

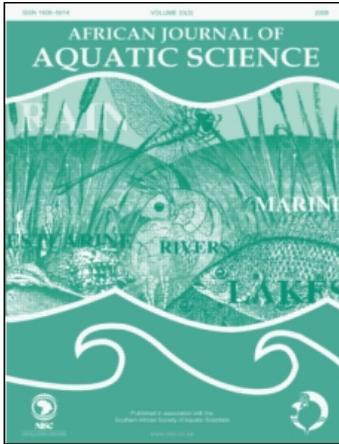
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African Journal of Aquatic Science

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t911320058>

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Online publication date: 07 January 2010

To cite this Article Shelton, JM , Day, JA and Griffiths, CL(2008) 'Influence of largemouth bass, *Micropterus salmoides*, on abundance and habitat selection of Cape galaxias, *Galaxias zebratus*, in a mountain stream in the Cape Floristic Region, South Africa', African Journal of Aquatic Science, 33: 3, 201 – 210

To link to this Article: DOI: 10.2989/AJAS.2008.33.3.2.614

URL: <http://dx.doi.org/10.2989/AJAS.2008.33.3.2.614>

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Influence of largemouth bass, *Micropterus salmoides*, on abundance and habitat selection of Cape galaxias, *Galaxias zebratus*, in a mountain stream in the Cape Floristic Region, South Africa

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Received 5 February 2008, accepted 21 August 2008

Predatory alien fishes have been widely introduced into streams in the Cape Floristic Region (CFR), South Africa, but little is known about their effect on native fishes. Results from this 2006 study suggest that the presence of alien predatory largemouth bass, *Micropterus salmoides*, may have influenced abundance and habitat selection of the native *Galaxias zebratus* at one location in a small CFR mountain stream. Numbers of adults, but not of juveniles, were significantly lower where *M. salmoides* was present, suggesting a size-specific influence on *G. zebratus* abundance. Because other studies have found the influence of a predator to be affected by prey size and the diel activity of predator and prey, we measured microhabitat use by adult and juvenile *G. zebratus* by day and by night. *Galaxias zebratus* selected deeper, faster-flowing microhabitats more strongly where *M. salmoides* was present than where it was absent. This suggests that *G. zebratus* adjusts its habitat use in the presence of *M. salmoides*, although differences in available habitat, or in interactions with other indigenous species, could be partly responsible for the observed differences. In-stream vegetation presence was strongly positively related to depth and strongly negatively related to velocity at positions where *G. zebratus* was observed, suggesting that the deeper, slower-flowing microhabitats occupied by *G. zebratus* were structurally more complex than the shallower, faster-flowing ones.

Keywords: alien species impacts, diel activity, microhabitats, native galaxiid fish, predatory alien fish

Introduction

Streams in the Cape Floristic Region (CFR) of South Africa were largely devoid of piscivorous fishes before alien species were introduced (Skelton 2001) to improve angling (de Moor and Bruton 1988, Skelton 2001). Largemouth bass, *Micropterus salmoides*, one of the most successful of the introduced game fishes (Skelton 1993), was introduced in 1930 from stock bred in the Netherlands (Harrison 1953) and is now widespread across the region, inhabiting the Olifants–Doring, Berg, Breede, Gouritz and Sundays river systems. It has been implicated in the reduction of native fish stocks in the CFR (de Moor and Bruton 1988, Skelton 1993, Woodford *et al.* 2005) and is considered a major threat to existing native fish populations in the region (Skelton 2001).

The native Cape galaxias, *Galaxias zebratus* Castelnau, 1861, is widespread in the CFR (Skelton 2001). The Galaxiidae comprise about 45 species (Skelton 2001) which occur in cool regions of the southern hemisphere (McDowall 2006). Galaxiid diversity is highest in Australia and New Zealand, where it is threatened by the impacts of predatory alien fish (McDowall 2006). A considerable body of scientific literature documents how salmonids, in particular, but also centrarchids (e.g. *Micropterus* spp.) and cichlids, have

adversely affected native galaxiid populations in these countries (see McDowall 2006 for review).

Information on the impact of exotic predators on Cape galaxias is comparatively scarce. Studies in two CFR mountain streams have found *G. zebratus* to be absent from sites invaded by rainbow trout *Oncorhynchus mykiss* (Woodford and Impson 2004) and smallmouth bass *M. dolomieu* (Woodford *et al.* 2005), but present at other locations. In a study on habitat availability and use by indigenous fish in the Olifants system, Gore *et al.* (1991) found sufficient available habitat for the indigenous species in the mainstem and attributed the lack of indigenous fish (including *G. zebratus*) there to the presence of *M. dolomieu*. Their study produced habitat suitability curves for adult and juvenile *G. zebratus*, and noted that the species was often found near in-stream vegetation. Knowledge of interactions between *Micropterus* spp. and native species such as *G. zebratus* is needed to develop strategies for conserving freshwater fish in the CFR (Cambray 2003), but such knowledge is limited (Impson *et al.* 2002).

In streams, predators can interact with their prey at different spatial scales (Magoulick 2004). They can reduce

prey density over the section of stream they inhabit, either through predation or competition (Mittelbach 1988), and can alter the distribution of prey in available habitats within a stream section (Van Snik Gray *et al.* 2005). Habitat selection by stream fishes has been conceptualised as a trade-off between net energy gain and risk, where energy gain is affected by food availability and swimming costs, and major risks include harsh environmental conditions, competition and predation (Hegennes 1996). The addition of a piscivorous predator, such as *M. salmoides*, into a stream environment that was previously devoid of predatory fish, can change the risk of predation (Werner *et al.* 1983) and degree of competition (Hegennes 1988) associated with different available habitats for indigenous fishes and, therefore, may cause them to alter their habitat use patterns (Schlosser 1988, Harvey 1991, Grossman *et al.* 1995). Furthermore, the effect of an introduced predator on other stream fish can be influenced by the size (Harvey 1991) and diel activity patterns (Schlosser 1988) of both the predator and the other stream fish.

