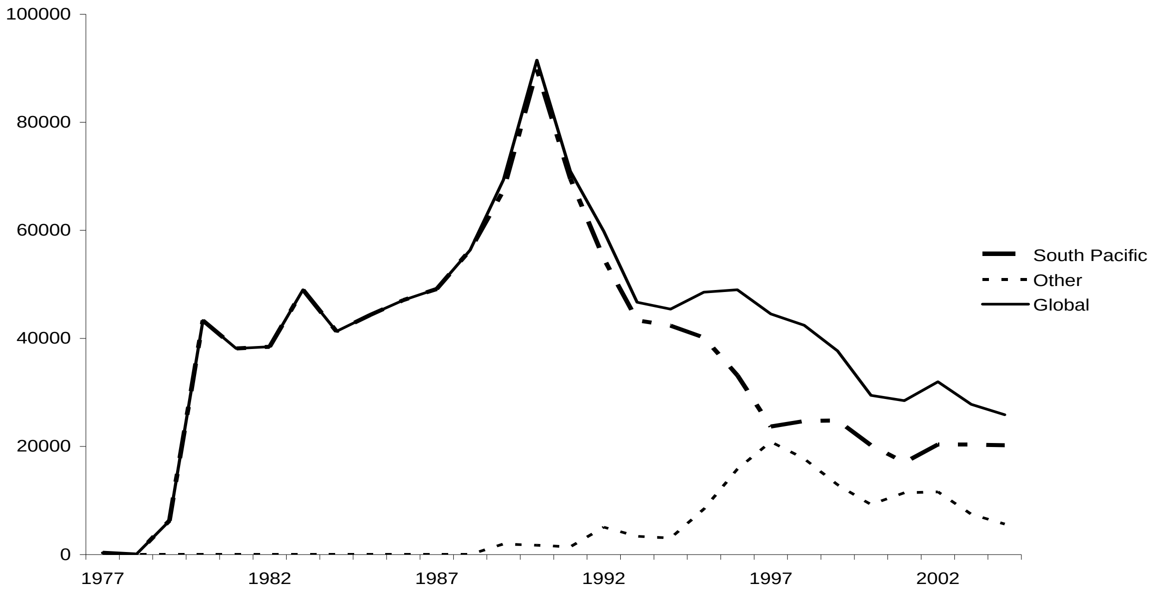


Table 2: Reported landings (t) of orange roughy by New Zealand outside EEZs by year and Southwest Pacific fishing ground from 1981 to 2006 (see Figure 2 for a definition of the fishing grounds).

NOTE: This table is based on New Zealand Ministry of Fisheries TCEPR-HSCER data extracted in early 2007 (with initial post logical grooming undertaken, e.g., plots of data to check E/W errors).

The NW Challenger fishery has been fished by other states including Australia and the catches in Table 2 represent approximately 83% of the total known catch from the fishery. The Louisville fishery has also been fished by Australia and the catches in Table 2 represent approximately 93% of the total known catch from the fishery. The West Norfolk fishery has also been fished by Australia and the catches in Table 2 represent approximately 96% of the total known catch from the fishery. The Tasman Rise fishery has been fished by other states including Australia and the catches in Table 2 represent approximately 24% of the total known catch from the fishery (Clark in prep).

4.4 Stock status

New Zealand

New Zealand stocks within zone range between moderately exploited (ORH 2A, 2B and 3A) to depleted (ORH 7A). For full details on a stock-by-stock basis see Ministry of Fisheries (2006a).

Australia

Australian stocks within zone, except that on the Cascade Plateau, are over-exploited and depleted.

Chile

According to current estimates, the status of the Chilean orange roughy stock on the seamounts of Juan Fernandez Islands is slightly under its MSY level. Notwithstanding, commercial activities are currently suspended since 2006, following a research plan designed to evaluate several hypotheses related to interference effects on abundance indexes, and on the factors affecting availability and abundance on survey estimates.

High Seas Stocks

The status of most high seas stocks is uncertain, but likely range from underexploited to overexploited. The stock status of the Tasman Sea orange roughy fisheries is depleted. Attempts to conduct stock assessments for Lord Howe, Northwest Challenger, and Louisville fisheries have not been accepted because of uncertainties in the application of CPUE indices as measures of abundance in these fisheries. However, CPUE has declined substantially in the Lord Howe fishery, and more recently also in Northwest Challenger and Louisville fisheries. (Clark 2004).

*****It would be useful to include the most recent assessment of the South Tasman Rise stock undertaken by CSIRO***. Will be provided by Australia.

4.5 Threats

In Australia this species was classified in 2006 - additional detailed wording to be provided. No threat status known.

