Post doctoral research project: update October 2007.

SAIAB/CIB collaboration

(with additional funding from the World Bank)

Researcher: Steven Lowe

Title: The impact of the invasive alien fish on foothill river ecosystems in the Cape Floristic Region.

Background of the project

The Cape Floristic Region (CFR) is characterised by exceptional endemism in many of its biotic components, including fish and aquatic invertebrates. Many of South Africa's indigenous freshwater fishes are currently threatened with extinction due to predation and competition from invasive fish, often in conjunction with other anthropogenic impacts such as pollution, water abstraction, dams and invasive trees. The impact of invasive fish on river ecosystems, beyond the depletion of indigenous fish populations, has not been studied in South Africa. Although invasive freshwater fishes are a global problem, relatively few studies exist on their effect at the community or ecosystem level, although some studies report significant impacts in both rivers and lakes. The community and ecosystem-wide influences that freshwater fish exert on their resident ecosystems are well studied and indicate that the nature of the impact of each invasive fish species is likely to be dependent on a range of factors including: the physical characteristics of the river; the nature of the invaded community; and the life history and feeding traits of the invasive fish species. Therefore, to predict the nature and extent of the impacts of invasion and to prioritise conservation strategies, an understanding of these criteria is required.

Within the CFR, 16 species of invasive fish have also been recorded. Smallmouth bass, *Micropterus dolomieu,* is currently the most widespread invasive fish in the CFR and is known to deplete most indigenous fishes.

We therefore designed a study to address the following question: Do bass alter the freshwater community beyond their impact on indigenous fish?

Methodology

Sites were chosen on two rivers with waterfall barriers to bass invasion and included adjacent invaded and non-invaded (indigenous) reaches for comparison.

Sampling was conducted seasonally over a one year period (March 2006 - March 2007). The distribution, mass and diet of fish were studied at each site. The diversity and density of aquatic invertebrates were studied and the drifting, foraging, development and adult stages of some taxa were analysed. The density and composition of periphyton was analysed. Physical parameters were measured.

Site selection

Witte River (fig 1.)

Eight sites were chosen: four in the indigenous reach and four in the bass-invaded reach. These sites were chosen due to the presence of in-current and out-of-current cobble-bed habitats proximate to pools containing fish populations. These sites span 800 meters of river and represent habitat typical of several kilometres of the river.

Ratels River (fig 2.)

The Ratels River was chosen due to the presence of a waterfall barrier to invasion by *M. dolomieu*, with indigenous fish above the barrier and few below (migrating adults only). Despite the presence of farming in the catchment and the possible complicating issues of some nutrient enrichment and water abstraction, the accessibility and presence of established bass, indigenous and fishless zones make it a useful comparison to the Witte River.

Sample frequency and intensity

Sampling was conducted in late summer (March 2006 & 2007), winter (late June 2006), spring (September 2006) and mid-summer (late November and early December 2006), in order to capture the seasonal dynamics and life cycles characteristic of the aquatic biota. The number of sample sites and the number of samples collected from each site was determined by the quantity of samples feasible to collect and process from each field trip and by the requisite number of samples that can provide statistically powerful data. Not all sites were sampled on each sampling occasion (see below for details).

Fish sampling

Rationale: Understanding the feeding preferences and biomass of each fish species provides an indication of the predation pressure exerted on the prey species. Seasonal sampling is essential to understand the intra-annual dynamics of trophic interactions.

Fish biomass

Using seine nets for indigenous species and line and spear-fishing for bass, representative samples of each species were caught and length and mass measured. Using these data, power curves were generated to determine the mass of a fish from its length. Size classes were determined for each fish species. Snorkel surveys were conducted to estimate the abundance of each size class of each species in pools at each site. The snorkel survey data and the length/mass curves were used to calculate the estimated total biomass of each fish species in each pool.

Fish diet

Fish were caught and a total of 20 individuals of each indigenous species and 12 bass were killed, the stomachs removed and placed in 95% ethanol. Stomach contents were analysed in the laboratory, classified into food types and the biomass of each food type estimated (plant material and detritus by volume; invertebrates by counting and measuring head capsules of each taxa and estimating biomass based on the known mass of each taxon). Relating the composition and mass of the diet of each fish species and the mass of fish at each site provides an indication of the relative predation pressure on prey taxa.

Invertebrate sampling

Rationale: Aquatic invertebrates represent multiple trophic levels in the aquatic ecosystem, composing the major herbivores, detritivores and prey items for most indigenous fish species. The large number of species with diverse life history requirements makes the group useful in assessing environmental or biotic changes (the rationale of the SASS technique for water quality monitoring). Comparisons of invertebrate species diversity, abundance, behaviour and community composition between indigenous and invaded reaches may provide an understanding of the impacts of invasive fish on the biodiversity and functioning of the river ecosystem.

Macroinvertebrate abundance

Macroinvertebrates were collected by kick sampling for total diversity and from individual submerged stones for density and diversity. At each site, 8 stones in-current (IC) and 8 stones out-of-current (OC) were collected by placing a hand net immediately downstream of the stone (IC stones) or by creating a current into the net by hand (OC stones) and lifting the stone into the net to ensure capture of mobile species. Invertebrates were then picked-off the stone and fixed in ethanol together with those flushed into the net. Algae was then removed from the stone into 1 litre of water, by scrubbing for a time-period determined by the size of the stone. Three axes of the stone were then measured for surface area estimation, the stone placed in its original position and the depth and bottom velocity over the stone recorded with a flow meter. This technique allows for a quantitative assessment relating invertebrate density and diversity to depth, flow and algal density and composition.

Macroinvertebrate behaviour and development

Rationale: It has been reported that invertebrates alter their behaviour in response to differing predation regimes and that changes in behaviour may have a greater trophic impact than changes in invertebrate abundance. Changes in foraging behaviour may also affect the development of invertebrates, influencing time to maturity and emergence. Invertebrate behavioural changes include the timing and amount of both drift and foraging behaviour.

