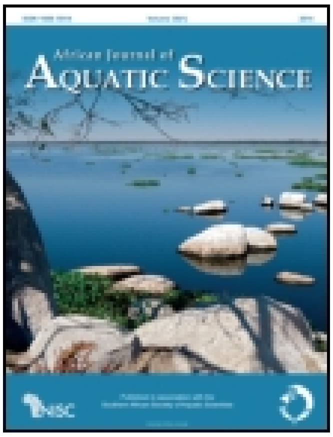

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A preliminary assessment of the impact of alien rainbow trout (*Oncorhynchus mykiss*) on indigenous fishes of the upper Berg River, Western Cape Province, South Africa

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Impacts of alien rainbow trout (*Oncorhynchus mykiss*) on critically endangered Berg River redfin (*Pseudobarbus burgi*), Cape kurper (*Sandelia capensis*) and Cape galaxias (*Galaxias zebratus*) in the upper Berg River were investigated in terms of predation and spatial interactions. Trout stomach contents revealed that invertebrates dominate trout diet within the study area, whilst only six fish were recovered from 45 stomachs. The apparent low fish predation success of *O. mykiss* within the stream suggests a smaller impact compared to that of other alien piscivores such as bass (*Micropterus* spp.). *Galaxias zebratus* was the only fish species identified as prey, and its conservation status in the river requires further investigation. Snorkelling surveys revealed that rainbow trout co-exist with *S. capensis* and adult *P. burgi* within pools on this river. *Galaxias zebratus* was absent from the pools, while *P. burgi* juveniles were segregated from rainbow trout along a depth gradient, possibly indicating avoidance behaviour. *Sandelia capensis* juveniles may avoid predation by hiding under rocks. Rainbow trout probably compete with indigenous fish for food and space in the pools, though this could not be quantified. The impacts of *O. mykiss* on all indigenous fauna within the river are likely to be density-dependent.

Keywords: alien fish, *Galaxias zebratus,* predation, *Pseudobarbus burgi, Sandelia capensis,* spatial interactions, threatened fish

Introduction

The indigenous fishes of South Africa's Cape Floristic Region (CFR) are arguably the region's most threatened biotic component, as 15 of the 19 species are threatened (Impson *et al.* 1999). Reasons for this vulnerability appear to be the species' high endemicity, inflexible life history traits and low tolerance to disturbance (Skelton 1987). Alien invasive fish species have contributed significantly to decreases in indigenous fish populations in the CFR (Skelton 1983, Impson *et al.* 1999, Impson and Hamman 2000). The major problem species is regarded as being smallmouth bass, *Micropterus dolomieu* (Lacepede), although rainbow trout, *Oncorhynchus mykiss* (Walbaum), common in mountainous regions in parts of the CFR, are also seen as a contributing factor (de Moor and Bruton 1988). Trout are well documented as causes of indigenous fish declines in New Zealand and Australia, where they are known to predate on many species of Galaxiidae, resulting in spatial displacement (McIntosh 2000), and extirpation from their former range (Townsend and Crowl 1991, Townsend 1996, Lintermans 2000). They have also been implicated as threats to indigenous fishes in South Africa (Engelbrecht and Roux 1998/1999, Skelton 2000). This study sought to assess the impact of rainbow trout in the upper Berg River, in which they have been established for nearly 100 years. According to recent fish surveys the trout here seem to co-exist with indigenous fishes. Three indigenous fish species are resident in the upper Berg River, namely Cape kurper *Sandelia capensis* (Cuvier), the near threatened Cape galaxias *Galaxias zebratus* (Castelnau), and the critically endangered Berg River redfin *Pseudobarbus burgi* (Boulenger). The vulnerable Berg-Breede whitefish *Barbus andrewi* (Barnard) used to occur here, especially during the spawning period, but now appears to have become extinct in the Berg River system. Rainbow trout were first stocked in the Berg, as well as in the Lourens and Eerste Rivers, in 1901 and are thought to have contributed to the extinction of the Berg River redfin in the Eerste River system (de Moor and Bruton 1988). In the Berg River today, this species is found in large numbers only upstream of the La Motte forestry plantation south of Franschoek. A weir, situated upstream of an inter-basin water transfer (IBT) terminal within the La Motte plantation, may also mark the lower limit of the three indigenous species' range, since further downstream the river is populated by smallmouth bass. As part of a Zoology Honours project, we studied the spatial interactions between the three indigenous fishes and rainbow trout within the pools of the upper Berg River, as well as the diet of rainbow trout captured from that river. The aim of the project was to make a preliminary assessment of the impacts of this invasive alien fish in a sensitive river ecosystem in the Cape Floristic Region.

