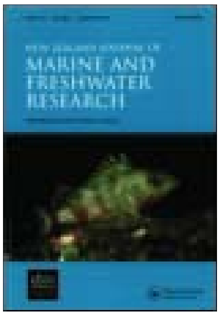

New Zealand Journal of Marine and Freshwater Research
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tnzm20

Quantifying the relative intensity of fishing on New Zealand seamounts

Richard L. O'Driscoll [a] & Malcolm R. Clark [b]
[a] National Institute of Water and Atmospheric Research Limited, Private Bag 14 901, Kilbirnie, Wellington, New Zealand E-mail:
[b] National Institute of Water and Atmospheric Research Limited, Private Bag 14 901, Kilbirnie, Wellington, New Zealand

Version of record first published: 30 Mar 2010

To cite this article: Richard L. O'Driscoll & Malcolm R. Clark (2005): Quantifying the relative intensity of fishing on New Zealand seamounts, New Zealand Journal of Marine and Freshwater Research, 39:4, 839-850

To link to this article: http://dx.doi.org/10.1080/00288330.2005.9517356

New Zealand Journal of Marine and Freshwater Research, 2005, Vol. 39: 839–850
0028–8330/05/3904–0839

Quantifying the relative intensity of fishing on New Zealand seamounts

RICHARD L. O'DRISCOLL
MALCOLM R. CLARK
National Institute of Water and Atmospheric Research Limited
Private Bag 14 901, Kilbirnie
Wellington, New Zealand
email: r.odriscoll@niwa.co.nz

Abstract New Zealand seamounts support major fisheries for several deepwater fish species, including orange roughy (*Hoplostethus atlanticus*) and smooth oreo (*Pseudocyttus maculatus*). Although a high proportion of features in the depth range 500–1000 m have been fished, very little is known about the ecological impacts of bottom trawling on seamounts. The potential impact is likely to be influenced by the spatial extent and frequency of fishing. A new index is presented to assess the relative intensity of trawling on New Zealand seamounts. The fishing effects index (FEI) incorporates information on the density of fishing on the seamount as a proportion of the seabed area and also on tow direction. Detailed fisheries data from more than 250 000 tows were examined to calculate FEI for New Zealand seamounts. The most intensively fished seamounts were on the south Chatham Rise, an area characterised by a large number of relatively small features which were fished serially for orange roughy in the 1980s and 1990s. Other seamounts with high FEI were on the north Chatham Rise, Challenger Plateau, and off the east coast of the North Island. A range of sensitivity analyses indicated that the general rankings of seamounts were relatively robust to the choice of arbitrary thresholds used to assign tows to seamounts.

M04141; Online publication date 17 June 2005
Received 8 October 2004; accepted 24 December 2004

Keywords impacts of trawling; deepwater fisheries; seamounts; fishing effort distribution; orange roughy

INTRODUCTION

Seamounts are important features of the New Zealand marine environment. About 800 seamounts with vertical elevation greater than 100 m above the surrounding sea floor have been identified in the general New Zealand region (Clark & O'Driscoll 2003). Seamounts are productive habitats for deepwater fish (Koslow 1997), and major fisheries for orange roughy (*Hoplostethus atlanticus*), oreos (black oreo *Allocyttus niger*, and smooth oreo *Pseudocyttus maculatus*), black cardinalfish (*Epigonus telescopus*), alfonsino (*Beryx splendens*), bluenose (*Hyperoglyphe antarctica*), and rubyfish (*Plagiogeneion rubiginosum*) occur on and around New Zealand seamounts (Clark & O'Driscoll 2003). They reported that nearly 80% of all known seamounts in the depth range 500–1000 m in the New Zealand region have been fished.

Although productive, seamounts are generally regarded as fragile habitats (Rogers 1994; Probert 1999). The environmental impact of fishing, especially bottom trawling, is the subject of growing public and political awareness (e.g., de Groot 1984; Hutchings 1990; Collie et al. 1997; Hall 1999; Koslow et al. 2001). The impacts of trawl gear have long been known, including gouging of the seabed, sediment resuspension and smothering, destruction of non-target benthic animals, and the dumping of processing wastes (see Jones 1992; Dayton et al. 1995). However, very little is known about the effects of fishing on the ecology of seamounts in the New Zealand region.