Micropterus salmoides occurs in the upper Driehoeks River, a tributary of the Doring River, where it inhabits a section downstream of a sandbag weir which forms a barrier to their upstream dispersal. *Galaxias zebratus* occurs above the weir in an uninvaded stretch of river, and also in the stretch colonised by *M. salmoides* below it. In this study we investigated whether the presence of *M. salmoides* affects habitat selection and abundance of two size classes of *G. zebratus* by day and by night. To do this, we compared habitat selection by, and abundance of, *G. zebratus* between two sites, one in which *M. salmoides* was present, and one in which *M. salmoides* was absent.

Study sites

The Driehoeks River is situated in the Cedarberg Mountains, in the north-western corner of the CFR, South Africa. Its headwaters lie at an altitude of 1 300 m asl from where it flows in a south-easterly direction for 23 km before joining the Matjies and Groot rivers and entering the Doring River (Figure 1). The area experiences a Mediterranean climate with dry summers and wet winters (Cowling and Holmes 1992). The upper catchment is characterised by quartzitic sandstones of the Table Mountain series (Tankard *et al.* 1982) and near-pristine mountain *fynbos* (low-growing sclerophyllous scrub characteristic of the mountains of the CFR). The study area included a 3 km section of the upper Driehoeks River, situated at approximately 32°25'50" S, 19°10'32" E at an altitude of 900 m asl on Driehoek Farm. This site is characterised by shallow (<1.5 m) stretches that contain pool-riffle-run complexes, and stretches where the water was deep (>1.5 m) and slow-flowing. Riparian vegetation consisted mostly of shrubs, restioids and sedges, with clumps of palmiet, *Prionium serratum*, occasionally extending into the wetted channel. Two 50 m study sites were selected within the study area: one with no *M. salmoides* present, 1.5 km upstream of the weir (the 'bass-free site') and one with *M. salmoides* present, 1.5 km downstream of the weir (the 'bass-present site'). Since both sites consisted exclusively of shallow habitats and contained pools, riffles and runs, in this study, data were not collected from the deep, slow-flowing stretches. In addition to *G. zebratus* and

M. salmoides, two indigenous cyprinids — the fiery redbfin, *Pseudobarbus phlegethon*, and the Clanwilliam sawfin, *Barbus serra* — also occurred in the upper Driehoeks River. *Galaxias zebratus* is the only galaxiid currently recognised in South Africa, but genetic studies (Waters and Cambray 1997, Wishart *et al.* 2006) have shown high levels of divergence among its different populations. The morph present in the Driehoeks River is listed in the National Fish Collection of the South African Institute for Aquatic Biodiversity (SAIAB) under Catalogue Number 65430.

Materials and methods

Field procedures

The relative abundance of *G. zebratus* at the sites was measured by setting one D-ring fyke net (basal diameter 300 mm, D-ring diameter 600 mm, mesh size 2 mm) at random locations within each site on seven consecutive nights (from 10–16 December 2006). This technique was chosen because Hardie *et al.* (2006) — in a comparison of backpack electrofishing, snorkelling and fyke netting sampling techniques in a small, relatively shallow off-stream dam in Tasmania — found that fyke netting yielded the largest catches of golden galaxias, *G. auratus*, and that it sampled adults and juveniles of this species representatively. In the present study, nets were set at dusk and checked the following morning. All netted fish were identified to species, measured (total length, TL) and assigned to the size classes used by King and Tharme (1993).

Habitat use by *G. zebratus* and habitat availability were examined at the microhabitat level so that fine-scale changes in habitat selection could be detected within the sites. Habitat availability surveys were conducted over four days (6–9 December 2006) during summer base-flow conditions. On 7 December, each 50 m site was sampled during the day and then at night to examine diel differences in habitat use.

Habitat availability was quantified using a modified version of the transect method (Todd and Rabeni 1989). At both sites, transects were positioned across the river at 1 m intervals, perpendicular to the direction of flow, and habitat data were collected at four evenly-spaced points in the wetted river channel along each transect. At each point, depth and velocity were measured and substrate type recorded. Total depth was measured with a calibrated rod and velocity (at 0.6 of total depth) with a Price AA Current Meter (Scientific Instruments, Inc.). Substrate characterisation was based on the method of Polacek and James (2003). The dominant particle size in a 0.40 m² area (demarcated by a metal quadrat, the centre of which coincided with each point along the transect) was determined visually and used to classify the substrate at that point according to the following modified Wentworth grade limits: 1 = <1 mm (silt), 2 = 1–2 mm (sand), 3 = 3–50 mm (gravel), 4 = 51–250 mm (cobble) and 5 = >250 mm (boulder and bedrock).