4.6 Fishery value

New Zealand's total export earnings for all orange roughy fisheries in 2005 were NZ$68,952,409 (New Zealand Seafood Exports Report 5A, 2005). Note that most of this relates to catch from within the EEZ with ~15% of the catch taken on the high seas. The highest values sought were for chilled and frozen fillets.

In Chile, the total revenue from exports of orange roughy captured within the EEZ in 2005 amounted to US$4,144,000 (Subsecretaría de Pesca, 2007). The 376 tons exported correspond to frozen products.

5. Current Fishery Status and Trends

5.1 Stock size

There are estimates of population size for various stocks of orange roughy in the Australasian region (e.g., Ministry of Fisheries 2006a) and for the Juan Fernández and Bajo O'Higgins regions in the Southeast Pacific (Niklitschek et al. 2004), but not specifically for stocks outside EEZs. Methods used to provide estimates of absolute or relative abundance include bottom trawl surveys, egg surveys, analyses of commercial catch and effort data, and acoustic surveys (see reviews by Clark 1996, 2006 and Branch 2001).

There are no estimates available for the high seas.

5.2 Estimates of relevant biological reference points

There are no current estimates for the high seas, however, for estimates inside the EEZs see Ministry of Fisheries (2006a), Boyer et al. (2003), Niklitschek et al. (2005).

5.2.1 Fishing mortality

There are no current estimates.

5.2.2 Biomass

There are no current estimates.

***** Australian stock assessment for South Tasman Rise?***

5.2.3 Other biological reference points

Commercial CPUE information is all unstandarised and therefore variable results have been concluded. Standardised analyses have been carried out for South Tasman Rise, Lord Howe Rise, Northwest Challenger, and Louisville Ridge fisheries, but the interpretation of trends in the indices has been uncertain (see Ministry of Fisheries 2006a).

6. Impacts of Fishing

6.1 Incidental catch of associated and dependent species

Orange roughy are often found in association with a large number of other fish species (see next section).

Incidental captures of seabirds, through interaction with trawl warps have been reported in some orange roughy fisheries. No mortalities have been observed to date on NZ vessels outside the EEZ however, inside the New Zealand EEZ in the 2003-04 and 2004-05 fishing years the total number of seabirds observed caught in orange roughy trawl fisheries were 5 and 9 respectively. Incident rates (the number of seabirds per 100 tows) were 0.5 and 0.6 for 2003-04 and 2004-05 respectively. Broken down into taxa these species caught were: 1 Northern royal albatross, 1 Salvin's albatross, 1 Grey petrel and 11 unknown taxa (Baird & Smith, unpublished data).

In a report prepared for WCPFC Waugh (2006) documented the distribution of seabird species in the western and central pacific area which overlaps a large portion of the proposed SPRFMO area. Several species with serious threat status (e.g. IUCN Endangered) occur in the area and interact with fisheries in the area.

6.2 Unobserved mortality of associated and dependent species

It is likely that deep-sea corals, other benthic fauna, fish and unobserved seabird mortalities go unrecorded.

6.3 Bycatch of commercial species

Based on New Zealand catch effort data for the high seas only, the main commercial bycatch species when targeting orange roughy on the high seas (that total over 100 tonnes from 1989 to mid 2006) include: oreos (*Allocyttus niger*, *Pseudocyttus maculatus*, *Neocyttus rhomboidalis*), cardinalfish (*Epigonus telescopus*), ribaldo (*Mora moro*), seal sharks (*Dalatias* spp.), alfonsino (*Beryx splendens*), and rattails.

Based on New Zealand catch effort data for the high seas only, species caught that total over 10 tonnes include: bluenose, coral rubble, deepwater dogfish, pale ghost shark, hake, hoki , long-nosed chimera, other sharks and dogfish, slickhead, shovelnose dogfish, sea perch, cat shark, ghost shark.

Based on New Zealand catch effort data for the high seas only, species caught that total over 1 tonne include: basketwork eel, basking shark, cucumber fish, cardinalfish, lucifer dogfish, frostfish, gurnard, javelinfish, ling, rubyfish, southern boarfish, silver dory, skates, spiny dogfish, spikefish, rig, slender-mouth hound, sea urchin, silver warehou, white rattail, warty oreo, white warehou.

A further 71 species have been recorded as bycatch from the orange roughy fisheries by New Zealand vessels operating in the South Pacific outside EEZs between 1989 and 2006.

The mix of species that orange roughy is associated with varies with latitude.

6.4 Habitat damage

The main method used to catch this species is a high-opening trawl generally fished hard down on the bottom. Trawling for this species on seamounts, knolls and pinnacles impacts habitat and benthic invertebrate species (Clark and O'Driscoll 2003, O'Driscoll and Clark 2005, Koslow et al. 2001), but the precise impact of this on the orange roughy populations or other species is unknown, although habitat loss is quite evident for benthic invertebrate species such as some crustaceans, echinoids, startfish (Koslow 2007).

