Return to previous file: drds251.pdf

the relationship with time was weak (NT zone: $\ln N_t = 0.016t - 32.448$, $F_{1,1208} = 5.158$, $p = 0.023$, $r^2 = 0.004$; RF zone: $\ln N_t = 0.01t - 18.874$, $F_{1,1185} = 3.917$, $p = 0.048$, $r^2 = 0.003$). Red moki decreased over time. This decrease was statistically significant in the NT zone ($\ln N_t = -0.017t + 34.323$, $F_{1,1208} = 6.322$, $p = 0.012$, $r^2 = 0.005$). Numbers of targeted fish showed a weak increase over time, with this being only significant in the RF zone ($\ln N_t = 0.047t - 90.254$, $F_{1,1185} = 4.808$, $p = 0.029$, $r^2 = 0.004$). Finally, total number of fish neither statistically decreased nor increased over time in either zone.

5.3 EFFECT OF DISTANCE FROM THE CORE OF THE NT ZONE

As expected, targeted fish numbers decreased with distance from the core of the NT zone. This occurred in all years except for 1997 and 1993 (Table 7). However, the declines in numbers with distance from the core were statistically significant for only 5 of the 11 years that we monitored the fish in the reserve (Table 7). In addition, the levels of decline with distance from the NT core were low throughout the entire monitoring period.

TABLE 6. RESULTS OF REGRESSION ANALYSIS BETWEEN RELATIVE ABUNDANCE OF SNAPPER, RED MOKI THE NUMBER OF TARGETED AND TOTAL NUMBER OF FISH AND TIME RECORDED IN SIX HABITAT TYPES IN THE NO-TAKE (NT) AND RECREATIONALLY FISHED ZONES (RF) DURING THE TEN YEARS OF MONITORING.

RESPONSE VARIABLE	HABITAT*	NT ZONE				RF ZONE			
		$\ln N_t = at + b$	*F*-value	*p*-value	r^2	$\ln N_t = at + b$	*F*-value	*p*-value	r^2
Snapper	1	**0.027t+0.242**	**4.123**	**0.043**	**0.010**	**0.049t–0.005**	**5.484**	**0.021**	**0.038**
	2	–0.019t+0.389	0.496	0.482	0.004	**0.025t–0.064**	**12.911**	**0.001**	**0.040**
	3	**0.061t+0.089**	**6.598**	**0.011**	**0.045**	–0.006t+0.144	0.240	0.625	0.002
	4	0.009t+0.261	0.217	0.642	0.001	–0.012t+0.123	2.131	0.147	0.015
	5	0.008t+0.233	0.354	0.553	0.003	0.011t+0.069	0.474	0.492	0.003
	6	0.009t+0.022	1.051	0.306	0.005	–0.008t+0.161	0.699	0.404	0.002
Red moki	1	–0.016t+0.599	1.651	0.199	0.002	–0.010t–0.262	0.434	0.511	0.003
	2	**–0.034t+0.486**	**4.189**	**0.043**	**0.030**	–0.011t–0.304	1.153	0.284	0.004
	3	–0.006t+0.325	0.136	0.713	0.001	–0.006t+0.267	0.187	0.666	0.001
	4	**–0.046t+0.583**	**9.512**	**0.002**	**0.062**	0.001t+0.395	0.007	0.935	0.000
	5	–0.038t+0.673	3.252	0.073	0.023	0.003t+0.193	0.053	0.818	0.000
	6	0.017t+0.395	1.024	0.313	0.005	0.001t+0.143	0.020	0.888	0.000
Targeted fish	1	0.038t+4.168	1.217	0.271	0.003	**0.122t+3.898**	**5.156**	**0.025**	**0.036**
	2	–0.052t+4.582	0.913	0.341	0.007	0.046t+4.294	1.226	0.269	0.004
	3	**–0.140t+4.488**	**7.726**	**0.006**	**0.052**	0.002t+3.779	0.001	0.976	0.000
	4	–0.006t+4.611	0.019	0.892	0.000	**–0.198t+4.411**	**14.004**	**0.000**	**0.092**
	5	0.027t+3.277	0.250	0.618	0.002	**0.159t+2.428**	**6.752**	**0.010**	**0.047**
	6	0.097t+2.195	6.515	0.110	0.030	**0.133t+2.640**	**10.427**	**0.001**	**0.030**
Total number	1	0.021t+4.614	0.470	0.493	0.001	**0.088t+4.511**	**4.064**	**0.046**	**0.028**
	2	–0.082t+5000	2.969	0.087	0.014	0.023t+4.733	0.388	0.534	0.001
	3	**–0.116t+4.811**	**8.421**	**0.004**	**0.050**	–0.070t+4.603	1.707	0.194	0.012
	4	**–0.003t+4.798**	**0.006**	**0.941**	**0.001**	**–0.415t+4.761**	**9.567**	**0.002**	**0.064**
	5	–0.013t+3.937	0.082	0.775	0.001	**0.116t+3.163**	**5.205**	**0.024**	**0.037**
	6	0.053t+3.129	2.342	0.127	0.011	**0.106t+3.244**	**9.538**	**0.002**	**0.028**

