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Visual census methods underestimate density and diversity of cryptic reef fishes

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The diversity and density of small, benthic reef fishes were estimated using visual census and enclosed rotenone stations. Visual census underestimated the number of species present and the density of common species by up to 91%.

Key words: sample bias; New Zealand; reef fishes; rotenone; underwater visual census.

Variants of the underwater visual census (UVC) technique first used by Brock (1954) have formed the basis of most studies of reef fish ecology. The non-destructive nature of UVC makes it appealing to workers conducting repeated observations. For study of large reef fishes, the biases associated with UVC have been well documented, whether resulting from variability in fishes (Jennings & Polunin, 1995; Kulbicki, 1998; Willis *et al.*, 2000) or observer behaviour (Thresher & Gunn, 1986; Lincoln Smith, 1988; Sale, 1997). However, assemblages of small, cryptic fishes that are strongly associated with the benthos have been either largely ignored, or sampled using UVC with little consideration of methodological bias (Ackerman & Bellwood, 2000).

As part of a larger research programme, the aim of the present study was to accurately estimate density and assemblage structure of cryptic fishes on subtidal reefs in north-eastern New Zealand. To determine whether UVC would be appropriate for such a sampling programme, UVC density estimates were compared with quantitative rotenone samples taken from the exact same area of reef.

Paired sampling of cryptic fishes was done between 15 November 1999 and 10 February 2000 (austral summer) in and adjacent to the Cape Rodney-Okakari Point Marine Reserve in northern New Zealand (36°17′S; 174°48′E). Each sample consisted of a 3×3 m plot, which was censused visually by a diver swimming 0·5 m above the substratum (so as not to disturb the fish prior to rotenone sampling) and counting fish in 3×1 m transects. The same plot was then enclosed by a 1·0 mm mesh, 3×3 m square cage and sampled using the piscicide rotenone. The cage was composed of a 1 m high wall section, which was weighted at its base with galvanized chain (so it could be moulded to the substratum), and a square roof section. To set the cage up, a 15 kg weight was carefully placed first to define each of the corners of the plot, and two corners of the wall clipped to two adjacent weights. The free corners of the net were then lifted off the bottom by two divers and moved into position. This procedure enabled the walls to be set in place with minimum disturbance to the plot. The roof section was then attached by means of continuous velcro strips. Finally, small floats were attached to the four corners to prevent the net from sagging. Rotenone (200 g of 7% rotenone powder mixed to a paste with sea water) was introduced to the cage either via small gaps at the base (which occurred at high rugosity sites) or through the velcro connection between roof and walls, which was then immediately resealed.

Divers continuously patrolled the circumference up to 2 m from the enclosure for 60 min after the rotenone was released to prevent large fish predators [mostly *Parapercis*

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TABLE I. Number of individuals of each species detected in 9 m^2 plots (n=26) using underwater visual census and quantitative rotenone collections

Species	Family	Total UVC count	Total rotenone collection
Ruanoho whero	Tripterygiidae	26	292
Forsterygion varium	Tripterygiidae	131	236
Forsterygion lapillum	Tripterygiidae	23	90
Dellichthys morelandi	Gobiesocidae		47
Notoclinops segmentatus	Tripterygiidae		22
Gastrocyathus gracilis	Gobiesocidae		21
Pseudophycis breviuscula	Moridae		19
Acanthoclinus marilynae	Plesiopidae		14
Optivus elongatus	Trachichthyidae		13
Trachelochismus melobesia	Gobiesocidae		12
Notoclinus compressus	Tripterygiidae		9
Acanthoclinus rua	Plesiopidae		8
Brosmodorsalis persicinus	Bythitidae		8
Notolabrus celidotus	Labridae	5	8
Scorpaena papillosus	Scorpaenidae		7
Dermatopsis macrodon	Bythitidae		6
Parika scaber	Monacanthidae		5
Haplocylix littoreus	Gobiesocidae		4
Conger wilsoni	Congridae		3
Ruanoho decemdigitatus	Tripterygiidae	1	3
Bidenichthys beeblebroxi	Bythitidae		2
Conger verreauxi	Congridae		2
Cryptichthys jojettae	Tripterygiidae		2
Lotella rhacinus	Moridae		2
Parablennius laticlavius	Blenniidae	5	2
Cristiceps aurantiacus	Clinidae		1
Forsterygion malcolmi	Tripterygiidae		1
Gobiopsis atrata	Gobiidae		1
Hippocampus abdominalis	Syngnathidae		1
Odax pullus	Odacidae		1
Stigmatopora nigra	Syngnathidae		1
Tewara cranwellae	Creediidae		1
Trachelochismus pinnulatus	Gobiesocidae		1
Total		191	845

colias (Bloch & Schneider), *Pagrus auratus* (Bloch & Schneider), *Notolabrus elidotus* (Bloch & Schneider) and *Notolabrus fucicola* (Richardson)] from accessing gaps at the base, and to capture any fish escaping from the enclosure. One diver then entered the net to complete the collection. The floor of the plot was intensively searched, with all interstices examined so as to ensure a complete census.