Methods

The study was conducted on the Berg River in the Assegaibos valley of the Groot Drakenstein Mountains (33°58'S, 19°04'E), in the Western Cape Province (Figure 1). Five pools were used to study spatial interactions between trout and the three indigenous species. Due to time constraints, and because the survey was for a Zoology Honours project, only pools were surveyed.

Each pool was sampled once a day for three days in March 2002, during which fish were observed by snorkelling from the outflow of each pool to its inflow. All fish were counted and their total lengths estimated using a ruler attached to a writing slate. The yellow plastic ruler, which was easy to read underwater, was held at arm's length and fish were usually measured side-on when less than one metre from the diver. The positions of fish were marked with a numbered cork anchored by a lead weight and the depth and habitat characteristics at each marker were noted. On the 9th and 10th of April 2002, and on the 13th September 2002, trout were captured for stomach analysis by angling along the entire stretch of the study area. The Fork Length (FL) of each trout was measured to the nearest centimetre, its abdominal cavity was opened, the stomach removed and perforated with a dissecting needle before being fixed in a solution of 10% formalin. In the laboratory, all the stomachs were transferred to 70% alcohol and dissected under a binocular microscope. Fish remains were measured by Total Length (TL) as the caudal fin was usually badly eroded. Aquatic insects were identified to family, non-aquatic insects to order and other invertebrates to class. For the autumn data set, the dry weight of consumed fish was compared to the combined weight of the remaining stomach contents (after Coetzee 1982). This was done using the successful piscivores, as well as all potentially piscivorous fish (those equal to or larger in size than the smallest trout found to contain fish). Dry weights were measured to four decimal places on a Mettler AE 163 digital scale.

Results

Diversity of trout prey

Baetid mayfly nymphs (Order Ephemeroptera: Family Baetidae) were proportionally the most abundant prey item in the autumn data set (Figure 2). Terrestrial and flying invertebrates, grouped together as they would all have been taken from the surface by drift-feeding trout, formed a smaller component of the diet of *O. mykiss* than did aquatic invertebrates (Figure 2), but were nevertheless found in all but two of the stomachs sampled. In the spring data set baetid larvae, drifting chironomid midge pupae (Order Diptera: Family Chironomidae) and winged adult Ephemeroptera dominated the stomach contents, being found in roughly equal proportions overall (Figure 3). This indicates that the trout caught in