Drift: Drift nets ($0.5m^2$ aperture, 0.5mm mesh) were secured to the river bed at various sites in bass-invaded and uninvaded sites simultaneously. The depth of the net and flow through the net was recorded. The nets were placed for approximately 1 hour at dusk, dawn, during the night or at mid-day and the contents preserved in ethanol. Data was expressed as the number of each taxa per volume of water over time (m^3/s).

Foraging behaviour: The numbers of crawling cased trichoptera was recorded within three pre-marked $0.25m^2$ quadrats on bedrock in slow flowing reaches (<0.03m/s) on three days at invaded and non-invaded reaches.

Note: In order to determine whether any differences in the abundance of drifting or foraging invertebrates between sites was due to behavioural differences or merely differences of invertebrate density, the numbers of each drifting or foraging taxa were corrected for their relative density between sites, as determined by stone sampling.

Development: The head capsule width of selected taxa (all ephemeroptera, odonata, plecoptera, megaloptera and simuliidae) from all stone samples were measured using a micrometer. T-tests (transformed for normality if required) was used to detect differences of head capsule size within each taxa between sites. The head size of uni- or multi-voltine species is a good indicator of the speed of development, whereas the head size of semivoltine species may provide an indicator of inter-annual survival.

Aerial stage of aquatic invertebrates

Light traps were deployed next to the river for one hour at dusk in invaded and uninvaded reaches simultaneously and invertebrates were preserved in 95% ethanol.

Algae

Rationale: Algae are the major primary producers in the rivers sampled in this study. The biomass and composition of algae varies greatly throughout the year: productivity increases with increasing water temperature and sunlight and accumulates in slower flowing water which is flushed downstream during winter. Algal productivity exerts a strong influence on the whole aquatic community and therefore ecosystem functioning.

Algae was collected from stones by scrubbing for a time-period determined by the size of the longest axis of the stone and washed into 1 litre of water of which, 25-100mls was filtered onto filter paper using a hand-operated vacuum pump, wrapped in tin-foil and kept cool for subsequent chlorophyll A quantification. A further 20mls was preserved in 10% formalin for subsequent analysis of algal composition.

Exclusion experiments

Exclusion experiments were carried-out but due to technical problems these experiments were not included (future inclusion/exclusion experiments with cages would greatly enhance the value of the results to date).

Physical measurements

Field measurements: Min/max temperature, flow and discharge, site description and mapping (substrate type and proportion, length of and distance between habitat types).

Laboratory measurements: phosphate, nitrates, pH, conductivity.

Samples collected

March 2006 (late summer), Witte River. Site selection and mapping. All eight sites sampled: 128 stones, 16 kick samples, snorkel surveys, 12 drift samples (6 pairs), and physical measurements. Not collected: Foraging behaviour; fish stomachs (permits for collecting indigenous fish were not yet approved: not a problem due to future field trips at this time of year).

March 2006, Ratels River. Sites selected. All sites sampled. Only out-of-current stones sampled due to low flow: 40 stone samples, 10 kick samples, physical measurements. Not collected: Fish diet, light trapping, foraging and drift samples. The Ratels River will be used to assess only the diversity and abundance of invertebrates and algae due to time constraints on sampling and processing.

June 2006 (mid-winter), Witte. Half the sites sampled (2 above the waterfall, 2 below): 64 stones, 8 kick samples, snorkel surveys, physical measurements. Not collected: invert behaviour, fish stomachs (high flows and minimal fish activity).

June 2006, Ratels River. All sites sampled: 14 kick samples, snorkel surveys, physical data. Not collected: Stone samples (time limits for sampling and processing).

September 2006 (spring), Witte. Half the sites sampled (2 above the waterfall, 2 below): 64 stones, 8 kick samples, drift samples, snorkel surveys, physical measurements. Not collected: fish stomachs (a few breeding males were observed but not collected). **Note:** P. burchelli sound production first noted.

November 2006 (early summer), Witte. Six of eight sites sampled for stone and kick samples. Drift, light trapping, fish abundance and length/weight measurement, 50 fish stomachs,

November 2006 (early summer), Ratels. All sites sampled for invertebrates (stone and kick sampling) and algae. Fish snorkel surveys. This was the final sampling event on this river for the current project.

March 2007, Witte River. Six of eight sites sampled for stone and kick samples. Drift and foraging behaviour, light trapping, fish abundance, physical measurements.

Data analysis

The invertebrate community composition from kick and stone samples was analysed by multivariate analysis of similarity using the Primer statistical programme. The abundance, development and behaviour of individual taxa were compared by univariate statistics. Possible collaboration with Stats. Dept. to generate a GLM.

Study sites.

Fig 1. The Witte River (Breede River tributary). Sampling sites and fish distribution.

