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The estimation of initial biomass and catch limits for Orange roughy in the SPRFMO Area

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The estimation of initial biomass (B_0) and catch limits for orange roughy in the SPRFMO area.

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July 2014

This paper is the product of discussions within New Zealand to initiate the development of a long-term approach to setting sustainable catch limits for the orange roughy fisheries operating in the SPRFMO Convention Area through a conservation and management measure (CMM) for bottom fisheries.

1 Introduction

Approaches to assessing orange roughy stocks have been under development in both New Zealand and Australia over recent years. This paper develops a practical approach to estimating stock status that would enable sustainable catch limits to be defined, broadly similar to that presented in earlier documents to the SPRFMO Science Working Group by New Zealand (MFish 2008; Penney, 2010). The basic approach is to use existing data to estimate the abundance of the different biological stocks of orange roughy prior to fishing by applying a range of approaches to estimate stock status for data limited stocks (e.g. Dick & MacCall, 2010, 2011).

This paper is to inform the SPRFMO Scientific Committee (SC) of the proposed science to develop orange roughy stock management advice to the Commission based on the scientific estimation of initial unfished biomass (B_0) as part of an overarching CMM for bottom fishing the SPRFMO Convention Area.

We are seeking feedback from the SC on the proposed approach, in advance of developing detailed numerical analyses of initial biomass (B_0).

This paper draws on previous work examining approaches to defining catch limits for orange roughy in the SPRFMO Convention Area (e.g. MFish 2008 and Penney, 2010), as well as other accepted approaches for fisheries in general in New Zealand (MPI, 2014).

1.1 DEFINING A SUSTAINABLE CATCH LEVEL

There are a number of approaches to defining sustainable catches levels for fish stocks. These range from sophisticated mathematical stock assessment models through to averaging recent catches. This paper considers approaches to estimate the initial unfished biomass of the demersal stocks based on the catch history. The proposed approach focuses on the principal target species, orange roughy (*Hoplostethus atlanticus*), which has the largest catches of demersal species in the area but the methods described could be applied to other demersal and bentho-pelagic species as well.

1.2 STOCK STRUCTURE

There is limited direct knowledge about the stock structure of orange roughy in the SPRFMO Area. Inference drawn from what is known about the structure of orange roughy stocks elsewhere, particularly stocks within Australian and New Zealand (MPI, 2014) waters, strongly indicate that the orange roughy in the SPRFMO area will most probably be composed of a number of different biological stocks, or that exchange between geographically isolated stock components is so low that they can be considered to be separate stocks for management purposes. As the boundaries of where these stocks occur is currently unknown, a pragmatic approach to 'stock' management will be needed until scientific research has been able to increase our knowledge of stock structure. This has formed the basic approach to reporting the SPRFMO bottom fishery activity in New Zealand National Reports, where analyses by geographically distinct fishery area (e.g. north Louisville, central Louisville and south Louisville) are presented (e.g. SWG-11-12, 2012).

1.3 DATA AVAILABILITY

The bottom fisheries within the SPRFMO area are 'data poor'. Despite this, there are a number of types of data relating to these fisheries that are available, including historical catch, effort and some recent biological data. Importantly, complete catch data reported by FAO area exist. These same catches have also been reported on smaller spatial scales for some flag states, specifically by 20' and 6' minute blocks for New Zealand and Australia. Catch data reported on fine spatial scales generally represent better quality data and are more usable in stock assessments.

An unresolved issue relates to the orange roughy catches that have been reported from the SPRFMO area, but for which the Secretariat has no detailed information as to catch location (other than the very large FAO areas). Table 1 shows the total quantities of orange roughy catch reported to the FAO and what can be allocated to a location on a spatial scale compatible with estimating sustainable catches. It can be seen from Table 1 that the South Pacific, catches by Australia and New Zealand, for which accurate spatial reporting is available, represent about 90% of the total historic catch. The catch location of the remaining 10% is unknown and complicates efforts to assess stock status for orange roughy in different fishing areas in the SPRFMO Convention Area.

1.4 INDICES OF ABUNDANCE

There have been virtually no biomass surveys aimed specifically at estimating either absolute or relative abundance of orange roughy stocks in the SPRFMO Convention Area. There is a New Zealand times-series from the Westpac Bank area, just to the west of the New Zealand EEZ, that is part of a survey time-series monitoring the orange roughy stock that straddles the New Zealand EEZ and high seas in this area and a single survey on part the southern Lord How Rise in 2014. However, these surveys covers small parts of a very large area and so do not provide useful indices of abundance for the larger area.