Snorkelling was used to observe microhabitat use. A single diver entered the river 5 m below the downstream boundary of a site, creating as little disturbance as possible, because snorkelling-related disturbance can alter fish

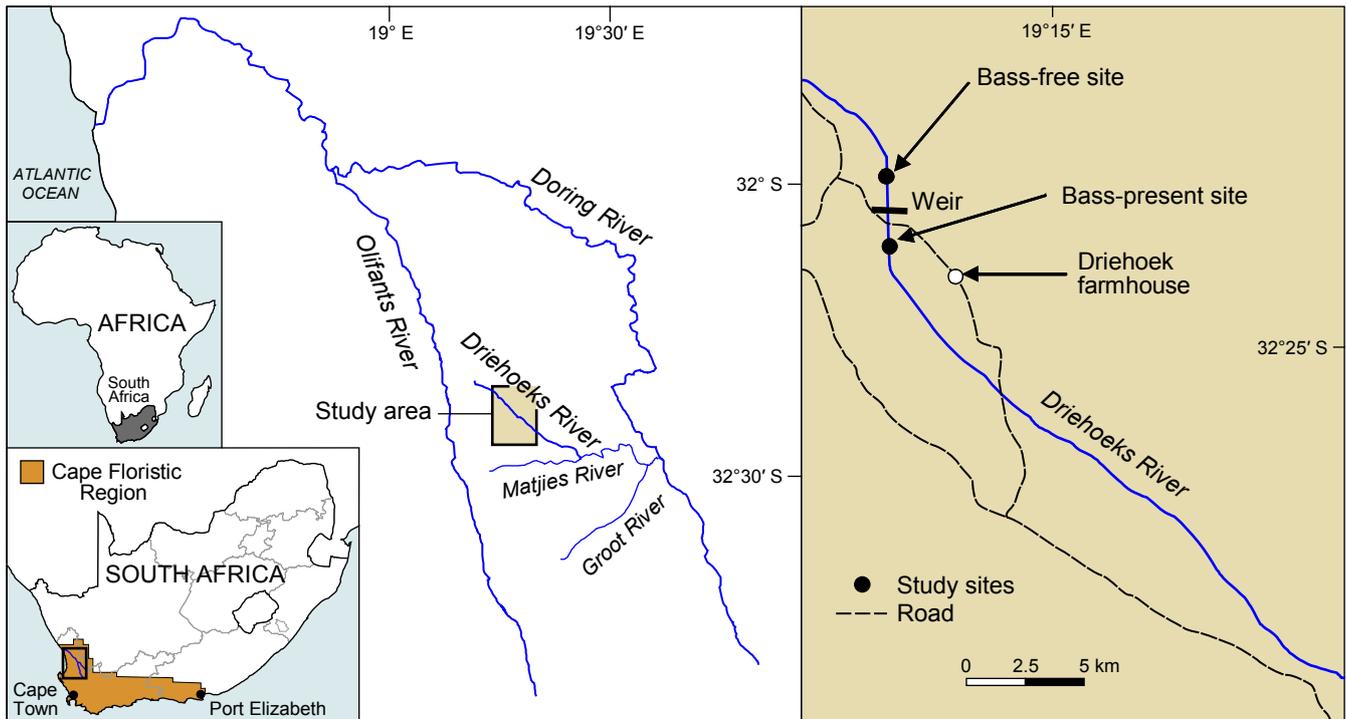


Figure 1: Location of study sites on the Driehoeks River in the Olifants–Doring river system within the Cape Floristic Region, South Africa (roads are indicated by dashed lines)

distribution patterns in streams (Petty and Grossman 2000). The diver then zig-zagged slowly upstream (after Mullner *et al.* 1998) and deployed a numbered, weighted buoy where each undisturbed individual fish or shoal of fish was observed. After each observation, species, length and number (for shoals) were recorded by an assistant on the river bank. Fish length was estimated by approaching a fish, aligning its snout and tail with a ruler and measuring distance from tail to snout (Thurow and Schill 1996). Length estimates for *G. zebratus* were assigned to the two size classes used by King and Tharme (1993): juveniles (20–40 mm TL) and adults (>40 mm TL). For shoaling fish the number of fish, as well as the proportion of adults to juveniles, were estimated. This procedure was followed until the upstream boundary of the site was reached. The diver and the assistant then re-visited each buoy and measured the depth, average velocity and dominant substrate there, following the measurement procedures used for the habitat availability surveys. The presence of in-stream vegetation at each buoy was also assessed by placing the depth rod vertically on the stream bed and noting whether or not it came into contact with any vegetation. Both aquatic plants and submerged terrestrial plants were included in the category 'in-stream vegetation', since both could provide refuge for *G. zebratus*. Snorkelling at night was performed with the aid of an underwater hand-held white light. Snorkelling and buoy deployment were performed between 10:00 and 14:00 during the day, and between 22:00 and 03:00 at night. For night-time observations, habitat measurements were undertaken on 8 December.

No rain fell during the study period, so it was assumed that baseflows remained relatively constant during the study.

Data analyses

Habitat selection, in terms of depth, velocity and substrate, by day and by night, was calculated for each site and size class using Jacobs' (1974) electivity index: $D = (r - p) / (r + p - 2p)$, where r is the proportion of resource used and p is the proportion of resource available. This equation quantifies habitat use in relation to habitat availability. D -values can fall between +1 and -1, with positive values indicating preference and negative values avoidance. Because a large number of individual fish at a particular position indicates selection of the microhabitat at that location, the observation frequency data were multiplied by the following semi-quantitative weighting factors: one individual = 1, 2–10 individuals = 2, and >10 individuals = 3 (King and Tharme 1993).

Chi-square goodness-of-fit analyses were used to test for differences in available depths, velocities and substrates between sites and to test whether the distribution of fish over available habitat differed between sites. Because habitat availability is likely to differ between sites, for each habitat variable we calculated the number of fish that would be expected in each category at the bass-present site, based on the distribution of fish at the bass-free site. This distribution was then compared to the observed distribution at the bass-present site. Where necessary, categories at the tails of the distributions were combined to ensure that there were at least five observations in all classes (Zar 1999).