Studies have shown that repeated trawl disturbances alter the benthic community by damaging or removing macro-fauna and encouraging anaerobic bacterial growth (see review by Cryer et al. (in prep)). Severe damage of coral cover from bottom trawl fishing for orange roughy inside the Australian EEZ has been documented (Koslow et al. 2001). Video images reveal bare rock and pulverized coral rubble where bottom trawling has occurred. Clark and Koslow (in press) have reviewed available data on the impacts of fishing (including bottom trawling) on seamounts, and have noted that damage to the habitat-forming corals is one of the most prominent and observable impact on the ecosystem structure of deepwater seamounts.

Bottom trawling also tends to homogenise the sediment, which damages the habitat for certain fauna. Benthic processes, such as the transfer of nutrients, remineralisation, oxygenation and productivity, which occur in undisturbed, healthy sediments, are also impaired (Cryer et al. in prep).

As fishing gear disturbs soft sediment they produce sediment plumes and re-mobilise previously buried organic and inorganic matter. This increase in the rates of nutrients into the water column has important consequences for the rates of biogeochemical cycling (Kaiser et al. 2002).

The actual extent of bottom trawling on different sediment types, how widespread the issue may be, and rates of recovery are all unknown.

7. Management

7.1 Existing management measures inside EEZs

Landings of orange roughy from the New Zealand, Australian, and Chilean EEZ are regulated by TACs. TACs have been reduced: several stocks in New Zealand and Australia have been closed to fishing or the TAC reduced to a nominal 1t. In the case of the Chilean stock, the commercial fishery has been suspended, allowing the catch of small amount, according to the purposes of a research plan.

Inside EEZ some New Zealand fisheries have spatial management regimes, such as feature limits, and Chile has implemented an ITQ system from 1999.

7.2 Existing fishery management in areas beyond national jurisdiction and fisheries management implications

NOTE: To be separated into two sections in future.

There are no regulations regarding limits on catch in international waters of the South Pacific with the exception of the South Tasman Rise region. This area has been subject to catch restrictions for Australian and New Zealand vessels under a Memorandum of Understanding between the two countries (Arrangement between the Government of New Zealand and the Government of Australia for the Conservation and Management of Orange Roughy on the South Tasman Rise).

There are currently no accepted stock assessments for orange roughy high seas fisheries in the South Pacific. Several have been attempted (for Lord Howe, Northwest Challenger Plateau and Louisville) based on catch per unit effort data, but these have not been accepted. This was generally on account of highly variable levels of effort and catch between years for considerable periods within each of the fisheries, which can make the use of CPUE as an index of abundance uncertain (e.g., Annala and Clark 2006).

Accordingly, the status of the five high seas orange roughy stocks (fisheries) in the Southwest Pacific is unknown. Unstandarised CPUE has declined in a number of areas. It is not known if recent catch levels are sustainable, but given our knowledge of orange roughy in general (e.g. Sissenwine & Mace, in press) it is highly unlikely in most of the described fisheries.

Experience from within EEZs

Orange roughy is a species characterised by very slow growth, high longevity, late age at maturity, and low fecundity relative to other teleosts. Their aggregating behaviour around prominent submarine features allows large catches to be taken easily. There are numerous distinct stocks within and between EEZs thus, they are vulnerable to overfishing (Francis and Clark 2005), and this has been the outcome on several fishing grounds off New Zealand, Australia, and Namibia.

Serial depletion of aggregations/populations may occur in some situations. On the Chatham Rise inside the New Zealand EEZ exploration along the southern slopes and fishing on small seamount features followed a sequence of discovery, heavy fishing, depletion of stocks, and eastwards extension of the fishing grounds as the fleet moved on to find new seamounts (Clark 1999).

7.3 Ecosystem Considerations

Two main issues exist in terms of ecosystem impacts: the first is changes in predator-prey relationships leading to shifts in food-web structure and other impacts associated with the extraction of large numbers of target and bycatch species; and the second is the physical impact of fishing on the ocean bottom, in particular on rare or fragile corals and benthic organisms that are important for ecosystem function.

Little is known about the effects of removing large proportions of higher predators in deep sea ecosystems (Butler et al. 2001). Two Morato's papers can illustrate more about this, for instance Morato, Cheung and Pitcher (2004: 51) states "seamount fishes, especially those that aggregate on seamounts, are highly vulnerable to exploitation and that fishing on seamount will tend to be unsustainable, given current levels of exploitation and current fishing methods". Additionally, a revision from Morato et al. (2006) and Johnson and Castillo (2004) conclude similarly. However, fundamental shifts on fish assemblage have been documented along the continental shelf in the North Pacific. Average fish size, across a diversity of species, has declined 45% in 21 years due to fishing exploitation (Levin et al. 2006). In certain stocks orange roughy have been fished down to 20% or less of unfished stock size, and because this species is the dominant biomass in the community the impacts of over extraction could potentially be large. In particular, changes in predateor-prey relationships that lead to shifts in food-web structure may not necessarily be reversed by the reduction of fishing pressure.

