DRAFT REPORT to the First International Meeting on the Establishment of the South Pacific Regional Fisheries Management Organisation – For First International Meeting on the Establishment of the South Pacific Regional Fisheries Management Organisation Discussions Only

SPECIES PROFILE FOR:

Orange roughy (*Hoplostethus atlanticus*)

1. Overview

This species occurs in the north and east Atlantic from Greenland to South Africa, the south-central Indian Ocean from South Africa to southern Australia, the Tasman Sea and New Zealand shelf, seamounts and ridges to the east of New Zealand, and off central and southern Chile. It inhabits deep, cold waters over steep continental slopes, ocean ridges, and seamounts. Target trawl fisheries for orange roughy have occurred in the South Pacific since the late 1970s to the present day.

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* Collett, 1889

2.6 Scientific synonyms: *Hoplostethus gilchristi*, *Hoplostethus islandicus*

2.7 Common names: orange roughy

3. Species characteristics

3.1 Distribution and depth

Hoplostethus atlanticus has been reported in the North Atlantic from Nova Scotia to Norway, down the eastern 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 seamounts in the Tasman Sea, around the entire New Zealand shelf, on seamounts 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 – 1100 m (Anderson et al. 1998).

3.2 Area occupied outside EEZs

3.2.1 Distribution outside EEZs

The area known to be occupied by this fish outside EEZs is ~220 000 km^2. The area of assumed presence outside EEZs is a further 90 km^2, mainly on the Louisville Ridge east of New Zealand. See Figure 1 for approximate distribution.

3.2.2 Other potential areas where the species may be found

Orange roughy is assumed to occur outside the Chilean EEZ on the Nazca Ridge, but this has not been confirmed.

3.3 Habitat

In the South Pacific, orange roughy aggregates in deep, cold waters (3–9 ºC) over steep continental slopes, canyons, ocean ridges, and seamounts, especially during spawning and feeding (Clark et al. 2000). It can also be dispersed over smooth bottoms, rough bottoms, and steep, rough grounds. It is benthopelagic, generally occurring near the bottom but ascending to feed or spawn 50–100m above the seafloor.

3.4 Biological characteristics

Sexes are separate but co-occur. 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, Australian and Namibian grounds; females reach a slightly larger size than males. Age and growth of orange roughy from a number of localities has been investigated, and the results have been controversial (Tracey & Horn 1999). However, annual zone formation in the otoliths of juvenile fish has been validated, indicating very slow growth to a length of only 7.6 cm after 3 years (Mace et al. 1990). Decay rates of naturally occurring radionuclides in otoliths to age fish was first applied to orange roughy by Fenton et al. (1991), who concluded that fish 38–40 cm long were 77–149 years old. Following criticisms of this method by West & Gauldie (1994), additional work by Smith et al. (1995) and Francis (1995a,b) addressed the criticisms, 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, Gili et al, 2002), indicating a very slow growth rate for this species. More recent and sophisticated radiometric ageing techniques have confirmed longevity of 100–150 years (NIWA data). Current productivity parameters used in assessments of New Zealand's orange roughy stocks are: L_∞ = 33–38 cm (dependant on sex and area), k = 0.065 yr^{-1}, M = 0.045 yr^{-1} (Sullivan et al. 2005). Current productivity parameters used in assessments of Chilean orange roughy stock are: females: L_∞ = 53.8 cm, k = 0.03 yr^{-1}, M = 0.04 yr^{-1}; males: L_∞ = 47.86 cm, k = 0.04 yr^{-1}, M = 0.04 yr^{-1} (Gili et al. 2002, Paya & Montecinos 2004). Australian productivity parameters vary between populations. For continental slope populations; females L_∞ = 31 cm (22-40), k = 0.048, M = 0.04; for males L_∞ = 40 cm (28-52), K = 0.064, and M = 0.04. Fish on the Cascade Plateau are larger and longer-lived with an M of 0.02 (Smith & Waite 2004).