Table 1: Total numbers of fish caught in fyke nets at two sites in the Driehoeks River

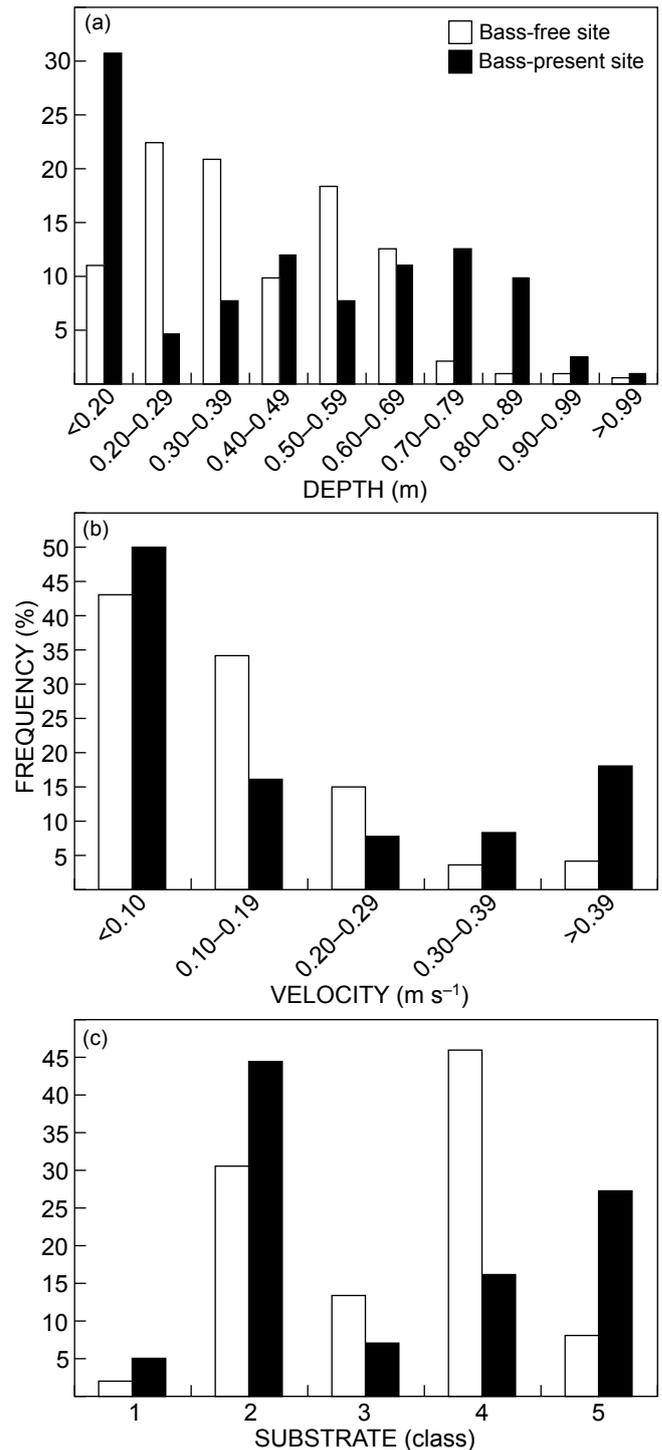
Species	Bass-free site		Bass-present site	
	Juveniles	Adults	Juveniles	Adults
<i>Micropterus salmoides</i>	–	–	–	–
<i>Galaxias zebratus</i>	39	128	50	56
<i>Barbus serra</i>	–	–	17	7
<i>Pseudobarbus phlegethon</i>	–	2	–	2

Results

Galaxias zebratus was by far the most abundant species caught in the fyke nets (Table 1). Adult catch per night was significantly higher at the bass-free site (mean = 18, SE = 4) than at the bass-present site (mean = 9, SE = 2) (t -test: $t = 2.21$, $df = 12$, $p < 0.05$). Juvenile catch at the bass-free site (mean = 6, SE = 1) did not differ significantly from that at the bass-present site (mean = 7, SE = 2) ($t = -0.75$, $df = 12$, $p > 0.05$). Adult *P. phlegethon* were caught infrequently at both sites, and juvenile and adult *B. serra* were caught only at the bass-present site. *Micropterus salmoides* was not caught in the fyke nets, but two adults were observed while snorkelling in the bass-present site.

In total, habitat availability data were collected at 198 and 200 points at the bass-free and bass-present sites, respectively. The range of depths, velocities and substrates available at the two sites was similar, but the distributions of available depths ($p < 0.001$, $\chi^2 = 89.6$, $df = 7$), velocities ($p < 0.001$, $\chi^2 = 38.6$, $df = 4$) and substrates ($p < 0.001$, $\chi^2 = 61.3$, $df = 4$) differed significantly between them (Figure 2). The bass-present site had a higher proportion of depths >0.70 m, whilst the proportion of depths of between 0.20 m and 0.60 m was greater at the bass-free site. Depths <0.20 m were more than twice as common at the bass-present site. The sites had similar proportions of velocities <0.10 m s^{-1} ; however, velocities of between 0.10 and 0.30 m s^{-1} were more common at the bass-free site, whilst velocities >0.30 m s^{-1} were more common at the bass-present site. The proportions of class 3 and 4 substrates (gravel and cobble respectively) were greater at the bass-free site, whilst class 1, 2 and 5 substrates (silt, sand and boulder/bedrock, respectively) were more common at the bass-present site.