Bold type = Statistically significant relationships.

* See Table 2 for expanded descriptions of habitat types.

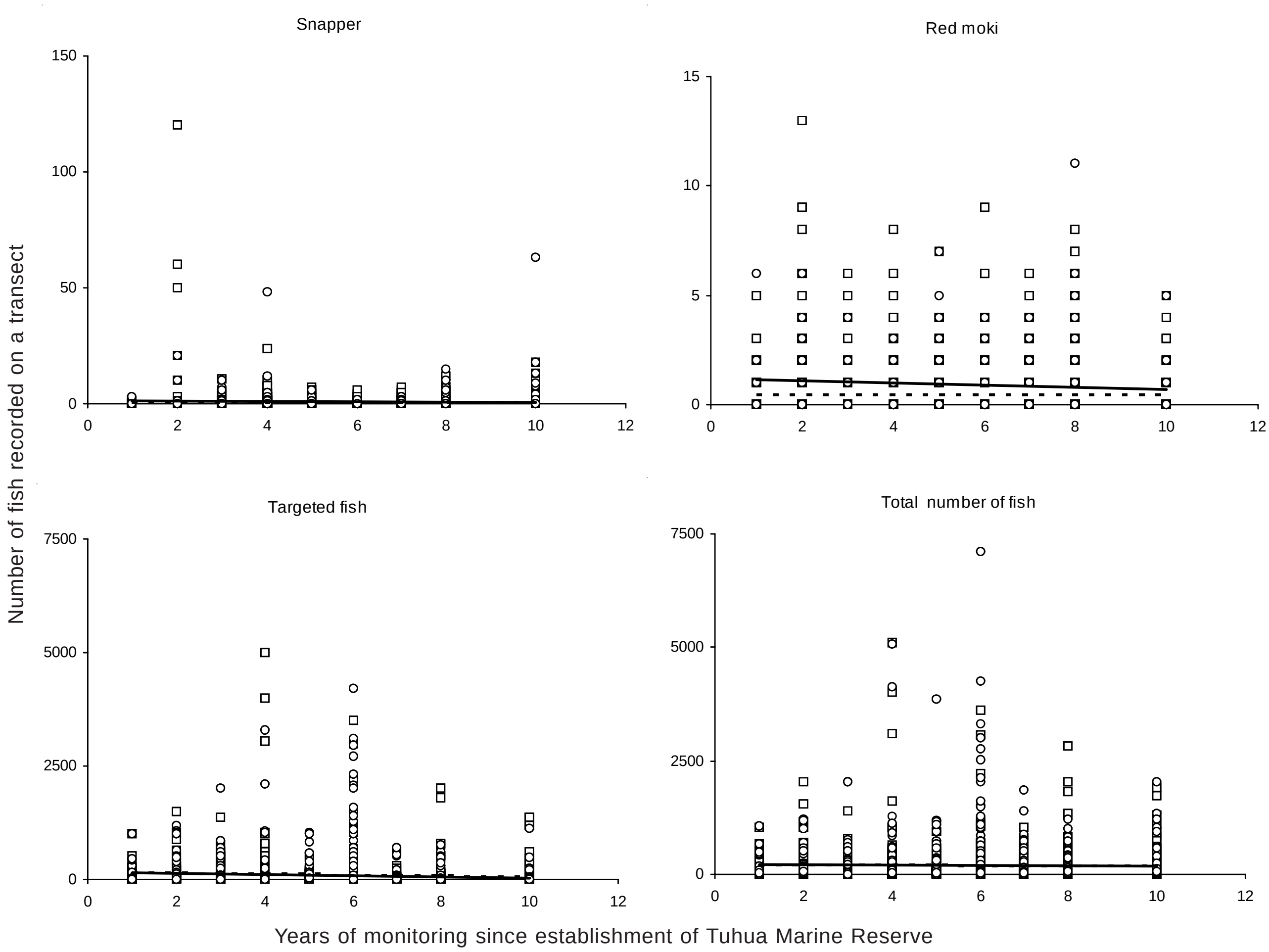

Figure 4. Relative abundance of snapper, red moki, targeted fish, and the total number of fish recorded during 10 years post establishment of the Tuhua Marine Reserve. The no-take (NT = open squares) and recreational fishing (RF = open circles) zones are illustrated separately. The trends defined by an exponential model for the NT and RF zones are shown by the solid and broken lines.

TABLE 7. RATE OF DECLINE IN TOTAL NUMBERS OF TARGETED FISH RECORDED AS THE DISTANCE BETWEEN A SITE AND THE CORE OF THE NO-TAKE ZONE (NT) OF TUHUA MARINE RESERVE INCREASES.

YEAR	RATE OF DECLINE FROM CORE	T-VALUE
1993	0.01 ± 0.010	$t_{88} = 0.98$
1994	−0.03 ± 0.020	$t_{150} = -1.84$
1995	−0.02 ± 0.080	$t_{178} = -2.43$*
1996	−0.03 ± 0.010	$t_{329} = -2.62$*
1997	0.00 ± 0.000	$t_{329} = 0.26$
1998	−0.00 ± 0.020	$t_{329} = -0.20$
1999	−0.01 ± 0.000	$t_{316} = -2.98$*
2000	−0.02 ± 0.010	$t_{332} = -1.50$
2002	−0.01 ± 0.000	$t_{328} = -3.32$*
2004	−0.008 ± 0.004	$t_{92} = -4.620$*
2005	−0.005 ± 0.004	$t_{92} = -2.615$

* Least square linear regression was used to identify those years when the decline with distance was significant.

NOTE: Data for Table 7 came from underwater visual censuses undertaken annually for 6 sites within the NT zone and 6 in the recreational fishing zone (RF) from 1993 to 2002, 41 sites in the NT zone and 52 sites in the RF zone in 2004, and 40 in the NT zone and 53 in the RF zone in 2005.

6. Discussion

Demonstrating the differences made by conservation management actions is fraught with issues of spatial and temporal scale. At what geographical scale should monitoring occur, and for how long? (Cole 2003a) Our ambiguous results from 11 years of monitoring of Tuhua Marine Reserve highlight these two issues. On the one hand, our comparisons of