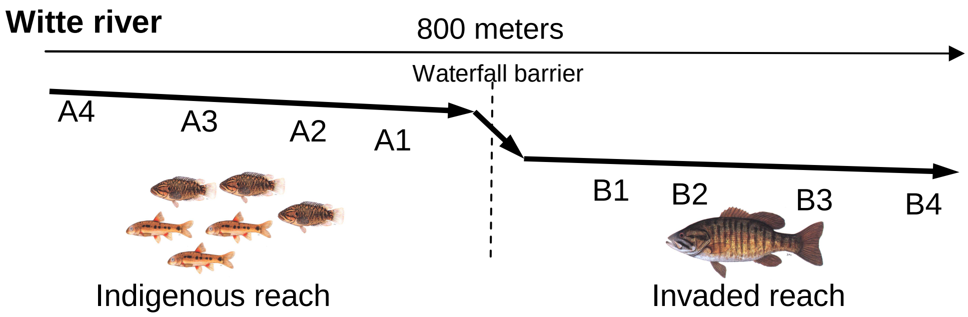
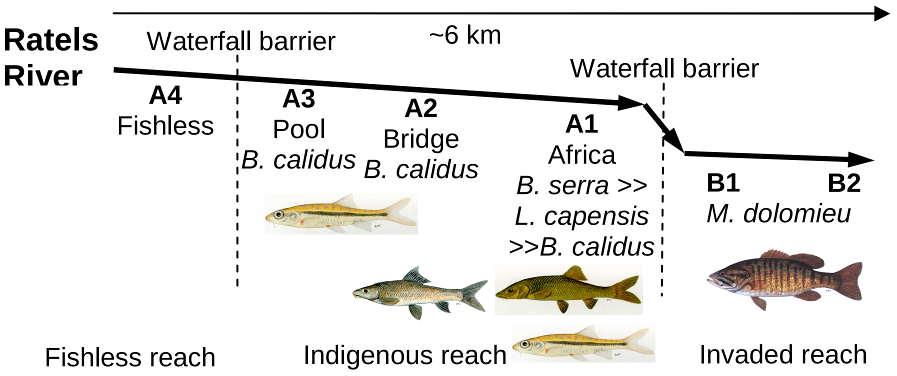


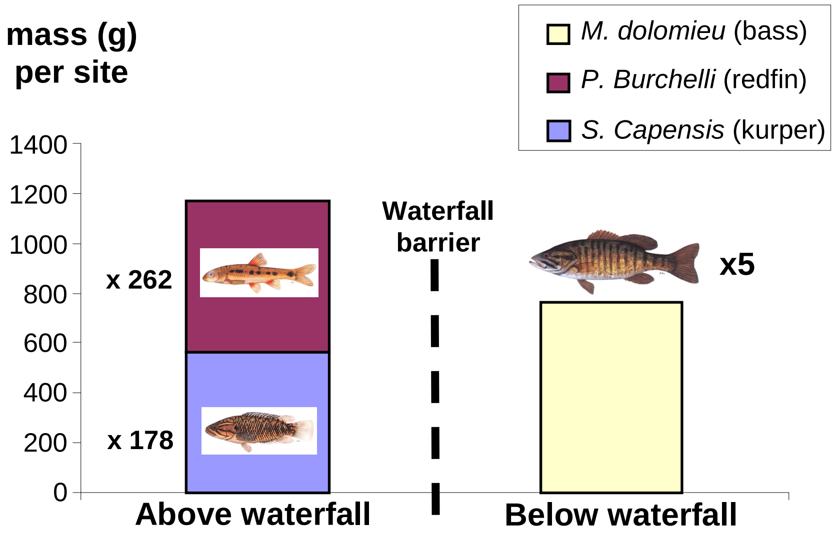
Fig 2. The Ratels River (Olifants River tributary). Sample sites and fish distribution.



Results

1. Fish distribution and biomass: Fish biomass is reduced at invaded sites. This effect is greatly dependent on the habitat type predominant in a river: the Rondegat River is less suitable for bass and fish biomass was reduced 10-fold at invaded sites.

Figure 3. Fish mass and abundance at invaded and non-invaded sites. Witte River.



2. Fish diet and predation pressure on prey: Although the range of prey found in the stomachs of bass, redfin and kurper were similar (with the exception of large adult dragonflies, large crabs and a single fish found in bass stomachs), the contribution of taxa to the biomass of the diet was similar for the two indigenous species (fig 4 b, c), but different between the indigenous species and invasive bass (fig 4 a). The predation pressure on benthic invertebrates was estimated to be nearly 10-fold higher in the presence of indigenous fish compared to invasive fish (fig 5).

Figure 4 a-c. Contribution of prey to the biomass of fish diets (animal taxa only)

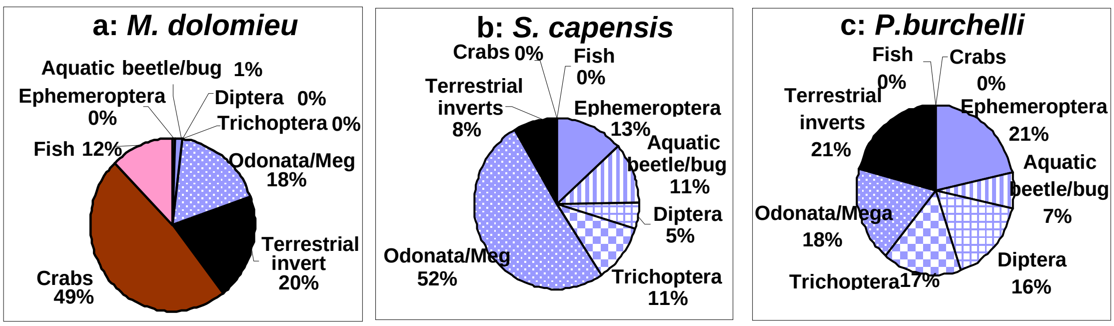
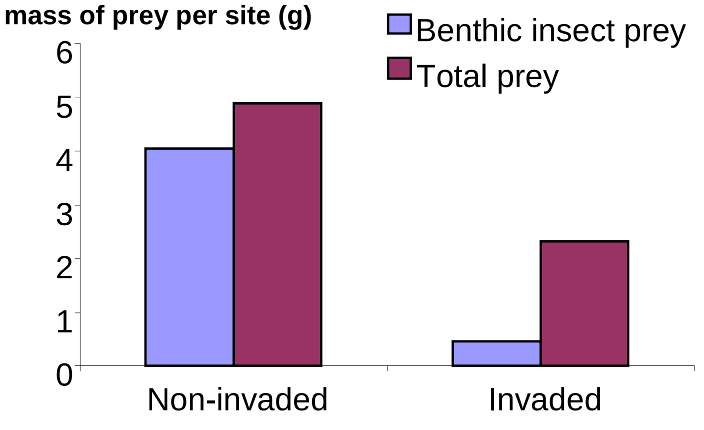
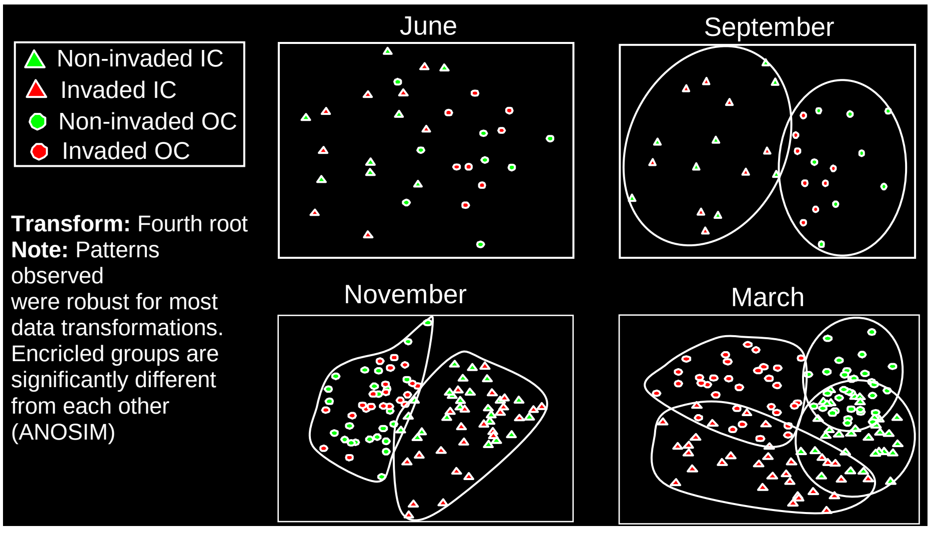