In all, 359 observations of *G. zebratus* microhabitat use were made (Table 2), of which 208 and 151 were taken at the bass-free and bass-present sites, respectively. Between 19 and 61 observations were made for each permutation of day/night and size class. The distribution of adult *G. zebratus* over available depths differed significantly between sites by day ($p < 0.001$, $\chi^2 = 91.35$, $df = 6$) and by night ($p < 0.05$, $\chi^2 = 16.31$, $df = 7$). By day, adults preferred depths of 0.70–0.99 m most strongly at the bass-free site, and depths >0.80 m most strongly at the bass-present site (Figure 3). Avoidance of intermediate depths was stronger at the bass-present site, and depths <0.30 m were strongly avoided at both sites. The pattern of depth selection by adults at night was similar to that during the day at both sites. The distribution of adult *G. zebratus* over

**Figure 2:** Frequency histograms of available depths (a), velocities (b) and substrates (c) in the bass-free (white bars) and bass-present (black bars) sites in the Driehoeks River (substrate classes: 1 = silt, 2 = sand, 3 = gravel, 4 = cobble and 5 = boulder and bedrock)

available velocities differed significantly between sites by day ($p < 0.005$, $\chi^2 = 13.31$, $df = 3$) and by night ($p < 0.001$, $\chi^2 = 38.89$, $df = 3$). At the bass-free site, adults avoided velocities >0.30 m s^{-1} during the day, and displayed strong

Table 2: Number of observations of microhabitat use by adult and juvenile *Galaxias zebratus* by day and night at two sites in the Driehoeks River

	Bass-free site		Bass-present site		Total
	Juveniles	Adults	Juveniles	Adults	
Day	61	44	59	31	195
Night	47	56	19	42	164
Total	108	100	78	73	359

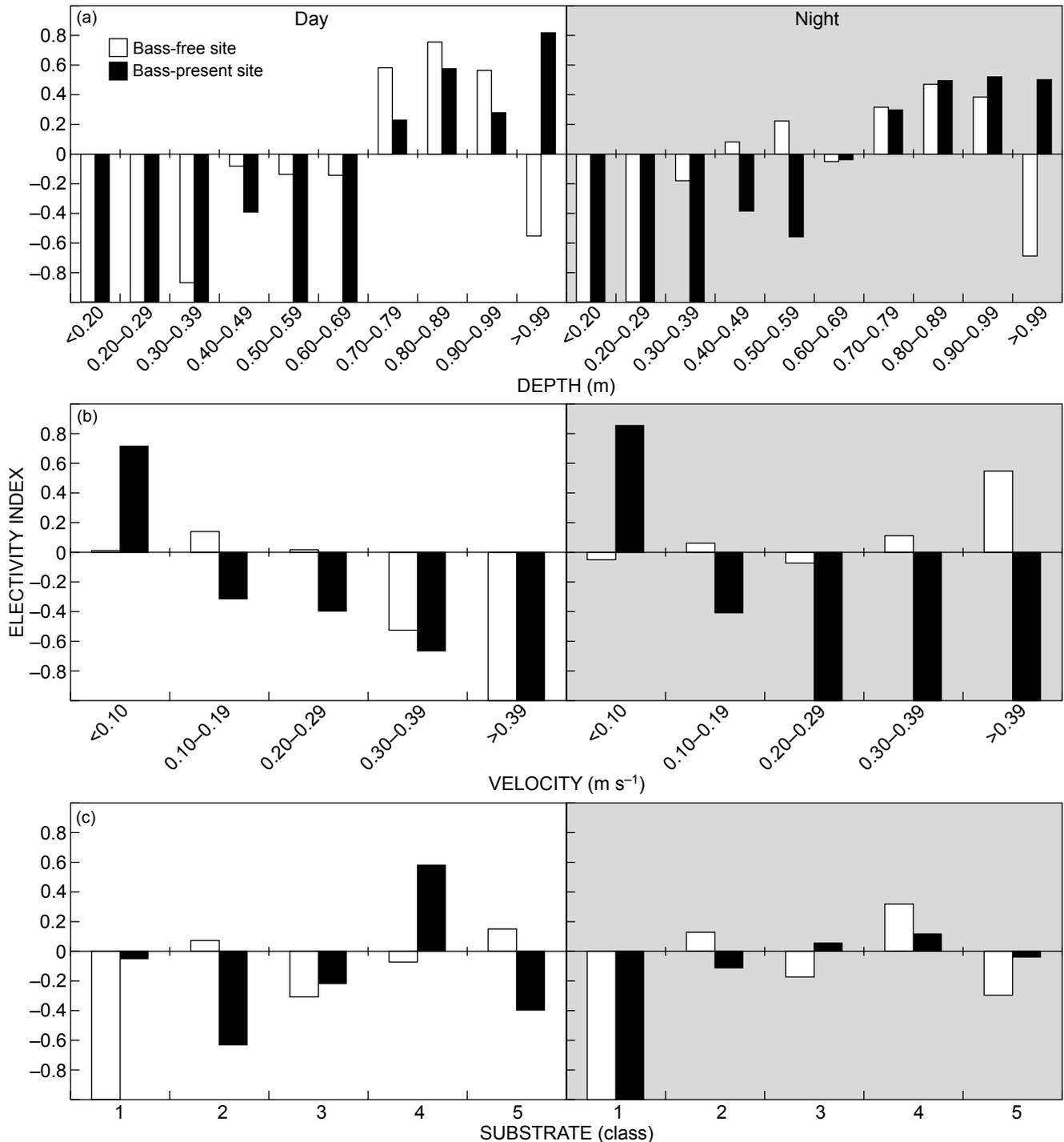


Figure 3: Selection of depth (a), velocity (b) and substrate (c) by adult *Galaxias zebratus* at the bass-free (white bars) and bass-present (black bars) sites by day and night using Jacobs' (1974) electivity index (substrate classes: 1 = silt, 2 = sand, 3 = gravel, 4 = cobble and 5 = boulder and bedrock)