Orange roughy are synchronous spawners (Pankhurst 1988). The onset of sexual maturity has been linked 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 and Horn, 1997; Horn et al. 1998). On the basis of this link, Horn et al, (1998) found significant differences in mean size and age at sexual maturity between grounds of Namibia, New Zealand, Tasmania and Hatton Bank southwest of United Kingdom, with a greater age at onset maturity found at grounds with a greater modal length of the mature population. In the southwest Pacific, parameters range from 28–34 cm and 23–31 years. Using the same method, Gili et al. (2002) estimated for the Chilean fishery in the southeast Pacific a length at onset maturity of about 33 cm with a range of 30 to 32 years. This parameter values does not differ much from those reported for New Zealand, although modal length of mature individuals is bigger for the Chilean grounds. Spawning occurs in a few specific areas, generally at depths of 700–100 m, and it is believed that some individuals may migrate up to 200 km to reach a spawning ground (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), nevertheless histological analysis did not found any immature fish in Chilean fishing grounds (Young et al. 2003). 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.

3.5 Morphological characteristics

Four to six dorsal spines, 15–19 soft dorsal rays, three anal spines, and 10–12 soft anal rays; 19–25 ventral scutes. Bright brick-red in colour, with mouth and gill cavity bluish black.

3.6 Role of the species in the ecosystem

Orange roughy are thought to be opportunistic predators, taking advantage of prey often associated with seamounts—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 seamounts 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.

3.7 Stock structure

There are clear genetic and biological differences between populations of orange roughy within and between 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, Sullivan et al. 2005). No genetic studies have been conducted for the Chilean grounds although some biological differences have been documented (Young et al. 2000, Young et al. 2004). It is therefore likely that stocks beyond EEZs will show unique structure.

4 Fisheries characteristics

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 continues to the east of New Zealand.

The Lord Howe Rise extends from the northwestern 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, but during the 1990s mainly New Zealand and Australian vessels have fished it.

New fishing grounds have recently developed on the West Norfolk Ridge, which runs northwest from the North Island towards New Caledonia. This comprises a chain of ridge peaks and seamount features both within (QMA ORH 1) and beyond the New Zealand EEZ.

The Louisville Ridge is a chain of seamount and guyot features extending southeast for over 4000 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 4000 m. The Ridge is outside the New Zealand EEZ in international waters. The 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. A fishery developed for orange roughy in 1997, and it has since been fished mainly by Australian and New Zealand vessels.

Fishing activity in the Southeast Pacific develops from autumn to winter (May to August), mainly associated with the spawning activity in the Juan Fernández area (JF, six seamounts) but also with aggregations of maturing fish in the areas of Bajo O'Higgins (BO, two seamounts namely BO1 and BO2) and Punta Sierra (PSI, a continental slope ground) all within the EEZ of Chile (see Figure 3). For all fishing seasons starting from 1999, Juan Fernández grounds have concentrated more than 90% of the trawling hours and a similar share of the total catch, in this area the JF1, JF2 and JF4 seamounts are by far the most preferred fishing grounds. The main ports for landings of the Chilean catch are Talcahuano and San Vicente.

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, to large 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.

As a result of the hiring of foreign advisors by the local fishing industry, fishing technology currently in use in Chilean grounds is perhaps very much the same equipment used in orange roughy fisheries worldwide. Predominant trawl designs in use are Arrow, Nova and Casanova trawls. In regards to marine electronics, modern sonar and sounding equipment are commonplace in all vessels. Most boats are equipped with Simrad EK60 Scientific Sounder systems allowing for data storage and analysis which in conjunction with GPS, digital charts and personal computers, allows the building of detailed representation of the fishing grounds, as data is gathered over time. A range of net sensors is also used including net sounder systems.

In Chile, fishing boats are wet fish trawlers with a length range of 43 to 53 m and an engine power range of 1500 to 2500 HP. 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.

4.3 Catch history

Hoplostethus atlanticus 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 also steadily declined afterwards.

Catches (t) for New Zealand and Australia taken outside EEZs in the South Pacific region by New Zealand and Australian vessels in the four most recent years have been:

Year	Australia (t)	New Zealand (t)	Total (t)
2000-01	1371	3340	4711
2001-02	454	3563	4017
2002-03	240	2499	2739
2003-04	306	2180	2486

Source: BRS Australia and MFish New Zealand.

