

Fig. 7 Sensitivity of fishing effects index (FEI) rankings to changes in thresholds used in the analyses: **A**, maximum tow length = 9.3 km; **B**, maximum tow length = 3.7 km; **C**, maximum distance from seamount centre = 5 km; **D**, only data from 1989 (post GPS). The distance from the 1:1 line indicates how much the new rank (y axis) changed from the base case (x axis).

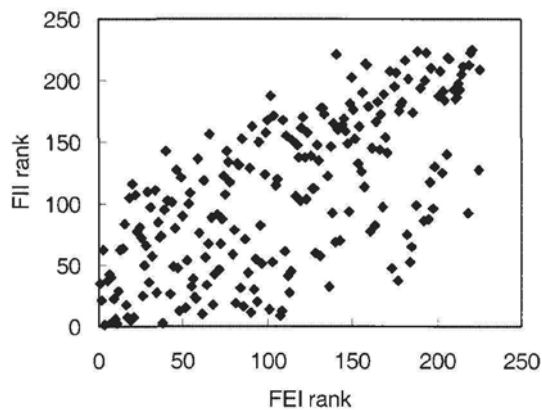


Fig. 8 Relationship between rankings of fishing effects index (FEI) and fishing importance index (FII). FII was updated from Clark & O'Driscoll (2003) to include data up to 2003.

Dolah et al. 1987; Freese et al. 1999; Pitcher et al. 2000). The coral cover present on many seamounts is fragile, and easily damaged by bottom trawl gear (Clark & O'Driscoll 2003), whereas the same intensity of trawling may have a smaller impact on a softer substrate (e.g., Sanchez et al. 2000).

Few data are available from New Zealand seamounts to evaluate the biological meaning of the FEI (i.e., to "ground truth" the index). One area where a comparison can be made between the FEI and measured biological impacts of trawling is on the Graveyard complex on the northern Chatham Rise. Clark & O'Driscoll (2003) presented data (summarised in Table 3) from a photographic survey showing the distribution of coral on four seamounts with varying levels of fishing intensity (Graveyard, Morgue, Diabolical, and Gothic). Table 3 shows that seamounts with higher FEI (Graveyard and Morgue) had lower occurrence and abundance of live habitat-forming coral than seamounts with lower FEI

Table 3 Occurrence and abundance of live habitat-forming coral (*Solenosmilia variabilis* and *Madrepora oculata*) on four seamounts on the northern Chatham Rise with different fishing effects indices (FEI). Coral data are from photographic transects (after Clark & O'Driscoll 2003). *N* is the number of camera stations.

Seamount	FEI (km ⁻¹)	FEI rank	<i>N</i>	Occurrence (% of images)	Abundance (mean % cover)
Graveyard	228	79	70	1.4	0.03
Morgue	94	123	55	1.8	0.04
Gothic	23	167	62	44	21
Diabolical	0	—	42	21	12

(Gothic and Diabolical). However the sample size is small, and, because these four seamounts are close together, there may have been errors assigning some tows to seamounts when calculating the FEI (see Methods). Further research is required to relate the intensity of fishing to observed impacts on the fauna of New Zealand seamounts.

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REFERENCES

- Clark MR, Anderson OF, Francis RICC, Tracey DM 2000. The effects of commercial exploitation on orange roughy (*Hoplostethus atlanticus*) of the continental slope of the Chatham Rise, New Zealand, from 1979 to 1996. *Fisheries Research* 45: 217–238.
- Clark MR, O'Driscoll RL 2003. Deepwater fisheries and their impacts on seamount habitat in New Zealand. *Journal of Northwest Atlantic Fishery Science* 31: 441–458.
- Collie JS, Escanero GA, Valentine PC 1997. Effects of bottom fishing on the benthic megafauna of Georges Bank. *Marine Ecology Progress Series* 155: 159–172.
- Cranfield HJ, Manighetti B, Michael KP, Hill A 2003. Effects of oyster dredging on the distribution of bryozoan biogenic reefs and associated sediments in Foveaux Strait, southern New Zealand. *Continental Shelf Research* 23: 1337–1357.
- Dayton PK, Thrush SF, Agardy MT, Hofman RJ 1995. Viewpoint: environmental effects of marine fishing. *Aquatic Conservation Marine and Freshwater Ecosystems* 5: 205–232.
- de Groot SJ 1984. The impact of bottom trawling on benthic fauna of the North Sea. *Ocean Management* 9: 177–190.
- Freese L, Auster PJ, Heifetz J, Wing BL 1999. Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska. *Marine Ecology Progress Series* 182: 119–126.
- Hall SJ 1999. The effects of fishing on marine ecosystems and communities. Oxford, Blackwell Scientific. 270 p.
- Hutchings P 1990. Review of the effects of trawling on macrobenthic epifaunal communities. *Australian Journal of Marine and Freshwater Research* 41: 111–120.
- Jones JB 1992. Environmental impact of trawling on the seabed: a review. *New Zealand Journal of Marine and Freshwater Research* 26: 59–67.
- Koslow JA 1997. Seamounts and the ecology of deep-sea fisheries. *American Scientist* 85: 168–175.
- Koslow JA, Gowlett-Holmes K, Lowry JK, O'Hara T, Poore GCB, Williams A 2001. Seamount benthic macrofauna off southern Tasmania: community structure and impacts of trawling. *Marine Ecology Progress Series* 213: 111–125.
- Piet GJ, Rijnsdorp AD, Bergman MJN, van Santbrink JW, Craeymeersch J, Buijs J 2000. A quantitative evaluation of the impact of beam trawling on benthic fauna in the northern North Sea. *ICES Journal of Marine Science* 57: 1332–1339.
- Pitcher CR, Poiner IR, Hill BJ, BurrIDGE CY 2000. Implications of the effects of trawling on sessile megazoobenthos on a tropical shelf in northeastern Australia. *ICES Journal of Marine Science* 57: 1359–1368.
- Probert PK 1999. Seamounts, sanctuaries and sustainability: moving towards deep-sea conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* 9: 601–605.
- Probert PK, McKnight DG, Grove SL 1997. Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. *Aquatic Conservation: Marine and Freshwater Ecosystems* 7: 27–40.

- Rijnsdorp AD, Buys AM, Storbeck F, Visser EG 1998. Micro-scale distribution of beam trawl effort in the southern North Sea between 1993 and 1996 in relation to the trawling frequency of the sea bed and impact on benthic organisms. *ICES Journal of Marine Science* 55: 403–419.
- Rogers AD 1994. The biology of seamounts. *Advances in Marine Biology* 30: 305–350.
- Sanchez P, Demestre M, Ramon M, Kaiser MJ 2000. The impact of otter trawling on mud communities in the northwestern Mediterranean. *ICES Journal of Marine Science* 57: 1352–1358.
- Thrush SE, Hewitt JE, Cummings VJ, Dayton PK, Cryer M, Turner SJ, Funnell GA, Budd RG, Milburn CJ, Wilkinson MR 1998. Disturbance of the marine benthic habitat by commercial fishing: impacts at the scale of the fishery. *Ecological Applications* 8: 866–879.
- van Dolah RF, Wendt PH, Nicholson N 1987. Effects of a research trawl on a hard-bottom assemblage of sponges and corals. *Fisheries Research* 5: 39–54.