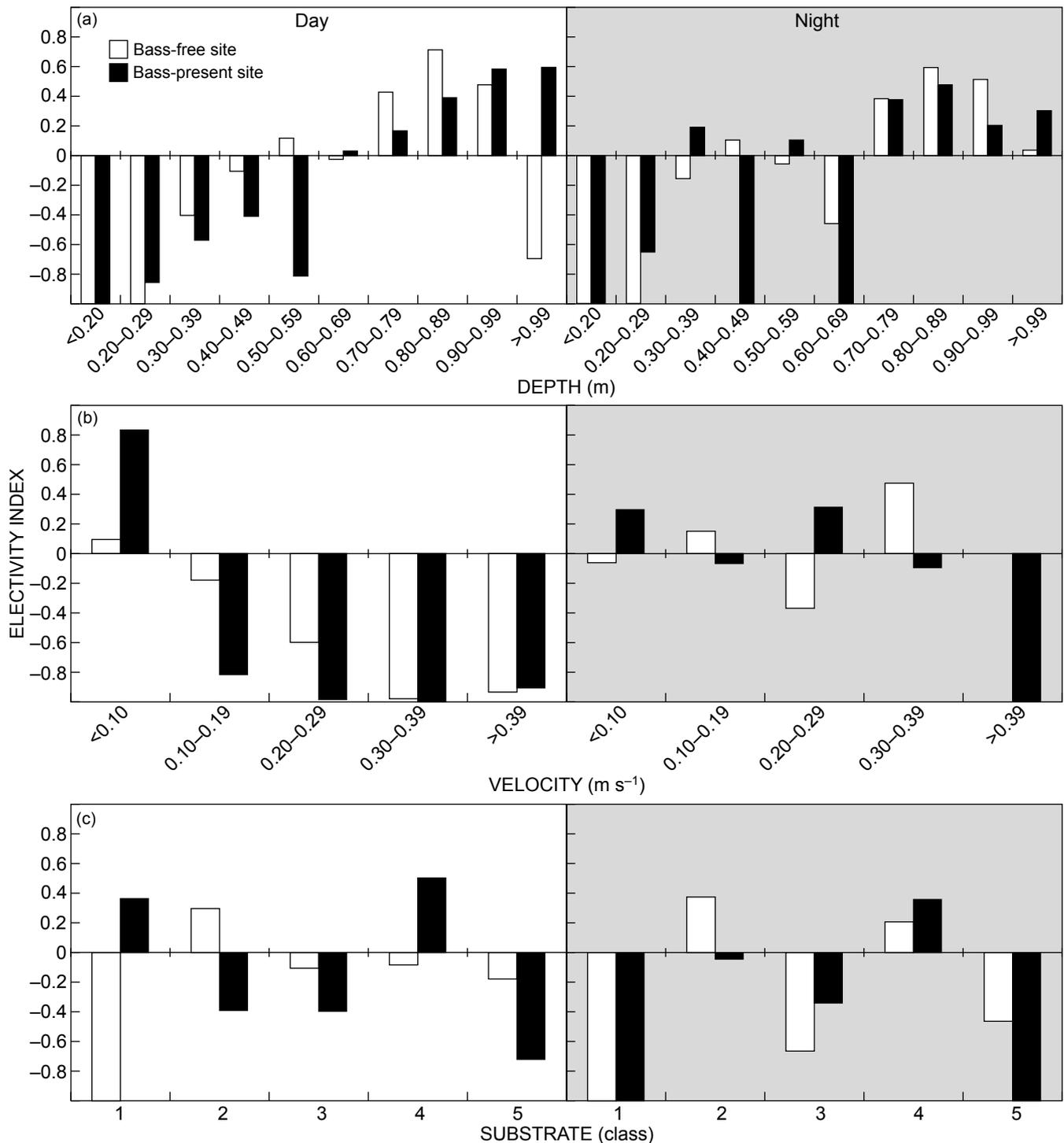


Figure 4: Selection of depth (a), velocity (b) and substrate (c) by juvenile *Galaxias zebratus* at the bass-free (white bars) and bass-present (black bars) sites by day and night using Jacobs' (1974) electivity index (substrate classes: 1 = silt, 2 = sand, 3 = gravel, 4 = cobble and 5 = boulder and bedrock)

selection for velocities >0.40 m s⁻¹ at night (Figure 3). At the bass-present site, adults displayed strong selection for velocities <0.10 m s⁻¹ and avoided all faster-flowing water by day and by night. The distribution of adult *G. zebratus* over available substrates differed significantly between

sites by day ($p < 0.05$, $\chi^2 = 11.25$, $df = 3$), but not by night ($p > 0.05$, $\chi^2 = 1.97$, $df = 4$). At the bass-free site, class 1 substrates (silt) were strongly avoided by both day and night (Figure 3). Substrate selection by adults was similar at the two sites at night. During the day, *G. zebratus* displayed

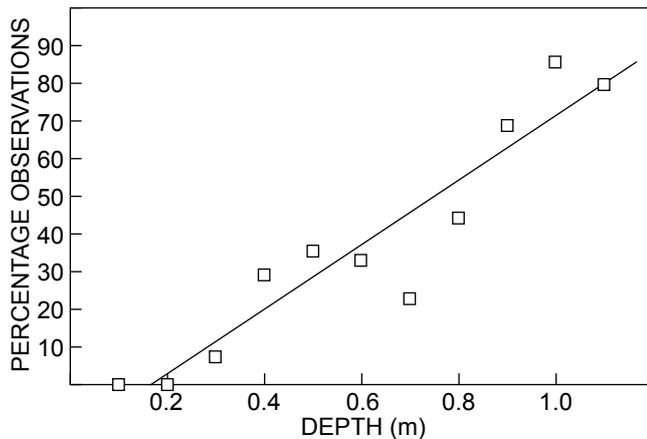


Figure 5: Linear relationship between the percentage of observations (with in-stream vegetation present) and depth at points where *Galaxias zebratus* were found (combined data from two sites and day and night observations)