Detailed sub-area data are available for all the areas described in 4.1 above. By way of example on the South Tasman Rise catches peaked in 1999 and have declined sharply thereafter:

Year	Orange roughy (t)	Oreos (t)
1997	1930	1140
1998	3590	1400
1999	4420	230
2000	820	290
2001	169	124
2002	102	46
2003	11	201
2004	56	42
2005	0	0

Source: BRS Australia.

In Chile, fishing activity started in 1999 with a total allowable catch of 1500 tons, which increased to 2500 tons in 2002, after which it remained constant until 2004. In 2005 a TAC of 2000 tons was set. In general official landings reports are smaller than the authorized quotas, with a peak in landings in 2000 to 2002.

Total annual landings reports and total allowable catch in the Chilean orange roughy fishery between 1999 and 2005 (partial):

Year	TAC (t)	Catch (t)
1999	1500	780
2000	1580	1482
2001	2140	1782
2002	2500	1493
2003	2500	1246
2004	2500	1187
2005[1]	2000	608.2

(1) Preliminary data

Source: Chilean National Fisheries Service 1999-2005.

4.4 Non-target fish catch

Orange roughy are often found in association with a large number of other fish species. The main commercial bycatch species include oreos (*Allocyttus niger*, *Pseudocyttus maculatus*), cardinalfish (*Epigonus telescopus*), and ribaldo (*Mora moro*). The mix of species that orange roughy is associated with varies with latitude.

Section still in progress

4.5 Non-fish catch

Incidental captures of seabirds, through interaction with trawl warps have been reported in some orange roughy fisheries.

Section still in progress

4.6 Fish stock potential

The Chilean stocks of orange roughy are in a fully exploited condition.

Australian stocks, except that on the Cascade Plateau, are overfished with current biomasses being <10% of virgin levels. Catches (TACs) have been reduced and most fisheries will be virtually closed in 2007.

New Zealand stocks range between moderately exploited (ORH 2A, 2B and 3A) and closed (ORH 7A). For full details on a stock-by-stock basis see Sullivan et al. (2005).

The stock status of the Tasman Sea orange roughy fisheries is uncertain. 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).

Section still in progress

4.7 Fishery value

Section still in progress

5 Status and trend

5.1 Fishery productivity

The productivity of orange roughy can be defined as very low. This is due to the late onset of maturity in relation to the observed values of maximum age; that fecundity is moderate in relation to body size; that the annual growth rate is relatively small in relation to size, especially after attaining maturity; and that it is a long-lived species. This all indicates the proportion of the biomass that can be harvested sustainably is very small. These values are in the range from 1.5 to 2.0% of virgin biomass.

5.2 Population size

There are estimates of population size for various stocks of orange roughy in the Australasian region (e.g., Sullivan et al. 2005) and for the Juan Fernández y 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 (towed body) acoustic survey.

In Chile, acoustic surveys for the whole Juan Fernández area under the hypothesis of a gradual aggregation of fish on each seamount (no alternate spawning of multiple groups of mature fish) render a total biomass estimate of 22000 tons (C.V. 29%) (Boyer et al. 2003). A second survey carried out in 2004, estimated a total biomass in the Juan Fernández area of 25300 tons (C.V 25%) and of 5800 tons for the Bajo O´Higgins area (Niklitschek et al. 2005). Chilean biomass acoustic estimates are currently under a process of review.

5.3 Fishery exploitation

Section still in progress

5.4 Stock status

Chilean stock biomass is at present at 62% of virgin stock (Paya and Montecinos, 2005).

5.5 Management implications

Orange roughy are prone to serial depletion due to their aggregation around isolated geographic features, their stock structuring and their low productivity.

There are currently no regulations in place for Chilean vessels if they were to target ORH outside the EEZ although a high seas 'regime' is in place that would control such a fishery.