Figure 5. Relative predation pressure on fish prey (derived from the biomass of each prey taxa per biomass of each fish species and size-class and the biomass of fish at each site).



3. The invertebrate community composition is altered at sites invaded by bass:

Fig 6. Invertebrate community composition grouped by habitat and invasion condition

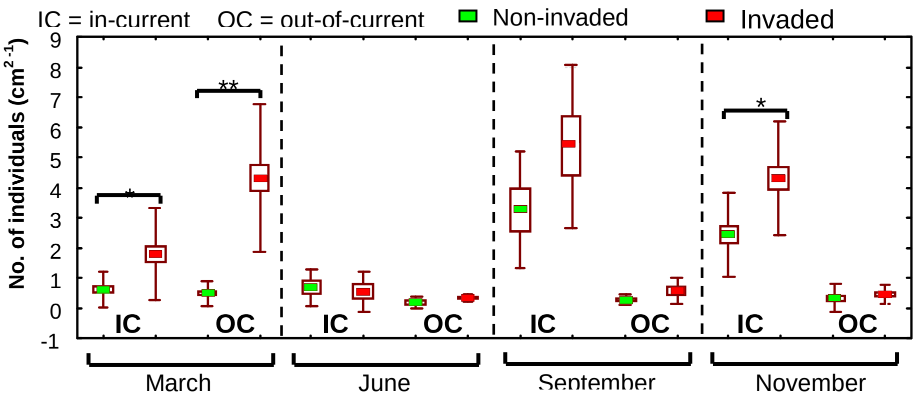


The invertebrate community at bass-invaded sites differ from sites with indigenous fish in a seasonally dependent manner. During winter and spring the river community, including the fish activity, the activity and abundance of invertebrates (fig 6 and) and the abundance of algae (fig) is reduced and effectively 'reset' by high flows, reduced sunlight and low temperatures.

The densities of many invertebrate taxa differ between invasion conditions. At bass-invaded sites, there are significant increases in some taxa that forage or filter-feed on stone surfaces, in particular the Baetidae nymphs (Ephemeroptera), Leptoceridae larvae (Trichoptera) and Simuliidae larvae (Diptera).

4. Removal of the indigenous fishes by invasive bass reduces predation pressure on some benthic taxa which may increase their abundance, drifting and foraging behaviour and development.

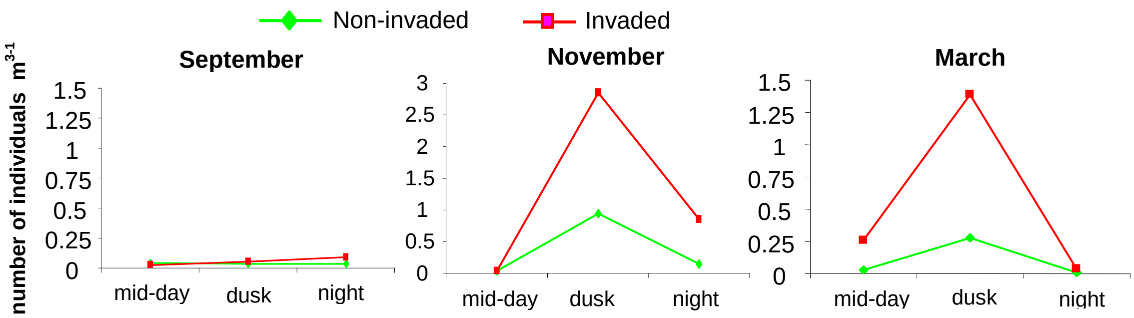
Figure 7. The abundance of Baetidae nymphs at invaded and non-invaded sites throughout the year.



Baetidae numbers are significantly greater during summer months at sites where bass have invaded and removed indigenous fish.