The ecological impact caused by fishing is influenced by the spatial extent and frequency of habitat disturbance (Thrush et al. 1998). One of the challenges facing researchers is how to quantify the intensity of trawling on individual seamounts. Simple measures, such as number of tows, may not adequately index fishing effort. For example, 100 tows on a very small seamount may represent a higher intensity of effort than 500 tows on a larger feature. The distribution of tows will also determine how much of the seamount area is affected by fishing. On some seamounts there is a "shotgun" type coverage with tows in all directions, whereas on others there appears to be a "trawl corridor" with most tows occurring in a single preferred direction.

Clark & O'Driscoll (2003) developed a fishing importance index (FII) which measured the effort, catch, consistency of fishing, and diversity of target species on each seamount. The FII was an attempt to quantify the relative importance of seamounts for the commercial fishery, but did not assess the likely impact of fishing on the seamounts. In this paper we describe a new measure, the fishing effects index (FEI), and use this to assess the relative intensity of trawling on New Zealand seamounts.

METHODS

Individual tow information, with location and estimated catch for each tow, have been recorded by most New Zealand deepwater fishing vessels since the early 1980s. Data are held in a database by the New Zealand Ministry of Fisheries, from which we extracted data for all tows which targeted orange roughy, oreos (black, smooth, and unspecified), black cardinalfish, alfonsino, bluenose, and rubyfish up to 30 September 2003. Orange roughy and oreo data extend back to the 1970s, but for the other species most of the fishing effort has occurred since 1989, and earlier data (collected under a slightly different system) were not included in the analysis. Positional data were less accurate before the introduction of global positioning systems (GPS) in about 1989. To assess the effect of this on the FEI, we also calculated indices excluding orange roughy and oreo data before 1989 as a sensitivity test. For all fisheries, some data were recorded on forms without detailed positional data, but these account for less than 10% of the total effort and were excluded from the analysis.

The start positions of tows were compared to the centre positions of over 800 seamounts on the NIWA database, which were determined from bathymetry and research surveys. The list of seamounts included all discrete hill-like structures with vertical elevation greater than 100 m above the sea floor (after Clark & O'Driscoll 2003).

The fishing effects index (FEI) for an individual seamount was defined as follows:

$$\mathrm{FEI} = \left(\frac{\sum \mathrm{L}}{\mathrm{A}}\right)\left(\frac{\mathrm{D}}{4}\right)$$

where ΣL is the summed tow length (in km) of all tows with start positions within 10 km of the seamount centre and tow length less than 5.6 km; A is the seamount area in square kilometres; and D is the number of tow directions (from 1 to 4) for each seamount that had more than 5 tows. The units of FEI are km^{-1}.

A distance of 10 km from the seamount centre was chosen following Clark & O'Driscoll (2003). This threshold was arbitrary, but was chosen to encompass the likely maximum distance of a vessel away from a seamount while still fishing on that seamount. We investigated the sensitivity of the final results to this threshold by calculating indices using a threshold distance of 5 km. When a tow started less than 10 km from more than one seamount, it was assigned to the nearest seamount only. This approach may have introduced some degree of error where seamounts were close together and a vessel was fishing one seamount while its reported position was closer to a neighbouring one. However, this is a minor problem, as most seamounts are at least 5 km apart, so that tow start positions could be assigned to the correct feature.

Tow length was calculated as the product of tow duration in minutes and tow speed in knots. Mean tow speed was c. 3 knots, so that a tow length of 5.6 km was equivalent to a tow duration of 1 h. This threshold was also arbitrary, but was based on our experience that tows on seamounts seldom exceed 1 h (and are usually less than 30 min), whereas tows on surrounding flat areas are typically much longer. Again, the sensitivity of results to the choice of threshold was investigated by calculating indices with alternative thresholds of 3.7 and 9.3 km (2 and 5 nautical miles).