The physical impact of bottom trawling damages long lived species (such as deepwater sessile epi-fauna), which reduces habitat complexity. Structurally complex and stable habitats, such as those in deep water associated with seamounts, have the longest recovery trajectories in terms of the recolonisation of habitat by the associated fauna (Kaiser et al. 2002). At the beginning of the orange roughy fishery in the late 90's on the South Tasman Rise, data from scientific observers were used to estimate a bycatch of ~ 1.6 tonnes of coral for each hour of trawling (Anderson and Clark, 2003). Extrapolated figures from this sampling indicated that almost 2000 tonnes of coral in the first year of the fishery was taken; this does not include coral damaged on the bottom. Clark & O'Driscoll (2003) carried out photographic surveys on the

Northwest Chatham Rise (within the New Zealand EEZ) and found a strong contrast in coral cover between fished and unfished seamounts with coral observed in <2% and 30% of images respectively.

The removal of topographic complexity may allow for higher predation rates due to a reduction in available refuge, and therefore may adversely affect recruitment of some species. This failure of recruitment, in addition to overexploitation, can lead to changes in community structure and decreases in biodiversity. Cryer et al (2002) found that invertebrate species richness and diversity was negatively correlated with fishing activity. Community structure can also be affected by sediment stirred up by bottom trawl gear that smothers bottom dwelling communities, which in turn can adversely affect feeding and or respiration of many benthic organisms. Geochemical cycles can also be altered.

Other potential ecosystem effects of fishing include: effects on abundance and body size distributions that can result in a fauna dominated by small sized individuals; genetic selection for different physical characteristics and reproductive traits; and effects on populations of non-target species as a result of by-catch or ghost fishing (Kaiser et al. 2002, and see review by Clark and Koslow in press).

Overall, there is little hard scientific information on the long term impacts of bottom trawling as it relates to the overall productivity of deepwater systems and their resilience.

Currently no methods other than trawl have been used successfully to catch orange roughy, and no practices other than spatial closures are employed to reduce the environmental impact of this fishery.

8. <u>Research</u>

8.1 Current and ongoing research

Within EEZs

Chile undertakes regular acoustic surveys; annual commercial fishery catch monitoring is in place, with full coverage of scientific observers in fishing trips. In Australia recent monitoring of standing biomass has largely been via industry based acoustic surveys, interspersed with towed-body acoustic surveys by dedicated research vessels. In New Zealand a combination of research trawl and acoustic surveys are regularly carried out, and CPUE is monitored in all fisheries (Ministry of Fisheries 2006b). At sea observer coverage which includes catch characterisation, effort data collection, non-target catch monitoring and sampling for biological data has been in place since the late 1980s.

In all areas the decline in landings has been accompanied by reductions in monitoring and research.

Chile has adopted an informative management strategy, implementing a medium-term research plan, oriented at evaluating the effects of the interferences caused by fishing activities on the distribution and abundance of the resource in spawning areas.

High seas

The only current research on high seas fisheries is examination of catch totals each year for New Zealand and Australian vessels, and unstandardised CPUE for New

Zealand fisheries on Lord Howe, Northwest Challenger, West Norfolk Ridge, and Louisville Ridge grounds (e.g., Clark 2004). New Zealand has undertaken regular at sea observer coverage (including catch characterisation, effort data collection, non-target catch monitoring and sampling for biological data) of its high seas fishing fleet.

8.2 Research needs

There are currently no fishery independent surveys of high seas fisheries. Data are needed on biomass or trends in relative abundance in order to assess status of the stocks.

Stock structure of orange roughy also needs to be clarified. There has been extensive work on some of the Tasman Sea fishing areas (Smith et al. 2002) but there is limited information on likely stock structure and distribution on the Louisville Ridge.

A major research gap for orange roughy in general is a lack of understanding of recruitment. This knowledge gap is a critical uncertainty but it is largely intractable at this time.

9. Additional remarks

Several other species of the family Trachichthyidae occur in southern Pacific waters. The two most common are the silver roughy (*Hoplostethus mediterraneus*) which occurs mainly from 300–700 m and the common roughy (*Paratrachichthys trailli*) occurring mainly from 200–600 m (Anderson et al. 1998). Neither species is targeted commercially. Little is known about the biology of either species.

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