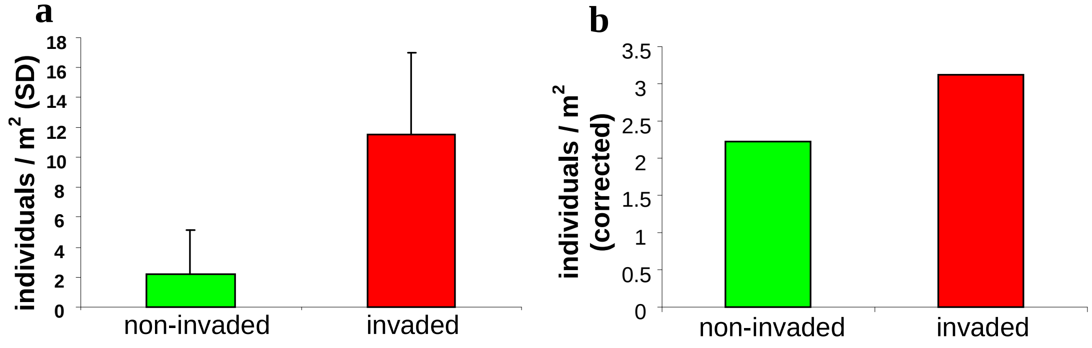
In addition to a change in the abundance of some invertebrates, their behaviour also appears to be influenced by invasive bass.

Figure 8. Baetidae drifting behaviour at bass-invaded or non-invaded sites (numbers of drifting Baetidae are corrected for the relative densities of Baetidae between sites).



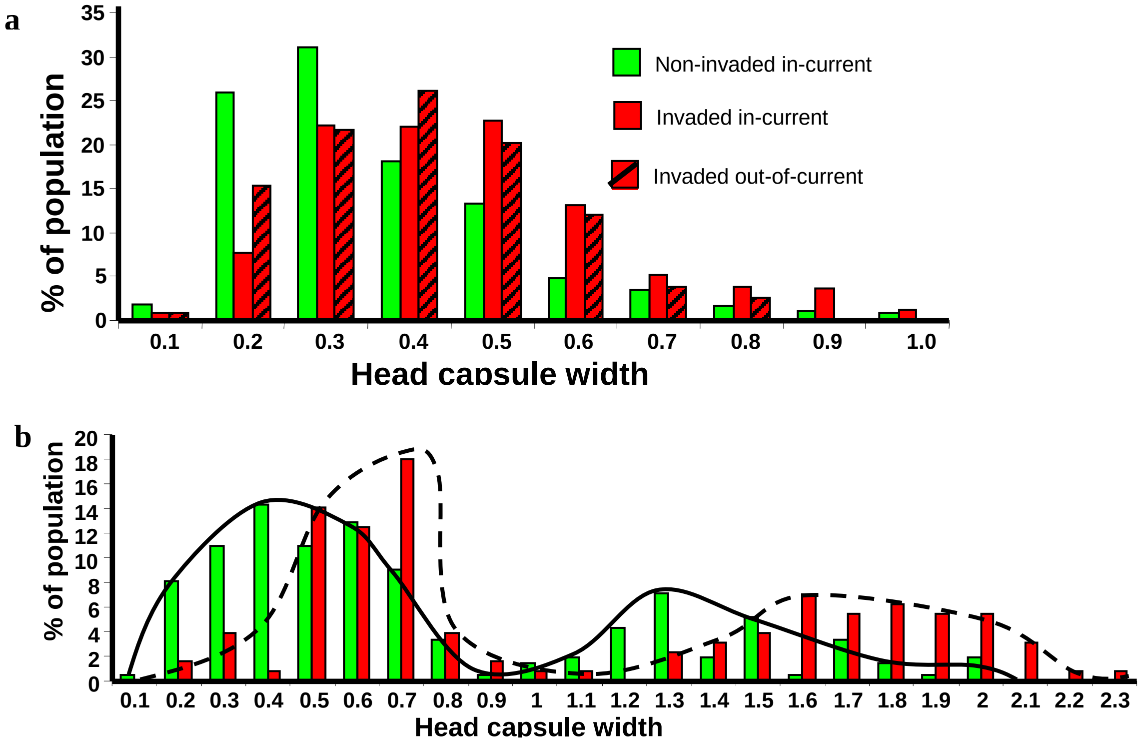
Baetidae increase their propensity to drift, but not the timing (diel pattern) of drift, at sites invaded by bass (fig 8.). This behavioural change is possibly a result of decreased threat of predation in the absence of indigenous fish. The reduction of predator control on epilithic, grazing taxa at bass-invaded sites (as for Baetidae nymphs, fig 7 and 8) is also likely to be responsible for the increase in the abundance and foraging behaviour of crawling trichopteran larvae as shown in Figure 9a,b.

Figure 9a,b. The abundance (9a) and foraging behaviour (9b) of crawling cased trichoptera.



The reduced drifting and foraging behaviour of some invertebrates in the presence of increased predation pressure from fish (in reaches with indigenous fish in this project) has been shown by other studies to decrease the development and time to maturity of invertebrates. Here we show that the size frequency of mayfly nymphs in the presence of invasive bass is increased compared to reaches with indigenous fish (fig. 10). This is consistent with the hypothesis that reduced predation pressure upon invasion by bass allows increased drifting and foraging behaviour which increases development of these taxa.

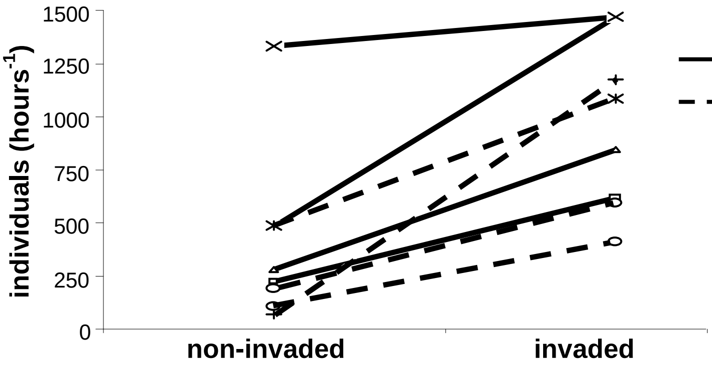
Figure 10a,b. The size frequency distribution of **a.** *Baetis* nymphs and **b.** *Aprionyx* nymphs at sites with invasive bass or indigenous fish.