Section still in progress

6 Species/community management

6.1 Fisheries management by area/sub-area/jurisdiction

Quotas regulate landings of orange roughy from the New Zealand, Australian, and Chilean EEZs.

The South Tasman Rise orange roughy fishery is managed by an Arrangement between Australia and New Zealand (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). TACs have been set more conservatively as the stock abundance has decreased.

6.2 Research underway

In Chile acoustic surveys are used to estimate the spawning stock. Also an annual commercial fishery catch monitoring is in place. 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. The latter is examined each year for New Zealand vessels working outside the EEZ on Lord Howe, Northwest Challenger, West Norfolk Ridge, and Louisville Ridge grounds.

Section still in progress

7 Threats

Many orange roughy populations are relatively close to land masses, and are vulnerable to fishing. 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—which has taken place—will bring about habitat change (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 on the seamounts is unknown. No methods other than trawl have been used successfully to catch orange roughy.

Orange roughy is a species characterised by very slow growth, great 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. Hence, 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.

8 Information on similar species

Several other species of the family Trachichthyidae occur in southern Pacific waters. The two most common are the silver roughy (*Hoplostethus mediterraneus*) occurring 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, and little is known about their biology.

9 Additional remarks

This document is still a draft and requires additional information in several sections.

10 References

Anderson, O.F.; Bagley, N.W.; Hurst, R.J.; Francis, M.P.; Clark, M.R.; McMillan, P.J. (1998). Atlas of New Zealand fish and squid distributions from research bottom trawls. NIWA Technical Report 42. 303 p.

Bell, J.D.; Lyle, J.M.; Bulman, C.M.; Graham, K.J.; Newton, G.M.; Smith, D.C (1992). Spatial variation in reproduction, and occurrence of non-reproductive adults, in orange roughy, *Hoplostethus* atlanticus Collett (Trachichthyidae), from southeastern Australia. Journal of Fish Biology 40: 107–122.

Branch, T.A. (2001). A review of orange roughy Hoplostethus atlanticus fisheries, estimation methods, biology and stock structure. South African Journal of Marine Science 23: 181–203.

Bulman, C.M.; Koslow, J.A. (1992). Diet and food consumption of a deep-sea fish, orange roughy Hoplostethus atlanticus (Pisces: Trachichthyidae), off southeastern Australia. Marine Ecology Progress Series 82(2): 115–129.

Bulman, C.M.; Koslow, J.A. (1995). Development and depth distribution of the eggs of orange roughy, Hoplostethus atlanticus (Pisces: Trachichthyidae). Marine and Freshwater Research 46: 697–705.

Clark, M.R. (2004). Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2002-03 fishing year. *New Zealand Fisheries Assessment Report 2004/51*. 36 p.

Clark, M.; O'Driscoll, R. 2003: Deepwater fisheries and aspects of their impact on seamount habitat in New Zealand. *Journal of Northwest Atlantic Fishery Science* 31.441-458

Clark, M.R.; Anderson, O.F.; Francis, R.I.C.C.; Tracey, D.M. (2000). The effects of commercial exploitation on orange roughy (Hoplostethus atlanticus) from the continental slope of the Chatham Rise, New Zealand, from 1979 to 1997. Fisheries Research 45: 217–238.

Clark, M.R.; Fincham, D.J.; Tracey, D.T. (1994). Fecundity of orange roughy (Hoplostethus atlanticus) in New Zealand waters. New Zealand Journal of Marine and Freshwater Research 28: 193–200.

Edmonds, J.S.; Caputi, N.; Morita, M. (1991). Stock discrimination by trace-element analysis of otoliths of orange roughy (Hoplostethus atlanticus), a deep-water marine teleost. Australian Journal of Marine and Freshwater Research 42: 383–389.

Fenton, G.E.; Short, S.A.; Ritz, D.A. (1991). Age determination of orange roughy Hoplostethus atlanticus (Pisces: Trachichthyidae) using 210Pb:226Ra disequilibria. Marine Biology 109: 197–202.

Francis, R.I.C.C. (1995a). The longevity of orange roughy: a reinterpretation of the radiometric data. New Zealand Fisheries Assessment Research Document 95/2. 13 p.