A total of 26 plots were sampled within three habitat types (*Ecklonia radiata* forest, *Carpophyllum maschalocarpum* stands, and urchin-grazed ' barrens '), which yielded 845 fishes (33 species) from rotenone samples, and 191 fishes (six species) from UVC counts (Table I). There was no significant correlation between the two methods in the number of species detected from each plot (r^2=0·014, P>0·1; Fig. 1). Only one species, the crested blenny *Parablennius laticlavius* (Griffin), was detected more often by UVC than rotenone (Table I). The three most common species [*Ruanoho whero* Hardy, *Forsterygion varium* (Bloch & Schneider) and *Forsterygion lapillum* Hardy] constituted 94% and 69% of UVC and rotenone counts, respectively. The density of all three of these species was underestimated by UVC (Fig. 2). Only 9% of *R. whero* and 25% of *F. lapillum* were detected using UVC. Over 55% of *F. varium* were seen in UVC counts, which agrees with previous characterization of this species as one of the least cryptic in its behaviour (Syms, 1995).

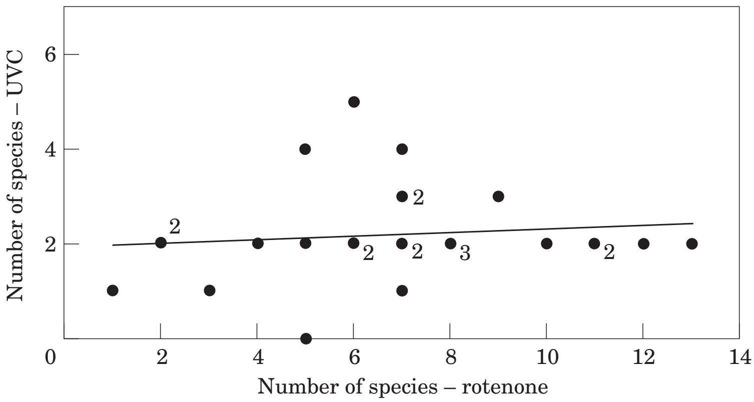

FIG. 1. Relationship between the number of species detected by underwater visual census (UVC) and quantitative rotenone collections. Numbers on the plot indicate a number of superimposed observation points.

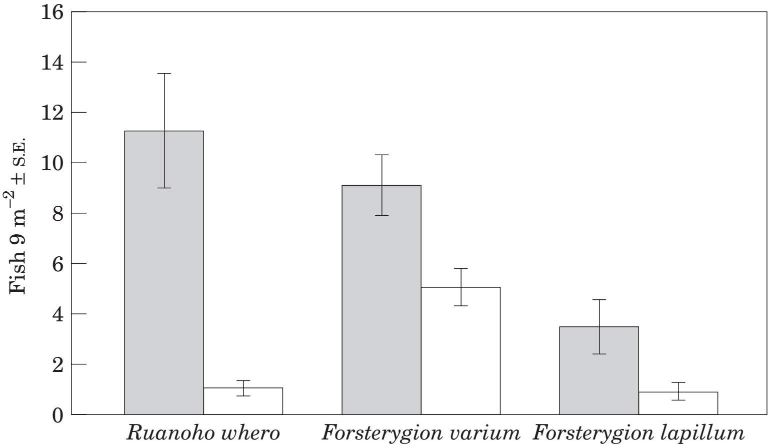

FIG. 2. Overall mean density (± S.E.) of the three most common species as estimated by underwater visual census (UVC, □) and quantitative rotenone collections (▩).

This study supports the conclusions of earlier studies that found UVC to significantly underestimate cryptic fish density (Christensen & Winterbottom, 1981; Brock, 1982; Kulbicki, 1990; Ackerman & Bellwood, 2000). The present UVC density estimates might have been biased slightly downward by the need to remain above the substratum (to avoid scaring fish from the plot) while conducting counts. However, even species such as *F. varium*, thought to be amenable to visual census (Connell & Jones, 1991), were underestimated by 45%. The use of toxicants or anaesthetics enables detection of species that inhabit reef interstices or burrows and therefore are not usually seen (Kulbicki, 1990; Sayer *et al.*, 1994; Ackerman & Bellwood, 2000). Although rotenone is destructive, several studies (Willis & Roberts, 1996; Polivka & Chotkowski, 1998) have indicated that the effects are generally short-lived, as small reef fishes with high turnover rates recolonize defaunated areas quickly. Accurate estimates of overall reef-fish diversity, abundance, biomass and productivity will require extractive sampling so that the cryptic fishes are not underestimated.

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