5. The abundance of the aerial adult stages of some invertebrate taxa are affected.

It is reasonable to suppose that the altered abundance of the larval aquatic stages of many invertebrates results in the altered abundance of adult stages of those taxa. Figure 11 shows that this hypothesis is true for trichoptera, with greater abundance of adult trichoptera at sites invaded by bass compared to sites with indigenous fish.

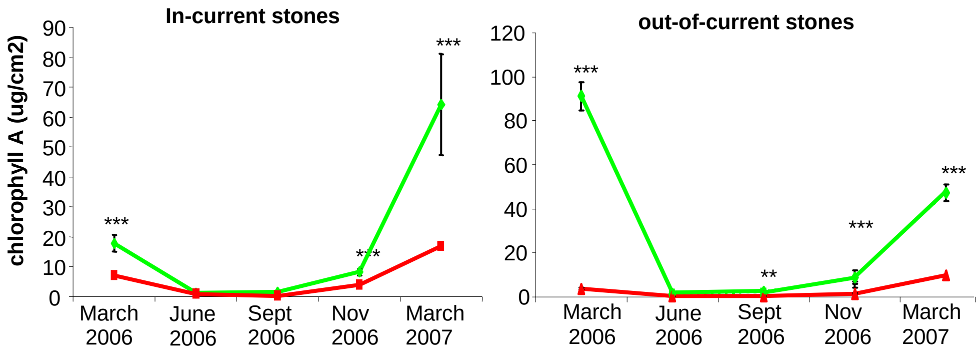
Figure 11. The abundance of adult trichoptera in light traps at sites invaded by bass and sites with indigenous fish (samples are paired by day).



6. Algal abundance is greatly reduced at bass-invaded sites compared to sites with indigenous fish in summer months.

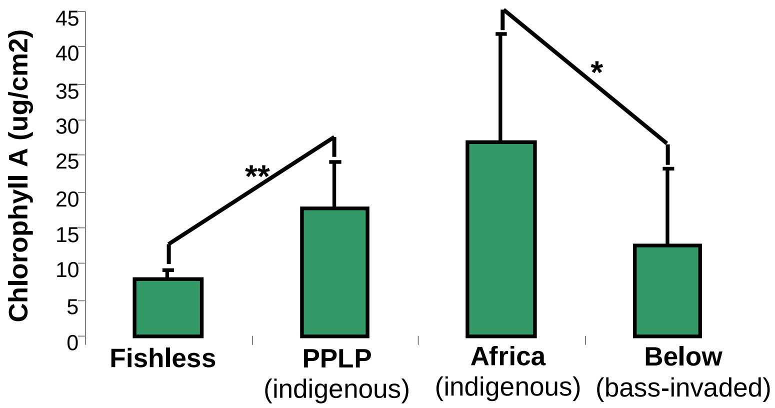
In many lake and river systems it has been shown that the abundance of grazers can influence the abundance of autochthonous production (usually algae), particularly in nutrient-poor systems. In this study we show that algal abundance is greatly reduced at bass-invaded sites in a seasonally dependent manner, probably as a consequence of the increase in the abundance and behaviour of many grazing invertebrate taxa in reaches without indigenous fish.

Figure 12a,b. Algal



These results from the Witte River are complemented by those from the Ratels River which suggest that the predation pressure on aquatic invertebrates is reduced at bass-invaded and fishless reaches compared to reaches with indigenous fish; that the invertebrate assemblages are distinct between these three zones; and that algal abundance in summer is lower at reaches invaded by bass or without fish than reaches with indigenous fish (fig 13).

Figure 13. Epilithic algal abundance from reaches of the Ratels River in summer.



In conclusion

This study reveals findings that are novel from a South African and an international perspective. We show that invasive fish can have far reaching consequences for the ecosystems they invade. In particular, bass remove the indigenous fish, which reduces predation on many grazing invertebrates, which results in the reduction of algae. Therefore, invasive fish have far reaching consequences both for aquatic biodiversity and for ecosystem functioning.

There are still many outstanding questions relating to the impact of invasive fish, including performing similar studies for invasive fish species other than bass, but the prevention of further spread of invasive fish and their removal from rivers of high conservation value must be a priority.

Other activities conducted

River Rehabilitation Project

Cape Nature is currently investigating the feasibility of implementing a programme to eradicate invasive alien fish from selected rivers in the CFR. If approved, this project is to be funded by the World Bank, Global Environment Facility (GEF). Four Rivers of high conservation priority have been selected as initial sites: the Rondegat, Krom and Suurvlei Rivers in the Cederberg, Western Cape and the Krom River in the Langekloof, Eastern Cape. This project represents an opportunity to safeguard populations of threatened fish species and to address novel restoration and ecological questions on the following issues: the impacts of rehabilitation methods (e.g. rotenone) on South African aquatic invertebrates; the potential for rivers to recover from alien fish invasion; the response of the aquatic community to loss of biodiversity with insights into competition and the biotic determinants of river community structure.

An initial environmental impact assessment is being conducted on these rivers prior to final approval of the project. I am conducting the aquatic invertebrate component of the EIA to assess the presence of rare or endangered species or unique assemblages of aquatic invertebrates in the rivers to be rehabilitated and the potential sources of recolonisation should the rehabilitation method deplete aquatic invertebrate taxa.

The methodology used to address these issues will be repeated kick sampling (with <300µm mesh net) at selected sites in all biotopes in reaches upstream, within and downstream of the reach to be rehabilitated.

Activities completed to date

Sites have been selected for invertebrate collection on all four rivers. In April 2006, all sites were sampled with the exception of the Suurvlei. Comprehensive collections already exist from previous work conducted on the Rondegat River. All samples have been sorted and identified to family level but will be identified to higher taxonomic resolution once the project funding and EIA has begun (i.e. in 2008).