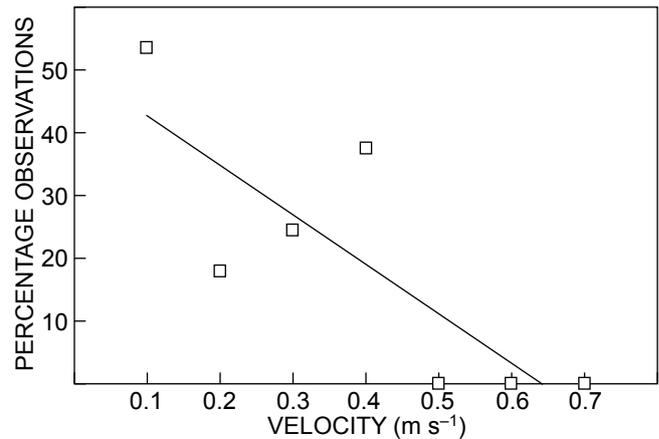


Figure 6: Linear relationship between the percentage of observations (with in-stream vegetation present) and velocity at points where *Galaxias zebratus* were found (combined data from two sites and day and night observations)

strong avoidance of class 2 (sand) and strong selection for class 4 (cobble) substrates at the bass-present site.

During the day, the pattern of microhabitat selection displayed by juveniles (Figure 4) was similar to that displayed by adults at both sites. The distribution of juvenile *G. zebratus* over available depths ($p < 0.001$, $\chi^2 = 74.51$, $df = 8$), velocities ($p < 0.001$, $\chi^2 = 46.13$, $df = 4$) and substrates ($p < 0.001$, $\chi^2 = 42.45$, $df = 4$) differed significantly between sites by day. At night, the distribution of juveniles over available velocities ($p > 0.01$, $\chi^2 = 11.99$, $df = 3$) differed between the two sites, but inter-site differences in the depth ($p > 0.05$, $\chi^2 = 2.99$, $df = 3$) and substrate ($p > 0.05$, $\chi^2 = 3.17$, $df = 2$) distributions were not significant.

There was a strong, positive linear relationship between the percentage of observations with in-stream vegetation and depth ($y = 0.86x - 14.08$, $r^2 = 0.88$) (Figure 5), and a strong negative linear relationship between the percentage of observations with in-stream vegetation and velocity ($y = -0.79x + 50.61$, $r^2 = 0.66$) (Figure 6), showing that in-stream vegetation was more common in deep, slow-flowing water than in shallow, fast-flowing water. The linear relationship between percentage of observations with in-stream vegetation and substrate particle size was weakly negative ($y = -0.05x + 0.53$, $r^2 = 0.23$).

Discussion

The fyke net data (Table 1) suggest that the presence of *M. salmoides* negatively influences the abundance of adult *G. zebratus* at the study sites. Studies in streams in Victoria, Australia (Fletcher 1979) and Tasmania (Ault and White 1994) indicated that the presence of introduced brown trout, *S. trutta*, caused declines in the abundance of mountain galaxias, *G. olidus* (Günther), and spotted galaxias, *G. truttaceus* (Valenciennes), respectively. The significantly lower relative abundance of adult *G. zebratus* at the bass-present site suggests that *M. salmoides* either preys on, or competes with, this species for food or

space. We did not investigate the mechanisms of interaction between *M. salmoides* and *G. zebratus* and information on interactions between *Micropterus* spp. and *Galaxias* spp. is scarce. There is a record of *M. salmoides* preying on *Nesogalaxias neocaledonicus* (Weber and de Beaufort) in a small lake in New Caledonia (Keith 2002) that provides some support for the notion that *M. salmoides* reduces adult *G. zebratus* abundance through predation. *Galaxias zebratus* and juvenile *M. salmoides* may also compete for food, since both feed on aquatic invertebrates (Olson 1996, Skelton 2001). However, we consider this an unlikely cause of the observed differences in abundance, since no juvenile *M. salmoides* were observed in the study area. The diets of *G. zebratus* and *M. salmoides* should be studied in order to improve our understanding of these interactions.

In contrast to the adults, the relative abundance of juveniles did not differ significantly between the sites (Table 1). This suggests that the presence of *M. salmoides* did not influence the abundance of juvenile *G. zebratus* and that their influence may vary with *G. zebratus* size. This is supported by evidence from Fletcher (1979), suggesting that predation by introduced *S. trutta* on *G. olidus* was size-specific.

Based on measurements taken in two tributaries of the Olifants River in the CFR, Gore *et al.* (1991) found that adult and juvenile *G. zebratus* were commonest in habitats characterised by low current velocities ($<0.10 \text{ m s}^{-1}$), shallow depths (0.20–0.40 m) and intermediate substrate particle sizes (150–600 mm), but they did not specify whether or not alien fish were present in their study sites. In our study, we found a similar pattern of velocity- and substrate-selection (Figures 3 and 4), but *G. zebratus* was observed to select notably deeper habitats ($>0.70 \text{ m}$). One reason for this difference in depth selection could be the scarcity of habitat at depths greater than 0.60 m in the streams studied by Gore *et al.* (1991).