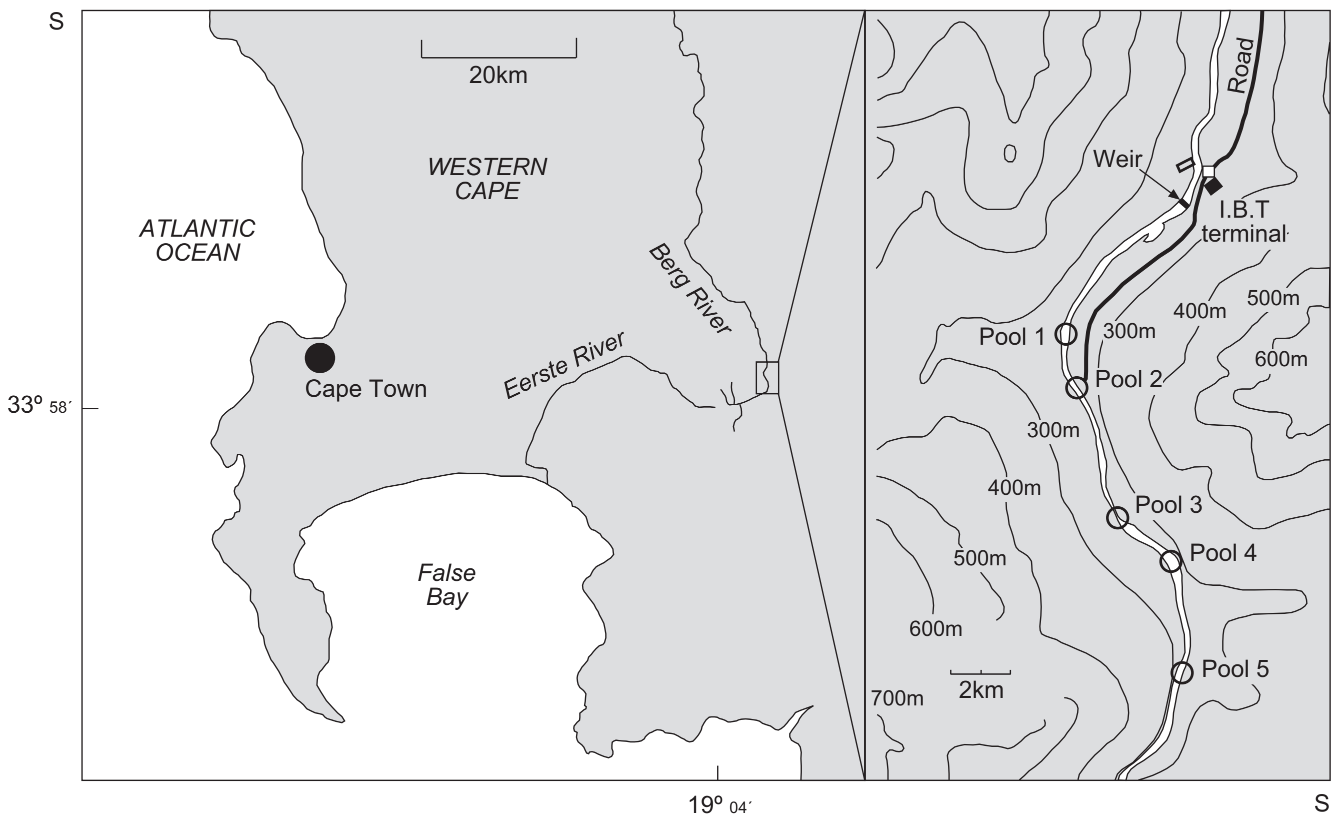

Figure 1: Map of the upper Berg River, showing the study area in the Assegaibos valley and the position of five surveyed pools

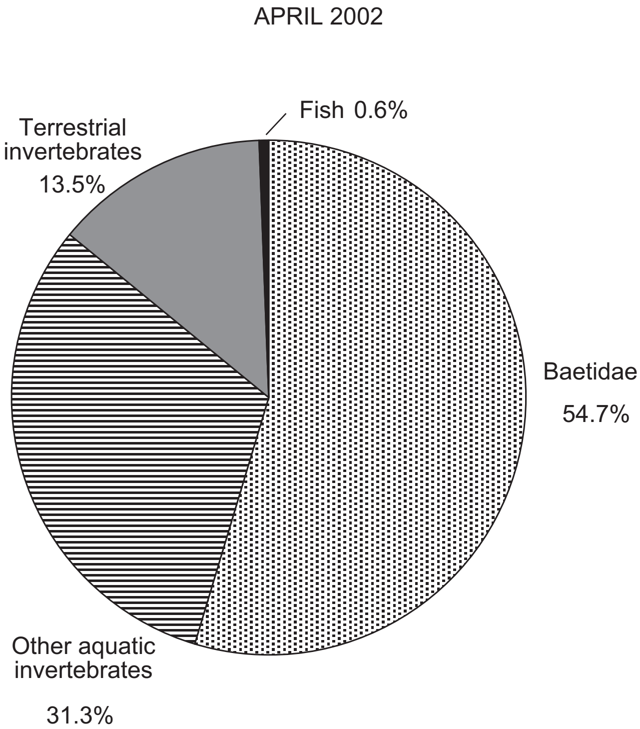

Figure 2: Proportional abundance of taxonomic groups of prey found in trout stomachs in autumn. Trout n = 33