relative abundance between two different levels of protection suggest recovery of targeted reef fish species in the fully protected no-take zone of Tuhua Marine Reserve. On the other, the variability of changes in relative abundance of our chosen response variables over time suggests that no (or at best limited) growth of targeted reef fish population sizes has occurred.

Despite only small (or no) changes occurring in previously targeted reef fish species in two East Coast marine reserves—Te Angiangi Marine Reserve (Freeman & Duffy 2003), Te Tapuwae o Rongokako Marine Reserve (Freeman 2005)—monitoring in other marine reserves in New Zealand, using the same or similar methodologies, suggests that targeted fish species usually recover well in no-take reserves. For example, snapper was more common in no-take reserves than in other areas around the north-eastern coast of New Zealand (Denny et al. 2003; Denny & Babcock 2004), hence our expectation that targeted reef fish would recover more strongly in the NT zone at Tuhua Marine Reserve. This is supported by our comparisons in relative abundance of fish between habitats (1993–2002) and management zones (2004–2005). For the former, when we combined data according to management zones, snapper and red moki were statistically more abundant in the NT zone a considerable proportion of the time (87.5% snapper, 78% red moki). For the latter we found that snapper was 12 times more abundant in the NT than in the RF zone in 2004, and 6.25 times more abundant in 2005. Red moki were 4.6 times (2004) and 8.63 times (2005) more abundant in the NT zone than the RF zone. These results compare well with the response to protection of targeted fish elsewhere. For instance, Willis et al. (2003) recorded 14.4 times more snapper inside the Cape Rodney to Okakari Point Marine Reserve than outside and concluded that recovery of targeted reef fish was occurring in this reserve.