Tow direction was calculated from tow start and finish positions for tows that fulfilled both of the above criteria ("seamount tows") and additionally had tow lengths greater than 0.9 km (0.5 nautical miles). This additional threshold was introduced to reduce inaccuracies in directions resulting from positional rounding, as fishers generally only record tow positions to the nearest minute of a degree. For very short tows (<0.9 km), start and finish positions were almost always the same. Only tows from 1989

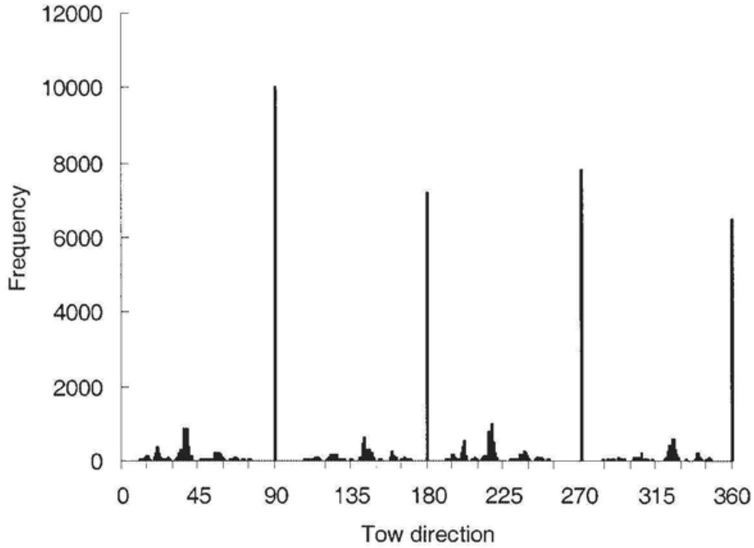

Fig. 1 Frequency of calculated tow directions for commercial tows (1989–2003) which started within 10 km of a seamount centre and were used in the analysis. On direction axis, 90 = east, 180 = south, 270 = west, 360 = north.

onwards had finish positions reported, so that tow direction could not be calculated for tows before 1989. Frequency histograms (Fig. 1) of reported tow directions indicated that fishers tended to preferentially report tows as being north, south, east, or west (i.e., latitude or longitude changed during the tow but usually not both). This directional bias was not a result of positional precision as the same pattern was apparent even for long tows (>5.6 km). To deal with this feature of the data, we categorised direction into four quadrants (north = 315°–45°, east = 45°–135°, south = 135°–225°, west = 225°–315°, where 0° = due north).

To test whether the direction of tows on an individual seamount x was non-random, we randomly took 1000 samples of size n_x from the total set of reported tow directions (Fig. 1), where n_x was the number of tows 0.9–5.6 km long where the tow start position was within 10 km of seamount x. We then compared the proportion of tows in each direction (north, south, east, or west) from the observed tows with the proportions from the random samples. The direction of trawling was considered to be non-random where there were fewer observed tows in one or more directions than in 95% of the random samples (i.e., one-sided test with $P = 0.05$).

Seamount areas (km^2) were only available for 138 of the 227 fished seamounts in the New Zealand region. Seamount area was estimated from the flat surface area of a polygon defined by the most complete depth contour that encircled the base of the seamount. This estimation did not account for differences in true surface area with elevation and steepness, but as most New Zealand seamounts have slopes of between 10° and 25° (NIWA unpubl. data), this was unlikely to be a major source of error. To calculate the FEI, we assigned the other 89 seamounts a nominal area of 1 km^2. This was reasonable because seamounts with no area information were known to be mostly small features.

The FEI incorporates data of the amount of fishing effort, tow direction, and seamount area. The index is essentially in two parts. The first part is a measure of the density of fishing on the seamount as a proportion of the seamount area. Summed tow length was used as a proxy for swept area because tow characteristics (doorspread and wingspread) were not reliably recorded. In general, orange roughy trawls have wingspread in the range 20–30 m, and doorspread of 100–200 m. The second part of the index is a scaling factor reflecting the proportion of tow directions in which the seamount was trawled. Seamounts have a high FEI if they have had a large amount of effort relative to their size and they have been towed in all directions.