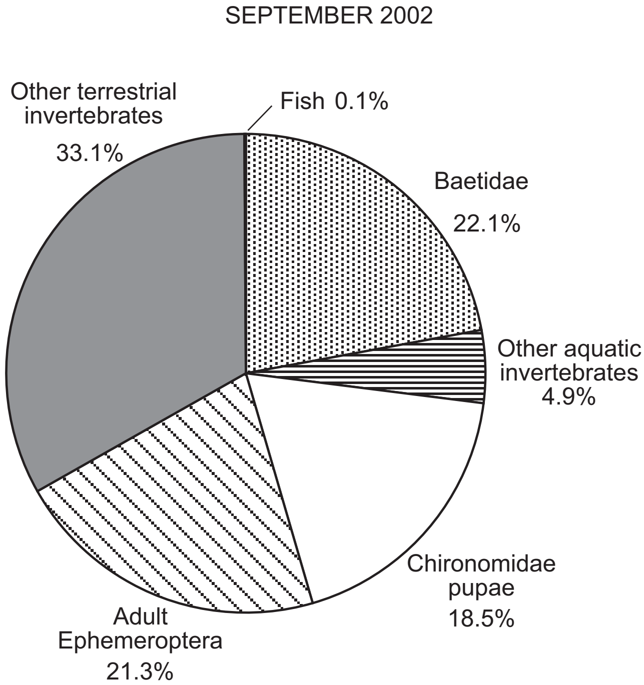

Figure 3: Proportional abundance of taxonomic groups of prey found in trout stomachs in spring. Trout n = 12

spring were feeding more extensively from the surface drift than those caught in autumn, owing to the larger proportion of terrestrial, surface-dwelling and flying taxa captured. Five fish were present in the autumn trout stomachs, but only one of these was recognisable as a Cape galaxias, *G. zebratus*. Of the 33 trout caught and sampled, only three had fish in their stomachs. One stomach from the spring data set of 12 trout contained a single *G. zebratus*. Piscivores therefore made up 13% of the sampled population.

The smallest trout containing a fish was 16cm FL, while all fish found in the trout stomachs were between 2cm and 4cm TL. Dry weights were taken of samples from each trout in the autumn data set equal to or greater than 16cm, since these could now be assumed to be potentially piscivorous. Fish comprised 14% by weight of the total diet of potentially piscivorous fish, while in the three which had consumed fish, it made up 61% of the total stomach contents (Figure 4). This indicates that, whilst fish are a very rewarding food source, they are not captured frequently. These data imply that while *O. mykiss* actively prey upon juvenile fish in the river, they are apparently not often successful.

Spatial co-existence within pools

Snorkelling surveys found *O. mykiss* and Cape Kurper, *S. capensis*, in all five pools, while the Berg River redfin, *P. burgi*, was found in all but pool 5. *Galaxias zebratus* were absent from all five pools, but were recorded in a backwater just below pool 2, and are likely to occur in other quiet, shallow areas of the river. *Sandelia capensis* and *P. burgi* were abundant in pools one to four on all three days, and appear to co-exist with the trout within those pools. *Pseudobarbus burgi* were divided into juveniles (0–5cm) and adults (>5cm) in order to assess whether the juveniles, which are likely to be vulnerable to predation by trout (L'Abée-Lund *et al*. 1992), were avoiding *O. mykiss* more than were the adults. *Oncorhynchus mykiss* depth distributions probably reflect the combined depth profiles of the five pools, since the trout for the most part were found in the deepest parts of each pool (Figure 5). *Sandelia capensis* closely mirrored the depth distribution of *O. mykiss*, apart from being absent in the very deep waters (Figure 5a). Numbers of *P. burgi* adults peaked at around the 1m and 1.5m marks (Figure 5b). In sharp contrast, juvenile *P. burgi* (Figure 5c) were found only in water shallower than 0.8m, and were most commonly found in water 0.2m to 0.4m deep. Since *O. mykiss* were seldom found in water less than 0.6m deep (and those recorded in shallower water were not near *P. burgi* juveniles), there would appear to be a real separation between juvenile *P. burgi* and *O. mykiss* along a depth gradient.

Discussion

From the stomach content data, it is clear that rainbow trout, *O. mykiss* prey on Cape galaxias, *G. zebratus*, in both autumn and spring, and may hunt them throughout the year. The fact that so few fish were eaten (only 6 in total) indicates that trout are not often successful in capturing fish, though a survey of brown trout in Norwegian lakes, which found only 5% of the sampled population to contain fish (L'Abée-Lund *et al*. 1991) shows that this is not unusual. Furthermore, river trout are known to feed mostly on drifting invertebrate prey rather than the generally less-accessible food fish present