Objectives to achieve

For the EIA: All sites will be visited in December 2007 and invertebrates from the Suurvlei will be sampled in December 2007 and/or April 2008 pending final approval of the EIA.

Invertebrate Barcoding Project

A major 3-year project proposal has been submitted to the WRC and is awaiting approval. The project objectives are to use species and population-level information from DNA barcoding of aquatic invertebrates to:

1. assess the diversity and biogeographic patterns of aquatic invertebrates in the Cederberg as a tool for conservation planning.
2. provide base-line data to monitor river health and the impacts of climate change, land-use and invasive species on indigenous biodiversity.
3. assess how indigenous and invasive fish variably structure river ecosystems and influence diversity and ecosystem functioning.

Additional outcomes: To build an aquatic invertebrate tissue bank and database to be housed at SAIAB linking a voucher specimen, photograph, DNA sample, DNA barcode and attribute data; resolve the identity of cryptic taxa and species complexes; link invertebrate life-history stages (egg - larval instars – pupae – adults); monitoring protocols and fund-raising.

The methodology will be to sample aquatic invertebrates, algae and physical characteristics from 15 rivers throughout the Cederberg in reaches without fish, reaches with indigenous fish and reaches with invasive fish. 30 species have been selected in order to assess physical, ecological and geographic determinants of biodiversity.

Riparian Zone Rehabilitation Projects

The Riparian Rehabilitation Project, a keystone initiative coordinated by WWF-SA in partnership with Working for Water and many other organisations and stakeholders, has begun in the Kouga mountains of the Baviaanskloof, Eastern Cape to rehabilitate riparian zones invaded by alien plants. I have collected invertebrates and periphyton in two of the three target tributaries to serve as base-line data for monitoring the impacts of invasive plants and of the rehabilitation strategies on aquatic biodiversity. This project represents an opportunity for SAIAB involvement with conservation measures with potential for nation-wide implementation.

3 Agreed outputs

3.1 Research papers

- In August/September 2007, I re-evaluated the research findings from my MSc at UCT which was a collaborative project with Cape Nature. I prepared the work as a manuscript for publication entitled:

"The impact of invasive fish and invasive riparian plants on the invertebrate fauna of the Rondegat River in the Cape Floristic Region, South Africa" and submitted to the African Journal of Aquatic Sciences.

- The main body of the work is being prepared in a manuscript for submission to *Ecology* with the provisional title:

"Species substitution and trophic uncoupling: mechanisms for invasion-driven ecosystem change."

- Two additional manuscripts are in preparation:

"The influence of fish predation and interspecific competition on grazer diversity and behaviour"

"Sound production in Pseudobarbus burchelli (Cyprinidae)"

3.2 Environmental Education and Outreach

- SciFest 2006: I co-chaired a stand on life in rivers, dealing with aspect of biodiversity, food-webs, ecosystem services and conservation issues. The stand featured an artificial river environment with live invertebrates and also preserved invertebrates for viewing under the microscope.
- SAIAB Winter School 2006 and 2007: I presented a river ecology and aquatic invertebrate component of the winter school designed to augment the knowledge of undergraduates from a range of southern African institutions. Each of these courses involved a field trip, a lecture and laboratory invertebrate identification.
- Fort Hare lecture series: I gave a series of two lectures and two tutorials at Fort Hare University on river ecology and conservation and set an exam question.
- Raphael Center visit to SAIAB: I organised a visit of the Grahamstown-based Raphael Center AIDS outreach project to SAIAB where we talked about and looked at life in rivers and painted fish T-shirts with help from SAIAB communications.

3.3 Presentation of research findings

3.3.1 CIB annual research meeting: I presented preliminary findings of the project at the ARM in 2006 in a poster entitled "The community Impacts of a Fish Invader". At the 2007 ARM on 15-16th November, I presented a poster entitled "Trophic substitution: a mechanism for invasion-driven ecosystem change", which will highlight the main messages from the research project to date.

3.3.2 SAIAB and research community: The following seminars have been given at academic institutions with variously updated information with the title (or similar): "Community Impacts of a Predatory Freshwater Fish Invader".

DIFS/SAIAB seminar series: 2006 and 2nd August 2007.

Rhodes University Zoology Department: 29th August 2007.

University of Cape Town Zoology Department: 6th September 2007.

Future talks: Jan / Feb 2008. Otago and Canterbury Universities, New Zealand.

3.3.2 Conferences

Society for Conservation Biology (SCB) conference 2007, Port Elizabeth. Oral presentation.

Future projects for potential funding.

The following project proposals address questions that have arisen from the current work on the impact of invasive fish on river ecosystems.

Project 1.

Question: How do invasive and indigenous fish influence their resident river ecosystem?

(Suitable for Masters project or reduced to suit Honours project)

How: Manipulation experiments using artificial runs and exclusion/inclusion cages.

Rationale: One of the major criticisms of the work from the current project (see above) is that, despite being a convincing documentation of the impact of invasive fish, in the absence of experimental manipulation it is not unequivocal and could merely be a description of the difference between two river reaches. Results from small-scale manipulation experiments will not only support the current findings, but will allow further insights into the role of indigenous and invasive fish in the structuring of river ecosystems.

Study sites: Witte River and Vink River, Rooiberg winery (where land-owner willingness has been established through SAIAB), both Breede River tributaries.

Methodology: Note: for the first few months of 2008, I will be working in New Zealand on projects utilizing laboratory and field river manipulation experiments. The insights gained through this experience will hopefully be put to good use in this and other projects (e.g. with nutrient cycling).

Cages (area approx. 1.5m^2, mesh size 5mm) or artificial reaches (approx. 5m long) will be constructed and placed in or alongside the target river. Cages will be stocked with known numbers and masses of fish including: no fish (exclusion); bass only (not in indigenous fish reaches); indigenous fish (in invaded and uninvaded reaches). Stones (approximately 5 per cage) of uniform size and shape without algal propagules (i.e. scrubbed and dried) will be marked and placed in each cage as substrates for algal and invertebrate colonisation. Samples to be collected once a month (see below).