RESULTS

More than 250 000 tows were extracted from the MFish database (Table 1). Of these, 84 793 tows (34%) fulfilled the criteria of occurring within 10 km

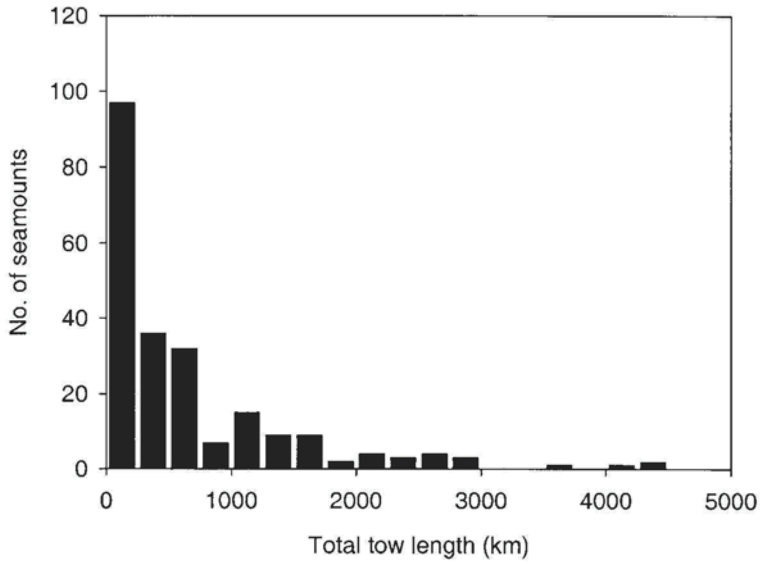

Fig. 2 Fishing effort (total tow length) on seamounts grouped into bins of 250 km. Two seamounts with 5500 and 10 500 km of tows are not graphed.

Table 1 Numbers of commercial tows included in analyses used in this paper. Directions were only calculated for tows occurring close to seamounts (–, not applicable).

Dataset	No. of tows	No. of tows with directions
All data	250 116	–
Base case	**84 793**	**54 922**
Sensitivity A	97 606	64 726
Sensitivity B	71 961	44 391
Sensitivity C	62 534	40 623
Sensitivity D	79 468	54 922

Base case: tow start <10 km from seamount centre, tow length <5.6 km
Sensitivity A: tow start <10 km from seamount centre, tow length <9.3 km
Sensitivity B: tow start <10 km from seamount centre, tow length <3.7 km
Sensitivity C: tow start <5 km from seamount centre, tow length <5.6 km
Sensitivity D: tow start <10 km from seamount centre, tow length <5.6 km, only data from 1989 (post-GPS)

of a seamount centre and being less than 5.6 km in length ("base case" in Table 1). Most of these seamount tows (76%) were targeted at orange roughy. The effect of varying the thresholds on the number of tows which were defined to be on seamounts is also shown in Table 1.

The total tow length on individual seamounts is shown in Fig. 2. The highest effort was on Hill 280 (NIWA seamounts database reference number) off the east coast of the North Island, which had over 10 000 km of tows. However, most seamounts had less than 750 km of tows. The median intensity of fishing was c. 130 km of tows per 1 km^2 of seamount area, although some seamounts had a much higher density of tows (Fig. 3).

The direction of tows was non-random for 81% of fished seamounts (Fig. 4). The pattern of tows on six example seamounts is shown in Fig. 5. On most seamounts, there were one or more clearly preferred tow directions. For example, on Hill 280, 88% of tows were north-northeast or south-southwest, whereas on Colville Knoll 77% of all tows were westwards (Fig. 5). On a few features, such as Mt Kiso, there was a shotgun-type coverage and the pattern of fishing was not distinguishable from random (Fig. 5).

The FEI results are shown in Fig. 6, with key data for the top 50 seamounts summarised in Table 2. Table 2 also shows the sensitivity of the ranking of seamounts to thresholds applied during the analyses.