Francis, R.I.C.C. (1995b). The problem of specifying otolith-mass growth parameters in the radiometric estimation of fish age using whole otoliths. Marine Biology 124: 169–176.

Francis, R.I.C.C.; Clark, M.R. (1998). Inferring spawning migrations of orange roughy (Hoplostethus atlanticus) from spawning ogives. Marine and freshwater Research 49: 103–108.

Francis, R.I.C.C., Clark, M.R. (2005). Sustainability issues for orange roughy fisheries. *Bulletin of Marine Science 76(2)*: 337–351.

Gili, R., Cid, L., Pool, H., Young, Z., Tracey, D., Horn, P. y Marriott, P. 2002. Estudio de edad, crecimiento y mortalidad natural de los recursos orange roughy y alfonsino. Informe Final. FIP N° 2000-12. 129 pAge, growth and natural mortality of orange roughy and alfonsino.(Final report in Spanish available in www.fip.cl) Final Report. FIP N° 2000-12. 129 p.(In Spanish).

Horn, P.L.; Tracey, D.M.; Clark, M.R. (1998). Between-area differences in age and length at first maturity of the orange roughy Hoplostethus atlanticus. Marine Biology 132: 187–194.

Koslow, J.A.; Gowlett-Holmes, K.; Lowry, J.K.; O'Hara, T.; Poore, G.C.B.; and Williams, A.. (2001). Seamount benthic macrofauna off southern Tasmania: community structure and impacts of trawling. Marien Ecology Progress Series 213: 111-125.

Koslow, J.A.; Bell, J.; Virtue, P.; Smith, D.C. (1995). Fecundity and its variability in orange roughy: Effects of population density, condition, egg size, and senescence. Journal of Fish Biology 47: 1063–1080.

Koslow, J.A.; Bulman, C.M. (2002). Trophic ecology of the mid-slope demersal fish community off south Tasmania, Australia. Marine and Freshwater Research 53: 59–72.

Kotlyar, A.N. (1996). Beryciform fishes of the world ocean. Moscow, VNIRO Publishing.

Mace, P.M.; Fenaughty, J.M.; Coburn, R.P.; Doonan, I.J. (1990). Growth and productivity of orange roughy (Hoplostethus atlanticus) of the north Chatham Rise. New Zealand Journal of Marine and Freshwater Research 24: 105–119.

Labbé, J; Arana, P.M. (2001). Alimentación de orange roughy, Hoplostethus atlanticus (Pisces: Trachichthyidae), en el archipiélago de Juan Fernández, Chile. Revista de Biología Marina y Oceanografía 36(1): 75–82.

Lester, R.J.B.; Sewell, K.B.; Barnes, A. Evans, K. (1988). Stock discrimination of orange roughy Hoplostethus atlanticus by parasite analysis. Marine Biology 99: 137–143.

Boyer, D., E. Niklitschek, I. Hampton, J. Nelson, M. Soule and H. Boyer. 2003. Acoustic surveys of orange roughyon the Juan Fernandez Archipelago, Chile. Centro de Estudios Pesqueros Universidad Austral de Chile – Fisheries Resource Surveys. 66 p.

Niklitschek, E., D. R. Boyer, R. Merino, I. Hampton, M. Soule, J. Nelson, J. Cornejo, A. Lafon, C. Oyarzún, R. Roa & T. Melo. 2005. Estimación de la biomasa reproductiva de orange roughy en sus principales zonas de concentración, 2004. Universidad Austral de Chile, Valparaíso. FIP 2004-13. 159 p. (Final report in Spanish available in www.fip.cl)

Pankhurst, N.W. (1988). Spawning dynamics of orange roughy, Hoplostethus altanticus, in mid-slope waters of New Zealand. Environmental Biology of Fishes 21: 101–116.

Paya, I. and M. Montecinos. (2004). Stock assessment and total allowable catch of orange roughy, 2005. Phase I. Final Report. IFOP-SUBPESCA. 17 p. (Report In Spanish held in IFOP Fisheries Division and at the Chilean Under secretariat of Fisheries library).)