Time frame (start and finish dates are flexible by up to two months).

- October 2008: build cages and plan trip.
- November 2008: set-up field sites by installing cages and reaches (1 x 5-day trip).
- December 2008-March 2009: four monthly 3-day sampling trips (can be reduced).
- March 2009: remove cages and reaches and store at SAIAB or Cape Nature for future experiments (extra 2 days).
- October 2009: Complete analysis and write-up of results. Together with recent findings, submit manuscript(s) for publication.

Budget.

Materials: Cages = x10 at R500 each = R5000; artificial river reaches = x2 at R750 each = R1500; consumables e.g. net repair, bottles, microscope bulbs, tweezers, tubes etc = R1980 (total = R8480)

Transport: 5 trips with bakkie from Cape Town at 400km/trip at R2.50/km = R3000; 5 return bus fares from Grahamstown at R300 each = R1500 (total = R4500).

Accomodation: Free with landowner or Limietberg Reserve agreement.

Food: total of 19 field days for two people (38 days) at R40/day = R1520

Total = R14,500

(Co-funding possibilities from Rooiberg winery).

Project 2.

Title: The impact of invasive fish on crabs and frogs.

(Suitable for an Honours degree project or could be expanded to suit an MSc. project)

How: An assessment of the density and abundance of crabs and frogs at fish-invaded and non-invaded sites by: 1. experimental manipulation at one or two sites; 2. analysis of the occurrence of crabs and frogs over a broader geographic range of indigenous and invasive fish.

Rationale: We have shown that invasive fish can dramatically alter the river community at multiple trophic levels by direct and indirect mechanisms. We have not, however, studied the impacts on crabs or frogs. Both these taxa may represent a high proportion of the river's faunal biomass and therefore fulfil important roles in the river ecosystem. Crabs are adaptable omnivores throughout their life cycle, whereas frogs are variably algivorous (as tadpoles) or insectivorous (as adults). Both have high fecundity and (with the exception of tadpoles) can seek refuge from predation in or out of water. Gape limitation of the small indigenous fishes of many Cape streams restricts them to feeding only on small life-stages of crabs and frogs, whereas invasive bass are able to feed on all but the largest crabs. The ability of different prey species to co-exist with fish will likely be determined by the duration for which the prey is vulnerable. Crabs are known to constitute a large proportion of the diet of bass, whereas their feeding on tadpoles and adult frogs is less-well reported. To date, no studies have been published in South Africa that address the impact of invasive or indigenous fish on crabs or frogs. It is known anecdotally that the abundance of ghost frogs (*Heleophryne* sp.) is reduced in the presence of fish in South Africa, and a study of frog populations in lakes in the USA showed dramatic declines coincident with invasive trout and dramatic recovery upon removal of trout.

Study sites:

Witte River and at least one other (possibly the Wit River in the Baviaanskloof, Eastern Cape) for the experimental approach. For the broader geographic approach

Methodology: Crabs: repeated mark/recapture experiments using baited traps. Frogs: calls, captures and sightings on transects along river banks. The size and species of captured/recorded individuals will be noted and compared between sites.

Time frame

(start and finish dates are flexible, can be 2008 if a student is found).

- January 2009: build cages and plan trip.
- February – April 2009: Two or three 8-day field trips.
- May – June 2009: Write-up results.

Budget:

Materials: At least 12 crab traps (R250 x 12 = R3000). All other equipment to be supplied by SAIAB. Contingencies and printing = R220. Total = R3220.

Transport: If coordinated with project 1 then R1500 for bus fares or extra pick-up and drop-off to Cape Town or Worcester (if not coordinated, then R3000).

Accomodation: Free with prior arrangement.

Food: total of 16 field days for two people (32 days) at R40/day = R1280

Total = R6,000

Co-funding possibilities from Rooiberg winery.

Project 3.

(Suitable for honours project or done personally this author)

Question: Do invasive fish disrupt the aquatic food web?

How: Analysis of carbon and nitrogen isotopes ($\delta^{17}C$ and $\delta^{15}N$) in a variety of components of the river food web (including). The isotope analysis will be performed at Rhodes University's new isotope laboratory.

Rationale:

Tracking naturally occurring carbon and nitrogen isotopes ($\delta^{17}C$ and $\delta^{15}N$) through the food-web can yield essential insights into the movement of nutrients through an ecosystem and, therefore, how the ecosystem functions. This technique can unravel the essential and otherwise elusive question of who eats who in invaded as opposed to indigenous river reaches not only strengthening the findings of the current study on community impacts of invasion, but also providing an understanding of how rivers in the region function.

Study site:

Witte River

Methodology:

A collection of detritus, algae, macrophytes, fish, six target aquatic invertebrate species, drifting invertebrate prey and crabs will be made and the $\delta^{17}C$ and $\delta^{15}N$ analysed according to standard protocol.

Time frame (very flexible):

Collection. April – May 2008.

Analysis. May – September 2008.

Budget (this project will rely on other field trips so will not require transport costs)**:**

Sample analysis: 75 samples at R52 each plus R300 for possible sample re-runs = R6000.

Collection: an extra field day plus assistance, food and equipment = R500

Total = R6,500

These three projects are interrelated and can be coordinated to reduce logistical costs. Funding for Masters requires R40k for two years (R80k total) and R10k for honours. Co-funding: The Center for Invasion Biology, Stellenbosch will provide funding for this author for the next two years (April 2008-April 2010) although this has yet to be finalised. Also, SAIAB will provide all the laboratory and office space and equipment necessary for this author and any students associated with the projects.

- The minimum total cost of these three projects assuming that student funding can be sourced from elsewhere = **R27,000**
- The full cost of these projects including student funding (one MSc and two Honors) = **R127, 000**