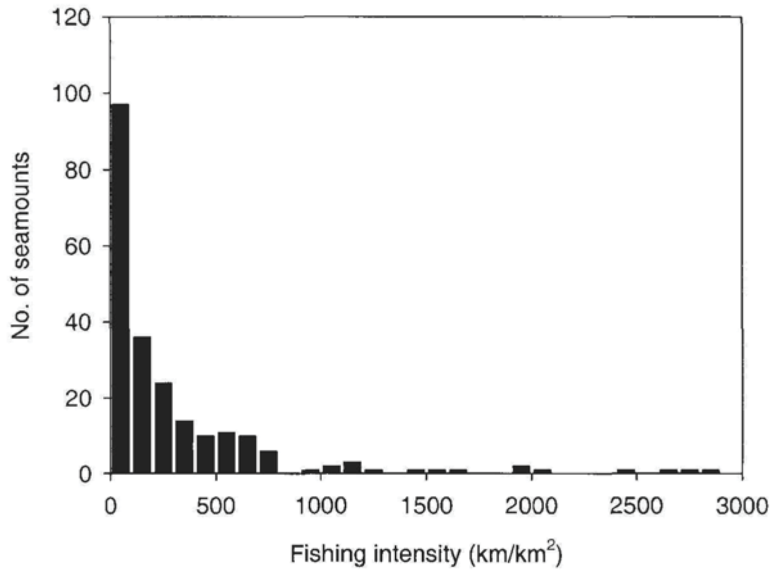

Fig. 3 Fishing intensity (tow length divided by seamount area) on seamounts grouped into bins of 100 km/km^2. Two seamounts with intensities of 3800 and 17 400 km of tows per km^2 are not graphed.

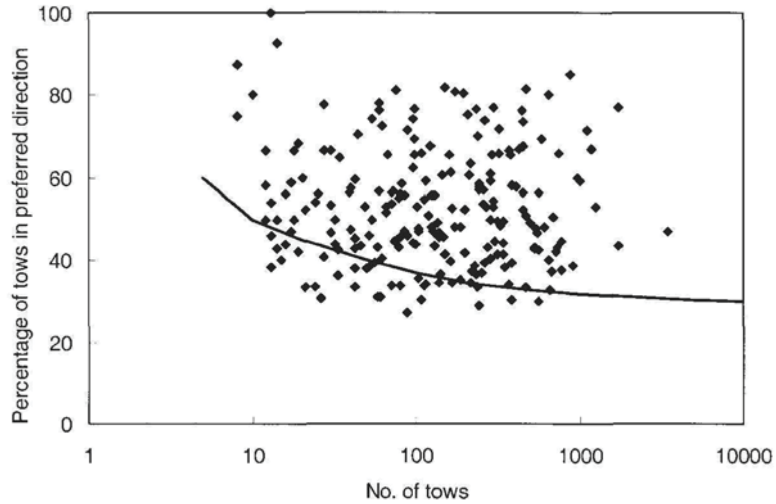

Fig. 4 Percentage of tows in preferred direction plotted as a function of total number of tows. Note $\log_{10}$ scale on x axis. Line shows the upper 95% confidence level for random tows from 1000 Monte Carlo simulations. Points above the line indicate seamounts which had significantly higher proportions of tows in the preferred direction than expected if the direction of trawling was random.

The most intensive fishing was on the south Chatham Rise, with 20 seamounts from this area ranking in the top 50 FEI (Table 2). The south Chatham Rise is characterised by a large number of relatively small features, which were fished serially for orange roughy in the 1980s and 1990s (Clark et al. 2000). Other seamounts with high FEI were on the north Chatham Rise (Crack, Zombie), Challenger Plateau (Northwest Pinnie, Spin Pinnie), and off the east coast of the North Island (Outer Castlepoint) (Fig. 6).

Changing the threshold criteria for seamount tows when calculating FEI caused small adjustments to the ranking of seamounts, but the general ordering was the same (Fig. 7). For example, the top 10 seamounts in Table 2 were ranked within the top 15 in all four sensitivities. Excluding data before 1989 (sensitivity D) had the smallest effect on the ranking of seamounts (Fig. 7), and we chose to include all available information for completeness in the base case. We also know that there was considerable fishing before 1989 on some seamounts (e.g., Crack, Mt Kiso, Trevs Pinni) (NIWA, unpubl. data).

There was only a weak relationship between the FEI and the fishing importance index (FII) as defined by Clark & O'Driscoll (2003) (Fig. 8). Some