Demersal trawling is the only fishing method that has been used to target orange roughy in the SPRFMO Convention Area. Various trawl effort data exist, including amounts of fishing in terms of vessel days, number of tows, distance towed and hours fished (trawlers). Coupled with the appropriate catch data, these effort data may be useful for exploring CPUE as an index of stock status.

Due to the highly aggregating behaviour of orange roughy, using CPUE as an index of abundance does have some serious limitations. There is a considerable body of literature on this (see MPI, 2014 for references). Most importantly, orange roughy aggregate to spawn and it is mostly these spawning aggregations that are fished, and CPUE on these aggregations is unlikely to be indexing stock abundance. In addition, the spatio-temporal pattern of exploitation of orange roughy in the SPRFMO area has included serial fishing operations, where one area has been fished until catches or catch rates drop and then the effort moves to another, often adjacent, area (Clark, *et al.*, 2010). Mixing catch and effort from more than one such area, either by time or in area, generates a high probability of generating a pattern of hyper-stable CPUE that is unlikely to bear a simple relationship to fish biomass and its use for stock assessment becomes problematic.

Table 1: Indicative orange roughy catch (tonnes) from the South Pacific and Eastern Indian Ocean.

These data have some unresolved quality issues, including possible double counting, but indicate the scale of catches. Those catches for which detailed spatial scale reporting is available are shaded pale green.

Year	Australia: Indian Ocean, Eastern	Chile: Pacific, Southeast	Belize: Pacific, Southeast	China: Pacific, Southwest	Australia: Pacific, Southwest	Russian Federation: Pacific, Southwest	Ukraine: Pacific, Southwest	USSR: Pacific, Southwest	Korea, Republic of: Pacific, Southwest	New Zealand: Pacific, Southwest	Norway: Pacific, Southwest	Total reported catch
1977								319				319
1978												
1979								1,251		5,000		6,251
1980								17,300		26,027		43,327
1981								14,076		24,060		38,136
1982								8,860		29,592		38,452
1983								7,229		41,759		48,988
1984								4,028		37,271		41,299
1985								4,306		39,999		44,305
1986					2,600			2,475		44,609		49,684
1987					5,400			130		49,014		54,544
1988					6,900	991				55,361		63,252
1989	1,966				13,542	1,132				51,538	1,153	69,331
1990	1,712				37,901	36				48,379	3,450	91,478
1991	959				33,111	506				35,819	82	70,477
1992	627				18,187					36,568	2	55,384
1993	432				12,050					29,681	1,602	43,765
1994	668				9,977					31,718	665	43,028
1995	227				7,070					33,077	1	40,375
1996	357				4,526					28,639	5	33,527
1997	350				3,129					20,545	12	24,036
1998	4,857				3,207					21,485	3	29,552
1999	7,553	779			28				234	23,780		32,374
2000	4,974	1,482			26		102			17,879		24,463
2001	5,197	1,868		520	17		195		93	14,044		21,934
2002	3,961	1,514		597	14				208	17,954		24,248
2003	4,455	1,249	9	562	54		176		243	17,778		24,526
2004	2,558	1,262	914	592	56		272		138	17,829		23,621
2005	3,250	783	506	710	144					18,451		23,844
2006	2,373	259	200	570	8		249		77	15,920		19,656
2007	1,120	5	332		9				44	14,276		15,786
2008	288	1			0					13,310		13,599
2009	659				2					12,446		13,107
2010	652				1					10,843		11,496
2011	278				2					6,958		7,238

2 Estimation of Initial Biomass (B_0)

Even without CPUE, a better understanding of stock structure and the spatio-temporal distribution of the fishery, there are opportunities to develop meaningful assessments for such data-poor fisheries (e.g. Dick & MacCall, 2010, 2011).Where data are limited, as for the high sea orange roughy fisheries, options for estimating initial biomass, B_0, are also limited. However, being able to develop some estimate of B_0, even given relatively high uncertainty, is preferable to working only from recent catch levels, providing options to estimate sustainable catch levels as some proportion of the best estimate of B_0 (Clark et al 2010, Penney 2010).