Based on our results, we should be able to conclude that recovery of targeted reef fish occurred in the fully protected NT zone of Tuhua Marine Reserve. However, the variability in numbers over time within habitats and management zones makes it difficult to demonstrate recovery of targeted reef fish populations. Snapper numbers increased in five of the six habitat types in the NT zone, but rates of increase were only statistically significant in two of these habitats, while the exponential growth models explained little of the variation. Much the same can be concluded for red moki numbers which decreased in five of the six habitats in the NT zone and the total number of targeted fish and total number of fish which both increased and decreased with time according to habitat. Both the total number of targeted fish and the total number of fish increased and decreased significantly in different habitat types. While differences in relative abundances are evident between the two management regimes, trends of reef fish populations are not that easy to detect.

6.1 SAMPLING DESIGN

Large variations in counts of a species can make it difficult to define trends or changes in a population. Highly mobile reef fish that move in large shoals can often exacerbate this problem. Survey techniques need to be robust and reliable enough to ensure observed patterns are real. The large variation in counts that we observed could simply be because the counts did not accurately measure relative abundance.

We found that the counts were not influenced by observer bias. A major limitation of the data was that the original design did not allow direct comparison between management zones. This meant that we had limited ability to measure real changes over most of the monitoring period at the management zone scale. We could only measure changes at the habitat or substrate scale. It was, perhaps, unrealistic to expect that we could measure changes at the habitat scale. Indeed many fish species can and do move over large distances and between habitats (see Halpern et al. 2004; Bentley et al. 2004b). This is particularly true for snapper which are known for large-scale seasonal movements by at least certain parts of populations (Willis et al. 2001; Crossland 1976). The effect of scale was indicated when we combined the data for different habitats in a zone even though it failed statistical assumptions. When we did this, we found that snapper and red moki were statistically more abundant in the NT zone 88% and 78% of the time respectively as opposed to 41% and 34% of the time using non-pooled data. This suggests that we may have had our scale wrong. Indeed changes could be occuring at scales well beyond the influence of the immediate habitat. Consequently we are presently undertaking further study to consider the effects of habitat on relative abundance of species. In the meantime, our new sampling design allows us to measure changes in a statistically robust manner at the management zone scale. Nevertheless, while scale may explain an inconclusive recovery of targeted reef fish species, there is also evidence to suggest that biological constraints and/or other factors also contribute to the variability in our results.

6.2 BIOLOGICAL CONSTRAINTS

The first practical question a manager asks is: when should monitoring stop? In other words, how long is it before one can detect changes in the fish numbers of a marine reserve (Cole 2003a)? The answer hinges on three aspects: the life-histories of individual species, the sources they can come from (if they are locally extinct), and other external influences (see Cole 2003a). These can combine to create time lags between the start of protection and the recovery of reef fish in a marine reserve. For instance Polunin & Roberts (1993) suggested time lags occur when populations are recovering from intense fishing pressure. For example, fish populations grew slowly in the first 3–5 years after protection of the Great Barrier Reef, but much quicker in the following 4 years (Russ & Alcala 1996).

It is unlikely that we are observing a time lag at the Tuhua Marine Reserve. Twelve years have passed since the reserve came into existence. At the Poor Knights Island Marine Reserve, which is similarly situated some 24 km offshore, Denny et al. (2003) found a 25-fold increase in snapper older than one year in the first year after full protection. Such an increase must have occurred through recruitment of adults from surrounding areas. Snapper are widespread throughout the Bay of Plenty (Hurst et al. 2000; Anderson et al. 1998). They form the basis of a large commercial fishery in this region, and support a large recreational fishery (Bentley et al. 2004b; Walsh et al. 2004), so we assume that sources of adult snapper are available. Why then have we not seen similar recovery in the 12 years since protection?