Rosecchi, E.; Tracey, D.M.; Webber, W.R. (1988). Diet of orange roughy Hoplostethus atlanticus (Pisces: Trachichthyidae) on the Challenger Plateau, New Zealand. Marine Biology 99: 293–306.

Smith, A.D.M.; and Waite, S.E. (Eds) (2004). Fisheries Assessment Report: The South East Fishery 2003. Australian Fisheries Management Authority, Canberra. 246pp.

Smith, D.C.; Fenton, G.E.; Robertson, S.G.; Short, S.A. (1995). Age determination and growth of orange roughy (Hoplostethus atlanticus): a comparison of annulus counts with radiometric ageing. Canadian Journal Fisheries and Aquatic Science 52: 391–401.
Smith, P.J.; Benson, P.G.; McVeagh, S.M. (1997). A comparison of three genetic methods used for stock discrimination of orange roughy, Hoplostethus atlanticus: allozymes, mitochondrial DNA, and random amplified polymorphic DNA. Fishery Bulletin 95: 800–811.

Smith, P.J.; Robertson, S.G.; Horn, P.L.; Bull, B.; Anderson, O.F.; Stanton, B.R.; Oke, C.S. (2002). Multiple techniques for determining stock relationships between orange roughy, Hoplostethus atlanticus, fisheries in the eastern Tasman Sea. Fisheries Research 58: 119–140.
Sullivan, K.J.; Mace, P.M.; Smith, N.W.McL.; Griffiths, M.H.; Todd, P.R.; Livingston, M.E.; Harley, S.J.; Key, J.M.; Connell, A.M. (Comps.) (2005). Report from the Fishery Assessment Plenary, May 2005: stock assessments and yield estimates. 792 p. (Unpublished report held in NIWA library, Wellington.).

Sullivan, K.J.; Mace, P.M.; Smith, N.W.McL.; Griffiths, M.H.; Todd, P.R.; Livingston, M.E.; Harley, S.J.; Key, J.M. and Connell, A.M. (Comps.) 2005: Report from the Fishery Assessment Plenary, May 2005: stock assessments and yield estimates. 792 p. (Unpublished report held in NIWA library, Wellington.)

Tracey, D.M.; Horn, P.L. (1999). Background and review of ageing orange roughy (Hoplostethus atlanticus, Trachichthyidae). New Zealand Journal of Marine and Freshwater Research 33: 67–86.

West, I.F.; Gauldie, R.W. (1994). Determination of fish age using 210Pb:226Ra disequilibrium methods. Canadian Journal of Fisheries and Aquatic Sciences 51: 2333–2340.

Young, Z., F. Balbontín, J. Rivera, M. Ortego, R. Tascheri, M. Rojas y S. Lillo. 2000. Estudio biológico pesquero del recurso orange roughy. Informe Final. FIP N° 99-05. 73 p. .(Final report in Spanish available in www.fip.cl).

Young, Z., E. Díaz, R. Bahamonde, R. Tascheri, Y. Muñoz, A. Olivares, M. I. Ortego, J. Rivera & J. Oliva. 2004. Monitoreo y propección de orange roughy, 2001. IFOP. FIP N° 2001-04. Final Report. 127 p.(Final report in Spanish available in www.fip.cl).

Zeldis, J.R.; Grimes, P.J.; Ingerson, J.K.V. (1995). Ascent rates, vertical distribution, and a thermal history model of development of orange roughy, Hoplostethus atlanticus eggs in the water column. Fishery Bulletin 93: 373–385.