Previous approaches within the SPRFMO area

One approach previously used in this area, for example, was that developed by Clark *et* al., (2001) who estimated initial biomass associated with individual underwater topographic features (UTFs – hills, knolls and seamounts) using general linear modelling of cumulative catch against the physical characteristics of UTFs (an underwater feature meta-analysis). The B_0 outputs from this approach were used by Penney (2010) to estimate sustainable catch levels for the different fisheries areas in the western SPRFMO area. It was noted that for the New Zealand fleet, the average 2002-2006 catches (used in the interim measures) exceeded estimates of sustainable catch (MCY, MAY and ½MB_0) for all areas except for the Central Louisville Ridge.

Defining Appropriate Spatial Scales for Estimating Initial Biomass (B_0)

The stock structure in the New Zealand EEZ has already been addressed and biological stocks defined, albeit with differing degrees of confidence (see MPI, 2014). In the absence of adequate information and analyses on spawning grounds, morphometrics, genetics and/or parasites, we propose to define management ‘stocks’ based on fishery attributes, such as where the principal catches have been made and distance between areas of significant catch.

Previous consideration of sustainable catches for the SPRFMO orange roughy fisheries (e.g. Penney, 2010) used established fishery areas (Clark *et* al., 2010) (see Figure 1) as the basis for estimating B_0 and sustainable catch.

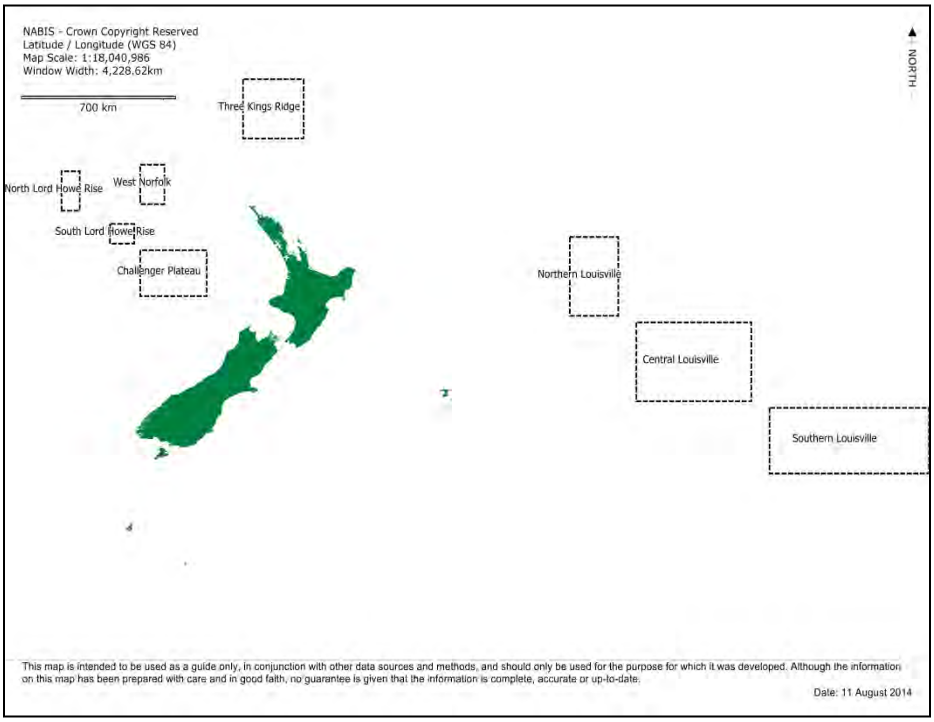

Figure 1: Plot of some of the fishery management areas described by Clark *et al*., 2010.

As the areas shown in Figure 1 have been defined with limited understanding of stock structure, these areas may not correspond to the distribution of biological stocks. However, this approach does at least assume separate stocks based on geographic separation similar to that found between separate orange roughy stocks in the New Zealand zone. The intention is to refine these stock boundary assumptions over time to reflect improving scientific understanding of stock structure.

2.1 ESTIMATING INITIAL BIOMASS, B_0.

The proposed approach is to apply simple, increasingly accepted methods, to estimate B_0 initially and, over time, apply more complex approaches as the necessary data become available to improve the estimates and reduce uncertainty.