The differences in the distribution of *G. zebratus* over available habitat between the two sites (Figures 3 and 4)

suggest that its habitat selection is influenced by the presence of *M. salmoides*. Studies in North America (e.g. Schlosser 1988, Harvey 1991, Magoulick 2004) have shown that predatory fish such as *M. salmoides* can induce habitat-use shifts in other stream fish. These studies found that, where predators were present, their prey tended to congregate in areas where the risk of predation was likely to be lower. Likewise, studies in New Zealand have documented shifts in habitat use by galaxiids in the presence of introduced salmonids (McIntosh *et al.* 1992, 1994, Glova 2003). In the present study we found that *G. zebratus* displayed stronger selection for deeper, slower-flowing water where *M. salmoides* was present than where it was absent (Figures 3 and 4). We also found that, at places where *G. zebratus* was observed, in-stream vegetation became increasingly common as depth increased (Figure 5) and velocity decreased (Figure 6). We suggest from this that *G. zebratus* congregate in deeper, slower-flowing water because vegetation is more abundant in such areas and offers more shelter from *M. salmoides*. In support of these observations we note the finding of Werner *et al.* (1983) that, in lentic environments where *M. salmoides* was present, bluegill *Lepomis macrochirus* (Rafinesque) moved from open-water habitats to vegetated habitats. Our finding that, during the day, *G. zebratus* selected cobble substrates more strongly where *M. salmoides* was present than where it was absent (Figures 3 and 4) is further evidence of a predator-avoidance response, since interstices between cobbles probably provide shelter from *M. salmoides*.

Our tentative finding that the distribution of juvenile *G. zebratus*, in terms of depth and substrate, did not differ significantly between sites at night (Figure 4), suggests that the influence of *M. salmoides* on this size class may be weak at night. This could be because *M. salmoides* is a visual hunter whose foraging ability is likely to decrease markedly at night when light intensity is relatively low (McMahon and Holanov 1995), making smaller fish harder to target. This could allow *G. zebratus* to move back into more optimal habitats at night. Our data do not allow us to test this or other possible explanations, and we emphasise that our findings must be treated with caution, since they are based on a relatively small number of juveniles ($n = 19$, Table 2) observed at night.

Interactions with other indigenous fish species that were present at sites used in this study (particularly *B. serra*, which was present only at the bass-present site), may have also influenced abundance and habitat selection by *G. zebratus*. Neither *B. serra* nor *P. phlegethon* is piscivorous, but both may compete with *G. zebratus* for space or food, although cyprinids mostly feed off the substrate (Skelton 2001), while *G. zebratus* is a drift feeder. A study of interactions between *G. zebratus* and other indigenous species is required to broaden our understanding of their habitat selection.

The quantity and quality of food eaten by stream fishes can change as a result of predator-induced habitat shifts (Power *et al.* 1985). *Galaxias zebratus* feed on small drifting invertebrates (Skelton 2001), the availability of which is influenced by flow velocity. Invertebrate drift is likely to be

lower in habitats with slower water flow, which were strongly selected by *G. zebratus* at the bass-present site. This may be detrimental to individual growth and fitness and could also affect organisms at other trophic levels. *Micropterus salmoides* may also have an indirect effect on algal and aquatic invertebrate communities through its effect on *G. zebratus* abundance and distribution, such as has been found in studies on interactions between *Micropterus* spp. and smaller stream fish in Oklahoma (Power and Matthews 1983, Power *et al.* 1985).

Habitat selectivity may not necessarily be completely independent of habitat availability (Heggenes 1991), which means that our use of Jacobs' (1974) electivity index may not have completely accounted for differences in habitat availability between the sites. However, in our study, where the sites were broadly similar in that the full range of habitats was present at both sites, differences in habitat selectivity between the sites is unlikely to have been the dominant effect.

Finally, we emphasise that our study should be treated as a preliminary investigation because only two sites were sampled and each was sampled only once by day and once by night. Data need to be collected from a greater number of sites and over a longer period of time to determine whether our findings are generally applicable. We consider it reasonable to conclude, from our limited data set, that *M. salmoides* appears to have a detrimental effect on the *G. zebratus* population in the upper Driehoeks River. We note, however, that other effects, such as differences in available habitat (despite our attempts to account for them), or in interactions with other indigenous species, could be partly responsible for the observed differences in abundance and distribution of *G. zebratus* above and below the weir. For conservation purposes, we recommend that the sandbag weir be maintained and that *M. salmoides* not be introduced upstream of it. Although less obvious, *M. salmoides* may have indirect effects on stream communities at other trophic levels by altering habitat selection by *G. zebratus*. Thus, studies to investigate the effect of *M. salmoides* on invertebrate and algal communities are needed to assess its impacts on riverine ecosystems where they have been introduced. Both *G. zebratus* and *M. salmoides* are widespread across coastal drainage systems in the CFR (Skelton 2001) and may co-exist in other rivers. Examination of interactions between these species at other locations would broaden our knowledge of the regional impact of *M. salmoides* in the CFR and would provide valuable information for the management of indigenous fishes that are threatened by this species in other areas.

Acknowledgements — This study was financed by a grant to CLG by the DST-NRF Centre of Excellence for Invasion Biology, and the production of this paper was financed by a Postgraduate Publication Incentive Bursary to JMS from the University of Cape Town. We thank G Moncrieff and JC du Pont for field assistance, and ND Impson (CapeNature) for providing access to the study sites as well as useful suggestions during the planning of the study. We also thank S Marr for constant advice and help with pilot studies and sampling design, Dr CL Moloney, Prof. PG Ryan and Prof. PAR Hockey for useful analytical advice, and I Hampton for useful comments on the manuscript.

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