Movement patterns and reserve size may influence the effectiveness of a marine reserve (Cole 2003a; Halpern et al. 2004). This is particularly symptomatic where edge effects exist and species are highly mobile. Thus the effectiveness of a reserve is relative to the species of interest and may explain the lack of recovery of previously targeted fish within Tuhua Marine Reserve. Snapper exhibit a range of behaviours in marine protected areas from high site fidelity (Willis et al. 2001) to large scale movements (Bentley et al. 2004b) with considerable interaction with the surrounding fishery (Parsons & Egli 2005). Indeed snapper make large seasonal movements to get to spawning and feeding areas (Denny et al. 2003). Data also suggests that snapper populations of offshore islands may be more mobile than inshore populations (Parsons & Egli 2005). Like the partially protected Tuhua environs, partial protection at the Poor Knights Islands Marine Reserve did not afford any recovery of previously targeted reef fish species (Denny et al. 2003). There the dramatic recovery of snapper only occurred after the entire Poor Knights archipelago was closed to fishing. This suggests that the original no take zones of the Poor Knights Islands were too small to meet the habitat needs of snapper which continued to be targeted beyond protected areas.

The size of the NT zone at Tuhua Marine Reserve (1057 ha) makes it one of the larger reserves in New Zealand. Smaller reserves with larger edge effects, such as Cape Rodney to Okakiri Point Marine Reserve (547 ha) and Whanganui a hei Marine Reserve (840 ha), have experienced large increases in the numbers of previously targeted species (Willis 2000; Willis et al. 2000). Indeed, the edge effect on total number of targeted fish at Tuhua was relatively small—the maximum effect was only a 3% decline in 1996, and in only 50% of the cases was it significant. Rather than reserve size being an issue, this small effect may indicate that fishing pressure is felt across the entire reserve.

6.3 COMPLIANCE

The above discussion brings us to one remaining explanation that we should consider: that fishing pressure continues within the NT zone. If this is so, the lack of compliance with the regulations of the NT zone translates into ongoing pressure on the targeted reef fish of the entire reserve. Our theory is not unfounded, but is presently unquantified. During our own surveys we observed recreational boats fishing within the boundaries of the NT zone (KY, pers. obs.) leading us to consider whether the NT zone only provides partial protection for the targeted species living there. Very little recovery of targeted reef fish will take place if, like elsewhere, only partial protection is implemented (see Denny et al. 2003; Denny & Babcock 2004).

7. Summary and recommendations

Our results at Tuhua Marine Reserve suggest that, while protection may have enabled a higher relative abundance of targeted reef fish species to exist in the fully NT zone than in the partially protected RF zone, other factors must explain the general lack of population growth in either management zone.

The sampling design used until 2002 did not allow for robust conclusions, so was changed in 2004. Further monitoring using the new survey design will now measure true estimates of the variation in the differences between the two zones from year to year. We can then confirm the 2004 and 2005 results and show consistent recovery of targeted reef fish, if the survey designs (up to now) were limiting our ability to measure change. In addition, we also know that observer bias had little influence on our results to date.

When we considered each habitat on its own, we found limited evidence for increased fish numbers in any of the zones. This result was exactly the opposite of what was expected. The reserve has had protected status for long enough, source populations were available, and fish could get to it; therefore, we should have seen increases in previously targeted reef fishes. However, populations of targeted fish living here appeared to experience fishing pressure across the entire no-take zone compared to smaller reserves where, despite large edge effects, numbers of targeted fish increased. We suggest that fishing inside the reserve, in addition to fishing at the reserve boundaries, may be affecting those targeted fish species supposed to be fully protected within the core of the NT zone.

From our observations we recommend:

- Future monitoring follows the random sampling design started in 2004 and used again in 2005.
- Compliance with the regulations of the reserve is enforced. This will show whether fishing in the NT zone was the factor limiting recovery of targeted reef fish populations there.