Simple catch summing is proposed as the initial approach for estimating unfished biomass of orange roughy in the defined fisheries areas within the SPRFMO Convention Area. The justification for such an approach is that orange roughy is a very slow growing species with a very low rate of natural mortality (*M*). As a result of these life-history traits, accumulated biomass can be rapidly depleted over comparatively short spans of time by fishing. Where biomass has become substantially depleted, the cumulative catch over that period provides an estimate of the original unfished biomass. For areas that have been fished over a relatively short time period (e.g. shorter than the lifespan of mature, recruited roughy), this will be an under-estimate, as little growth or recruitment will have occurred over that period and some fish remain uncaught. For areas with a long fishing history, some correction could be applied to correct for growth and recruitment. Provided this is done appropriately, the biomass estimate will still tend to under-estimate the unfished biomass.

When estimating B_0 from cumulative catches, a model, implemented in an appropriate programming package (e.g. CASAL (Bull *et al*., 2012)), will be applied to the summed catches to account for natural mortality (*M*), growth and recruitment. This modelling approach will use the best estimates of M and recruitment available but sensitivities to the assumptions of M and recruitment should be run so as to understand the risks inherent in using specific assumptions.

It is proposed that these approaches be applied to all orange roughy catch data for which the spatial origins of the catches are well defined. This will, at least, include the New Zealand and Australian catches, accounting for approximately 90% of the total catch of orange roughy from the SPRFMO Convention Area.

While efforts will be made to define where the remainder of the catches were made, it is anticipated that some catches will remain for which the approximate area or origin will remain unknown. To provide an understanding of the uncertainties in the estimation of B_0 and the sensitivity to different assumptions of spatial distribution of the catch of unknown origin, sensitivity analyses will be developed to explore the impact of different assumptions about where the spatially unallocated catch was taken.

2.2 DEVELOPING SCIENTIFIC ADVICE FOR MANAGEMENT

A range of methods are available for estimating sustainable catch levels from acceptable estimates of initial biomass, B_0. These include Maximum Constant Yield (MCY), Maximum Annual Yield (MAY) (see MPI, 2014 for definitions of these) and $½MB_0$ (Gulland, 1971). To define options for biological reference points both deterministic B_{MSY} and various levels of $\%B_0$ should be explored.

Any measure of B_{MSY} based on a low B_0 estimate will also be underestimated and this needs to be considered in providing scientific advice for defining management thresholds. Provided that catch limits are then based on some biologically safe proportion of the (conservatively estimated) B_0, those catch limits will, themselves, be conservative.

2.3 GUIDANCE FOR FUTURE RESEARCH

Focussing on those elements where we lack information, and where the research is technically feasible and affordable, and where improvement in knowledge will yield improvements in our understanding and our ability to manage the fisheries, will guide the prioritisation of future research. Likely focuses of future stock assessment related research will be:

1. **Stock structure research**
   i. Review the current biological information collected from fishing operations (especially observer monitoring) and ensure that the programmes collect adequate data to enable appropriate analyses (spawning condition, morphometric, parasitological, genetic) in the future.
   ii. Analyse existing biological information for morphometric or other differences that could imply stock separation.
   iii. Review recent genetic studies and approaches to stock separation and assess technical feasibility, potential benefits and costs of applying these to orange roughy in the SPRFMO Area.

2. **Estimation of B_0**
   i. Apply the most appropriate methods to estimate initial biomass based on catch history.
   ii. Develop defensible CPUE indices where possible, addressing the main concerns about (a) over-aggregated data and spatial serial depletion; (b) hyper- and hypo-stability; and (c) changes due to regulatory or commercial fishery change over time.
   iii. Explore more complex assessment methodologies using available indices of abundance (including CPUE, acoustic survey and swept-area trawl survey estimates of biomass).

3. **Estimation of sustainable catches**
   i. Using the best estimates of B_0, explore the options for setting catch limits that will conserve the orange roughy stocks and provide for a viable, sustainable fishery.
   ii. Develop options for setting sustainable catch limits to a range of plausible spatial scales for the SPRFMO Convention Area that will conserve the orange roughy stocks and provide for a viable, sustainable fishery.

2.4 FUTURE DEVELOPMENTS

The assessment approaches described in this paper are not intended to restrict the development or application of assessment approaches to demersal (benthic) and bentho-pelagic fish in the SPRFMO Convention Area in future. Novel approaches to estimate stock status and sustainable catch limits will continue to be explored as data and techniques allow and these will periodically be brought to the Scientific Committee for consideration.

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