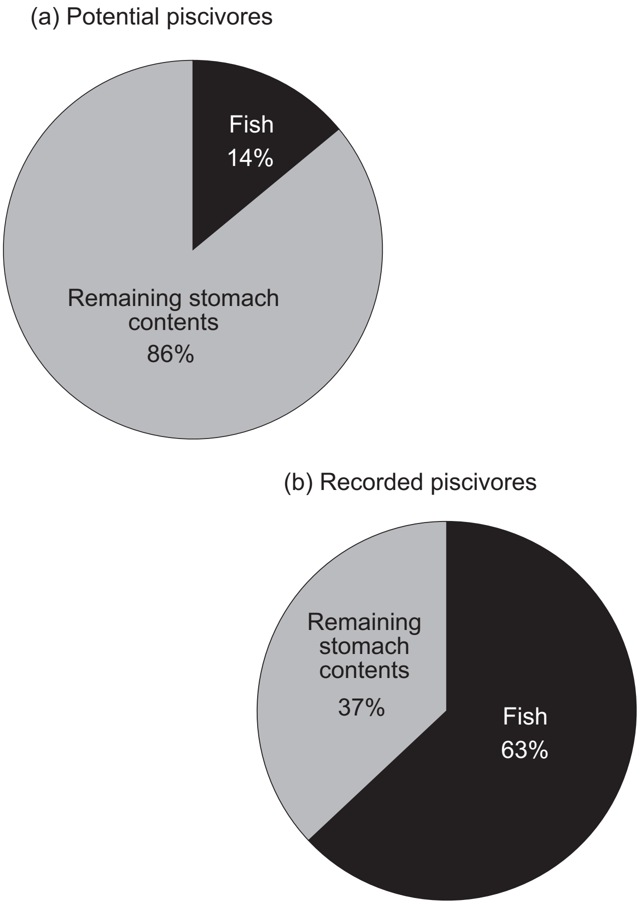

Figure 4: Proportional dry mass of fish and remaining trout stomach contents for a) all potential piscivores (≥16 cm), and b) all successful piscivores in autumn. Potential piscivores n = 28, recorded piscivores n = 3, total sample n = 33

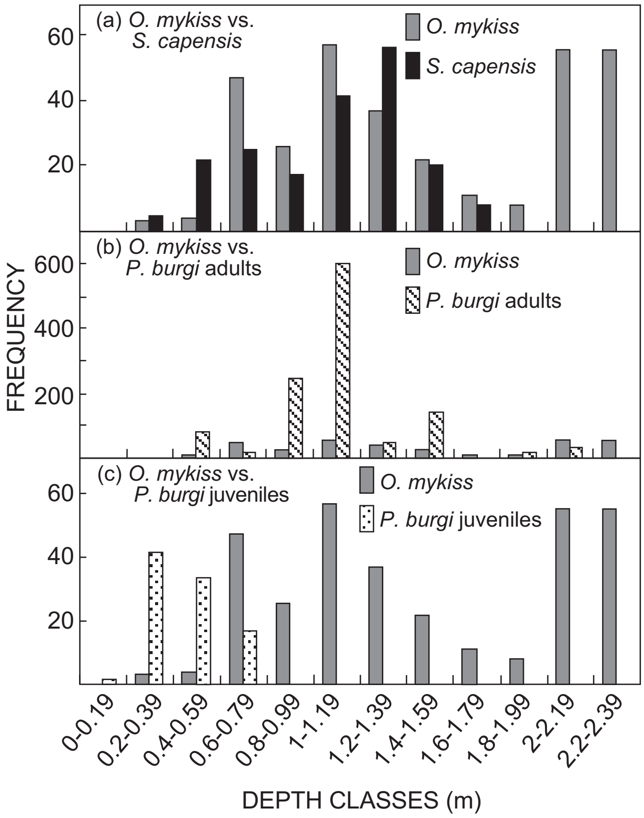

Figure 5: Frequency distributions of water depths where *Oncorhynchus mykiss* and a) *Sandelia capensis*, b) *Pseudobarbus burgi* adults and c) *P. burgi* juveniles were found, using the combined data from five pools over three days' sampling.

(Keeley and Grant 2001). This contrasts with the impacts of bass (*Micropterus* spp.), which through predation are capable of eradicating the indigenous fish fauna from invaded rivers (de Moore and Bruton 1988, Skelton 1993).