Our study highlights the value of designing a marine reserve monitoring program at a suitable scale, with clearly defined space- and time-bound management and monitoring goals at the outset. Predictions at the correct spatial scale over a realistic timeframe can assess the original objectives set for a reserve.

8. Acknowledgements

We thank the Bay of Plenty Polytechnic for support in the development and implementation of the monitoring program since the establishment of the reserve. Rika Milne and Daniel Sharp assisted with the training of students and the co-ordination of divers and implementation of the monitoring programme in the reserve. Our thanks to all those students who eagerly took part, sometimes under trying conditions. We thank Dr Brian Coffey, Dr Russell Cole

(NIWA), and Dr Jake Overton. Russell undertook all statistical analysis for variance component modelling, and interpretation of results. Jake provided the revised random sampling design for 2004 and 2005, field assistance, and ongoing valuable ecological advice regarding the field set up and interpretation of results. Clinton Duffy (Marine Conservation Unit, DOC) gave constructive and helpful comments which greatly improved and aided the development of this manuscript. We are indebted to the Tuhua Island Trust Board for their continued support of this project since the establishment of the reserve. Finally, our grateful thanks to Ian Rogerson (conservation volunteer), who contributed endless hours organising the dataset for analysis. The study was funded through the Science Advice Fund, and DOC Science Investigation no. 3539.

9. 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.

Babcock, R.C.; Kelly, S.; Shears, N.T.; Walker, J.W.; Willis, T.J. 1999: Changes in community structure in temperate marine reserves. *Marine Ecology Progress Series 1989*: 125–134.

Belyea, L.R.; Lancaster, J. 1999: Assembly rules within a contingent ecology. *Oikos 86*: 402–416.

Bentley, N.; Davies, C.R.; McNeill, S.E.; Davies, N.M. 2004a: A framework for evaluating spatial closures as a fisheries management tool. *New Zealand Fisheries Assessment Report 2004/25.* 25 p.

Bentley, N.; Davies, N.M.; McNeill, S.E. 2004b: A spatially explicit model of the snapper (*Pagrus auratus*) fishery in SNA1. *New Zealand Fisheries Assessment Report 2004/26.* 64 p.

Caughley, G. 1977: Analysis of vertebrate populations. Wiley, London.

Cole, R. 1994: Abundance, size structure, and diver-oriented behaviour of three large benthic carnivorous fishes in a marine reserve in northeastern New Zealand. *Biological Conservation 70*: 93–99.

Cole, R. 2003a: How long should marine reserves be monitored for and why? *DOC Science Internal Series 130*. Department of Conservation, Wellington, New Zealand.

Cole, R. 2003b: What are the ecological impacts of marine reserves in New Zealand? *NIWA Client Report NEL2003-010* prepared for the Department of Conservation, New Zealand.

Crossland, J. 1976: Snapper tagging in North eastern NZ, 1974. Analysis of methods, return rates and movements. *New Zealand Journal of Marine & Freshwater Research 10*: 675–686.

Denny, C.M.; Babcock, R.C. 2004: Do partial marine reserves protect reef fish assemblages? *Biological Conservation 116*: 119–129.

Denny, C.M.; Willis, T.J.; Babcock, R.C. 2003: Effects of Poor Knights Islands Marine Reserve on demersal fish populations. *DOC Science Internal Series 142*. Department of Conservation, Wellington, New Zealand.

Freeman, D.J., 2005: Reef fish monitoring—Te Tapuwae o Rongokako Marine Reserve. Unpublished report held by East Coast/Hawke's Bay Conservancy, Department of Conservation, Gisborne New Zealand.

Freeman, D.J.; Duffy, C.A.J. 2003: Te Angiangi Marine Reserve. Reef fish monitoring 1995–2003. *East Coast/Hawke's Bay Conservancy Technical Support Series 14*. East Coast/Hawke's Bay Conservancy, Department of Conservation, Gisborne, New Zealand.