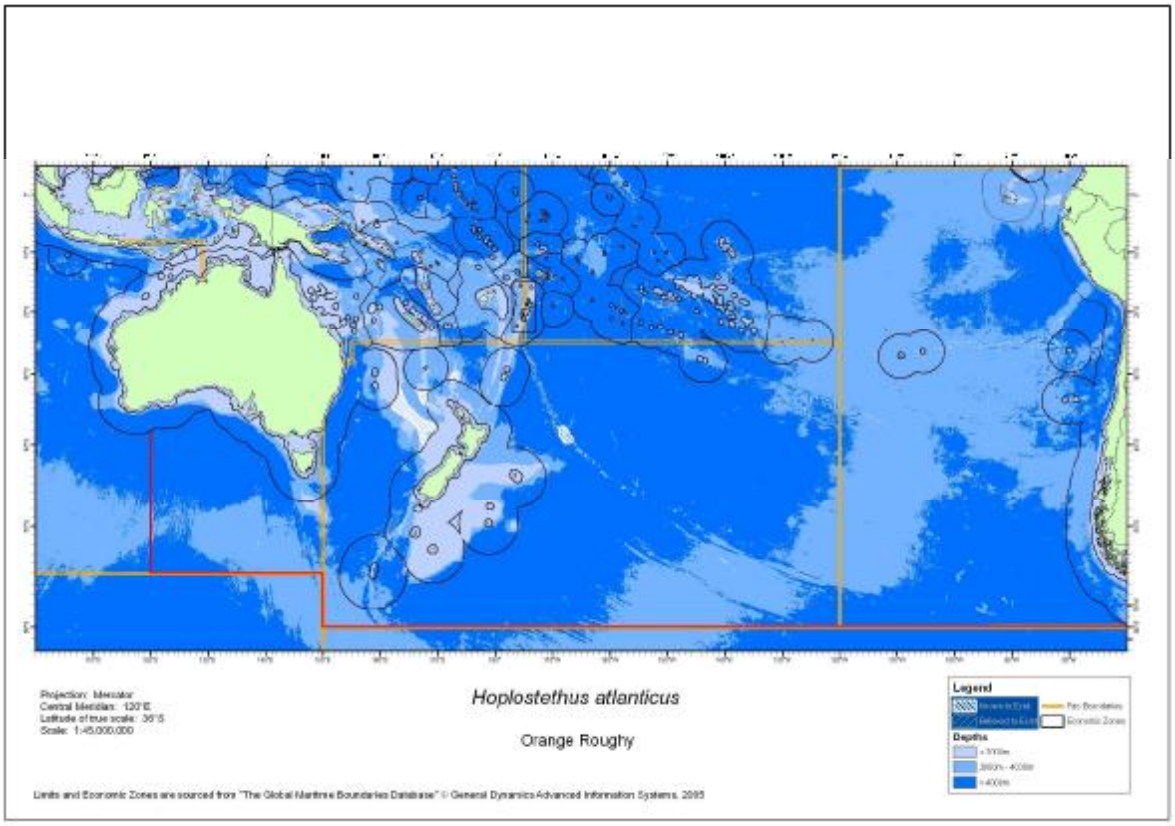

Figure 1: Distribution of orange roughy fishing grounds in the South Pacific.