Oncorhynchus mykiss has been implicated as a predatory threat to small barbine species such as the Maluti minnow (*Pseudobarbus quathlambae*) in the Drakensberg region (Skelton 2000) and the Treur River redfin (*Barbus treurensis*) in Mpumalanga (Engelbrecht and Roux 1998/1999), and was found to prey on the Border barb (*Barbus trevelyani*) in the Eastern Cape (Jubb 1979). Whilst it is unclear whether or not *O. mykiss* feed on the redfin, *P. burgi*, and Cape kurper, *S. capensis*, within the Berg river, the fact that these species were observed in large numbers co-inhabiting the pools with trout, suggests that the effects of any predation by them are currently not severe. Confirmation of this will require further study. In contrast, the fact that the much smaller *G. zebratus* was wholly absent from the pools suggests that they do not spatially co-exist with trout, and may be avoiding the pools as a result of the relatively high numbers of trout recorded in them. This is consistent with the situation prevalent in New Zealand, where the presence of trout is a major factor in the displacement of galaxiids within rivers (McIntosh 2000), or in their complete extirpation from certain systems (Townsend and Crowl 1991, Townsend 1996). Since a full survey of all physical habitats (apart from pools) was not carried out in this study, the status of the *G. zebratus* population within the study area could not be fully ascertained.

While the absence of *G. zebratus* from the pools could suggest their avoidance of predatory trout, adult *P. burgi* and *S. capensis* appear to co-exist spatially with trout in the pools, which may imply that *O. mykiss* is only a limited threat to these fish. However, the separation of juvenile *P. burgi* from *O. mykiss* by habitat-depth suggests avoidance behaviour, since the juveniles were utilising habitats within the pools that were potentially difficult for the trout to access. Indeed, the shallow backwater in which *G. zebratus* was observed during fieldwork also contained juvenile *P. burgi*, suggesting that that habitat was relatively safe from predators. It is possible that habitats like these are sub-optimal areas that the indigenous species would not usually inhabit, but into which they have been forced through predation pressure from trout. This ecological phenomenon has been observed in the case of New Zealand galaxiids (McDowall 2003) and should be investigated further here.

Since no fish longer than 4cm TL was found in the trout stomachs it is reasonable to assume that the smaller *G. zebratus*, along with juvenile *P. burgi* and *S. capensis*, are the fish most threatened by trout. While juvenile *S. capensis* and trout both occupied the same pool habitats (data not shown), many *S. capensis* individuals of all sizes of were observed hiding under rocks, some only becoming visible when they emerged to investigate the researcher. This cryptic behaviour is acknowledged as a potentially effective predator-avoidance strategy in the species (Skelton 1993) and may explain why they are better able to co-exist spatially with trout within the pools, compared to *P. burgi* juveniles, all of which spent their time shoaling or swimming singly in open water.

Since the trout stomachs contained a large quantity and diversity of invertebrate prey, and since both *P. burgi* and *S. capensis* are insectivorous (Skelton 2001) these fish must compete with *O. mykiss* to some degree for this food source. It is also likely that, within the various habitats of the river where these species co-exist, there is some competition for space. In New Zealand, juvenile trout and galaxiid juveniles both inhabit the slack margins of rivers, and the trout appear to out-compete the smaller galaxiids for both space and food, as well as feeding on the emerging galaxiid larvae (McDowall 2003). Adult *P. burgi* and *S. capensis* may also suffer from the presence of *O. mykiss*. Rodriguez (1995) found that large salmon (*Salmo* spp.) tend to out-compete the smaller charr (*Salvelinus* spp.) for space in the riffles and runs in American rivers, forcing the charr out of these productive habitats and into pools where they could better compete with the salmon for food by shoaling. The dense shoals of indigenous fish observed in this study's pools may therefore have been further enlarged through the displacement by trout of *S. capensis* and *P. burgi* individuals from the stretches of river above and below. The study of such interactions was beyond the scope of this survey, but should be investigated in the future. While such competitive threats to food and space are density-dependent (Rodriguez 1995), this could also apply to the predatory threat posed by *O. mykiss*. During the initial stocking of the Berg, Lourens and Eerste Rivers large numbers of trout were introduced each year to satisfy angler demand, creating an abnormal and very high predator-to-prey ratio. This would have resulted in raised predation pressure, and may have led directly to the extinction of *P. burgi* in the Eerste River. If the threat currently posed by rainbow trout to the indigenous fishes of the upper Berg River is density-dependent, local conservation authorities should seek ways of lowering the population density of this species in that river through active management (e.g. removal by angling) in order to lower the threat they pose to the indigenous fishes.

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