Halpern, B.S.; Gaines, S.D.; Warner, R.D. 2004: Confounding effects of the export of production and the displacement of fishing effort from marine reserves. *Ecological Applications 14(4)*: 1248–1256.

Hurst, R.J.; Bagley, N.W.; Anderson, O.F.; Francis, M.P.; Griggs, L.H.; Clark, M.R.; Paul, L.J.; Taylor, P.R. 2000: Atlas of juvenile and adult fish and squid distributions from bottom and midwater trawls and tuna longlines in New Zealand waters. *NIWA Technical Report 84*. 162 p.

Jones, A.J.; Garrick, A.S. 1991: Tuhua (Mayor Island) marine habitats. A preliminary intertidal and subtidal survey. *Bay of Plenty Conservancy Technical Report series 4*. Bay of Plenty Conservancy, Department of Conservation, Rotorua, New Zealand.

Lockwood, J.L.; Pimm, S.L. 1999: When does restoration succeed? Pp. 363–392 in Weiher, E.; Keddy, P. (Eds): Ecological assembly rules: perspectives, advances, retreats. Cambridge University Press, Cambridge, UK.

McCook, L.J. 1994: Understanding ecological community succession: causal models and theories, a review. *Vegetation 110*: 115–147.

McCormick, M.I.; Choat, J.H. 1987: Estimating total abundance of a large temperate-reef fish using visual strip-transects. *Marine Biology 96*: 469–478.

McCrone, A. 2001: National overview of biological monitoring in Marine Protected Areas. Report for the Northern Regional Office, Department of Conservation, Hamilton, New Zealand.

Parsons, D.; Egli, D. 2005: Fish movement in a temperate marine reserve: new insights through application of acoustic tracking. *Marine Technology Society Journal 39*: 15–22.

Polunin, N.V.C.; Roberts, C.M. 1993: Greater biomass and value of target coral-reef fishes in two small Caribbean marine reserves. *Marine Ecology Progress Series 100*: 167–176.

Rees, M.; Condit, R.; Crawley, M.; Pacala, S.; Tilman, D. 2001: Long-term studies of vegetation dynamics. *Science 293*: 650–655.

Russ, G.R.; Alcala, A.C. 1996: Marine reserves: rates and patterns of recovery and decline of large predatory fish. *Ecological Applications 6*: 947–961.

Shears, N.T.; Babcock, R.C. 2002: Marine reserves demonstrate top-down control of community structure on temperate reefs. *Oecologia 132*: 131–142.

Stanton, B.R.; Sutton, P.J.H.; Chiswell, S.M. 1997: The East Auckland Current, 1994–95. *New Zealand Journal of Marine & Freshwater Research 31*: 537–549.

Sokal, R.R.; Rohlf, F.J. 1995: Biometry. The principles and practice of statistics in biological research. 3rd ed. W.H. Freeman, New York.

Taylor, N; Buckenham, B. 2003: Social impacts of marine reserves in New Zealand. *Science for Conservation 217*. Department of Conservation, Wellington, New Zealand.

Walsh, C.; Middleton, C.; Davies, N. 2004: Length and age composition of commercial snapper landings in SNA 1 and SNA 8, 2002/03. *New Zealand Fisheries Assessment Report 2004/18*. March 2004.

Willis, T.J. 2000: Te Whanganui-a-Hei marine reserve fish monitoring program. Unpublished contract report, Northern Regional Office, Department of Conservation, June 2000. Investigation NRO/02/04.

Willis, T.J.; Babcock, R.C.; Anderson, M.J. 2003: Cape Rodney to Okakari Point Marine Reserve fish monitoring 2000–2002. Final report. Prepared for Northern Regional Office, Department of Conservation, by Auckland Uniservices Limited, University of Auckland, New Zealand.

Willis, T.J.; Millar, R.B.; Babcock, R.C. 2000: Detection of spatial variability in relative density of fishes: comparison of visual census, angling, and baited underwater video. *Marine Ecology Progress Series 198*: 249–260.

Willis, T.J.; Parsons, D.R.; Babcock, R.C. 2001: Evidence for long term site fidelity of snapper (*Pagrus auratus*) within a marine reserve. *Marine and Freshwater Research 35*: 581–590.