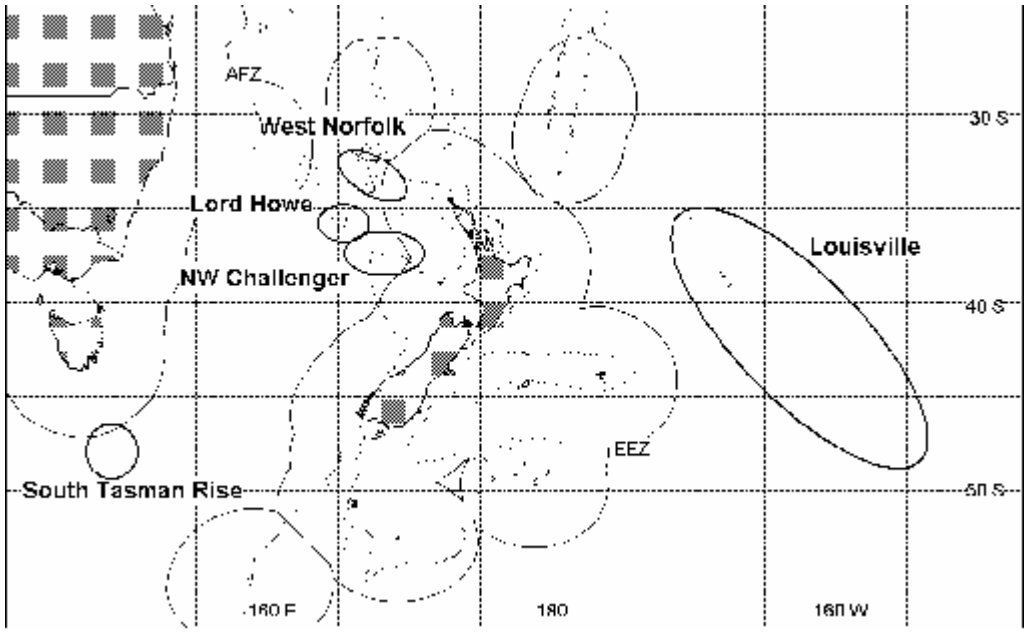

Figure 2: The New Zealand/Australia region, showing location of major fisheries for orange roughy outside New Zealand and Australian EEZs (1000 m depth contour shown around New Zealand).

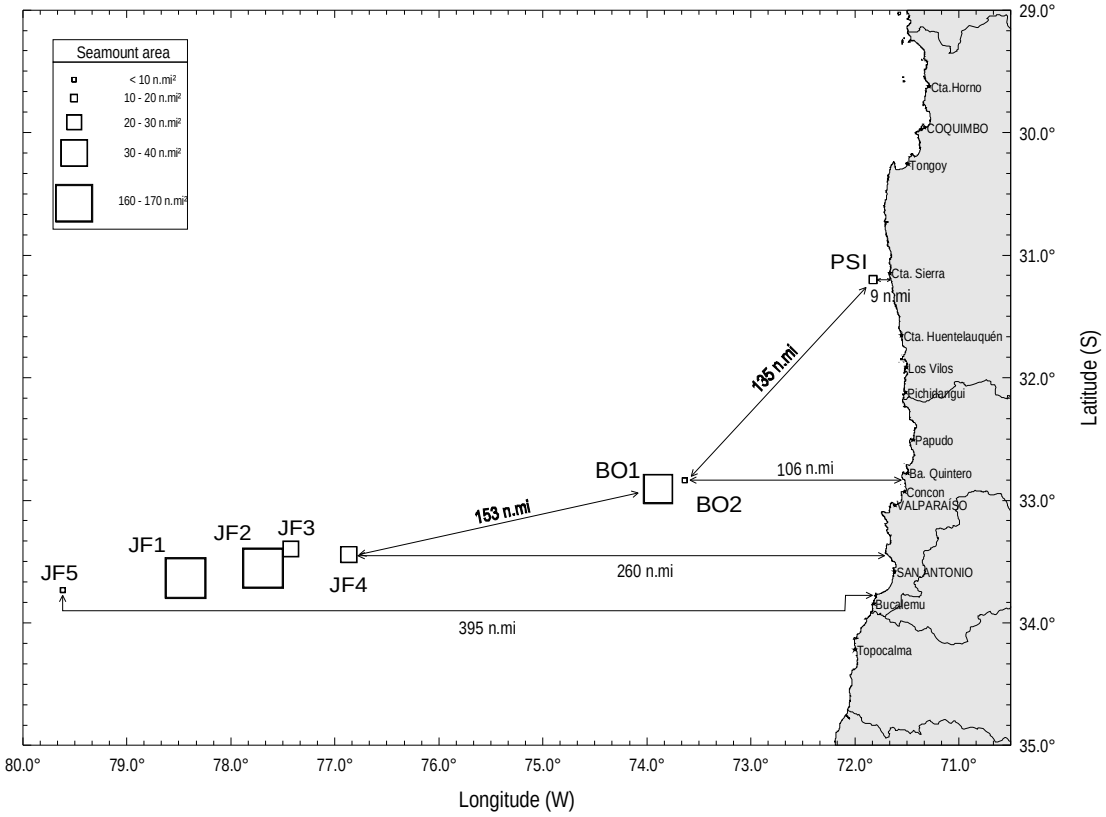

Figure 3: Distribution of orange roughy fishing grounds off central Chile.