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The impact of introduced trout on aquatic ecosystems

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Abstract

A study of brown trout interactions with stream ecosystem was conducted in Tasmanian streams. Direct and indirect interactions with macroinvertebrates and epilithic algae were studied. Two approaches were taken – a field survey comparing similar streams containing trout or now fish, and a mesocosm study evaluating the potential for trophic cascades under varying levels of shade.

The field survey consisted of separate sampling of macroinvertebrate epifauna and infauna, as well as algae, in three habitat types and with three levels of shading, in a set of trout-infested and fishless streams. The mesocosm study was used to assess the presence of trout – macroinvertebrate-algal interactions under carrying shade in a depositional environment. Strong trout effects on mobile, large, grazing predominantly epifaunal macroinvertebrate taxa were detected in the field survey, with the overall macroinvertebrate community also being affected. A high degree of trophic cascade was observed with algal abundance being significantly elevated in habitats experiencing strong trout-induced reductions in large grazing macroinvertebrates. The degree of these effects was controlled by both habitat type and degree of shading. Shade strongly controlled the intensity of trout impacts and resulting trophic cascades. Both the degree of trophic cascade and its control by light intensity was weaker in the depositional environment of the mesocosm trial, due both to the lower abundance of larger mobile taxa, but also the effect of algal self-shading.

Overall, three major factors controlled the intensity of trout impacts in streams – shading, type of dominant macroinvertebrate taxa (abundance, mobility and size), and habitat type. Brown trout are expected to have intense impacts on productivity and standing crop of both macroinvertebrate and algae in Australian streams. The degree of impact within a stream system is however dependent on a number of environmental and biological factors.

Project Objectives

- To assess the direct impacts of brown trout on aquatic fauna in Tasmanian streams using evidence from field surveys and stream mesocosm experiments;
- To assess the indirect impacts of brown trout on algae in Tasmanian streams;
- To assess the extent of and conditions which affect the degree of trophic cascade resulting from the presence of brown trout in streams;
- To compare the above responses to the presence of brown trout with those from native fish (*Galaxias* sp.).

Project Methods

This project formed the basis of W. Elvey's PhD (still being written as this report was being prepared, and hence not all analyses are completed). Initially the project was focused on impacts on lake systems in the Tasmanian Highlands, but owing to a number of logistical and design problems, the focus was changed in late 1997, soon after project commencement, to stream systems.
The project had two major, core components:

- a field comparison of similar streams with brown trout and without fish;
- an experimental evaluation of the effects of brown trout in artificial stream mesocosms on macroinvertebrate and algae, under varying light levels.

An additional component - an experimental evaluation of the effects of galaxiids (*Galaxias brevipinnis*) in artificial stream mesocosms on macroinvertebrates and algae – was conducted but not analysed further due to low abundances of macroinvertebrates and the resulting low statistical power.

A fourth component (funded separately) – a field comparison of stream macroinvertebrate communities between Tasmanian Highland streams with and without *G. brevipinnis* – awaits completion following termination of the PhD.

Field survey

Survey components

a) Are the impacts of trout on macroinvertebrates habitat specific? Comparison of macroinvertebrate communities from glide, riffle and run habitats.

b) Effect of trout on the diel substrate positioning and drift behaviour of macroinvertebrates: Do trout affect the foraging behaviour and movements of the dominant grazing fauna? Comparison of benthic positioning during night and day, and of drifting invertebrates during night and day.

c) The effect of riparian shading on the top-down effects of trout on macroinvertebrates and algae: comparison of the standing biomass of benthic algae and benthic abundance of invertebrate browsers from areas of streambed subject to heavy, medium or light shading in five streams containing brown trout and in four nearby streams that are naturally fishless but similar in habitat. The top-down effects of trout were predicted to decrease as shade increased if algae and macroinvertebrates were resource-limited under heavy shade.

Description of study sites

The study streams were all in the South Esk River drainage basin, northeast Tasmania. Electro-fishing surveys indicated that most streams contained brown trout; however, fishless sites are present where significant barriers (usually waterfalls > 2 metres) prevent the upstream movement of trout. We selected 6 stream sites containing trout and 6 stream sites with no fish. Six of these sites were in streams that had a downstream trout site and a fishless site upstream of a significant fish barrier. The remaining six sites were in separate but physically adjacent streams. The study sites run through wet sclerophyll forest and are generally subject to heavy shading from overhanging vegetation, although sections are subject to partial or full sunlight through windthrow or wildfire. All the study streams had similar instream habitats (third order streams with mean summer wetted widths of 2-6 m), and are dominated by low gradient erosional zones (glides and riffles) with a substrate of boulder and cobble surrounded by a matrix of coarse and fine gravel.

Faunal sampling

Benthic invertebrates: Sampling methodologies were identical for all components of the survey. Glides and riffles were sampled using a surber quadrat sampler. Separate samples were taken from epi-benthic (on top of the substrate) and infauna (within the substrate) habitats. Pool samples were collected with a sweep net. The epibenthic samples were pooled (usually 10 individual samples, occasionally 5), as were the infauna samples. All samples were preserving in 70 % alcohol before being taken back to the laboratory to be sorted and identified.

Drift: 4 trout streams and 4 fishless streams were studied. Three drift nets were set up in a glide section of each stream, each net separated by 30 – 50 metres. Nets were set for 8 hours during daylight, emptied, and then set during the night and again emptied.

Algal sampling

Algal samples were collected with a scourer sampler (Davies and Gee 1993) by taking a single sample from the top of 15 randomly selected cobbles (cobble diameter 50 - 200 mm) from each of the three levels of shading. We estimated algal biomass (as total chlorophyll *a* corrected for phaeophytin after extraction in 90% acetone: Greenberg et al. 1980).

Mesocosm experiment

We used bank-side plastic stream channels (4 m long, 40 cm wide by 40 cm deep) with stream substrate and flows that mimicked depositional habitats to test whether the top-down effects of brown trout can induce a trophic cascade in depositional habitats, and whether any trophic cascades are limited to high light environments. We allocated sixteen channels to four treatments: shaded channels containing brown trout; shaded channels containing no fish; unshaded channels containing trout, and unshaded channels containing no fish. The experiment ran for four months, at the end of which the channels were sampled for benthic invertebrates and algae. Greater top-down effects of trout in open than shaded channels were predicted if algal and macroinvertebrates were limited by available light in the shaded channels.

Data analysis

Both field and experimental components of the project used a split-plot design and split-plot analyses of variance (ANOVA) were used to analyse differences between the treatments in the mean abundance of the most common invertebrate taxa, mean drift rates and the mean biomass of benthic algae. We used univariate ANOVA to test for significance within the treatments in the case of interactions. After each ANOVA, residuals were checked for normality of error terms and homogeneity of variances to ensure that the assumptions of ANOVA were satisfied. If necessary the data were log or square root transformed and ANOVA models re-run and assumptions re-checked.

Project Results

Field survey

a) Habitat specific effects of brown trout on macroinvertebrates: Only epi-faunal abundance has been analysed to date.

- Effects of trout are progressively weaker from glides to riffles to pools.
- Glide habitats were dominated by baetid mayflies, cased trichopterans, stoneflies, larval elmids and chironomids. Large, mobile taxa were significantly reduced in trout than fishless streams: baetids and stoneflies three times less abundant, leptophlebiid mayflies five times less abundant. There was no difference in the abundance of small taxa (chironomids, larval elmids and cased trichopterans).
- Riffle habitats had a greater proportion of smaller bodied taxa (simuliids, adult and larval elmids, cased trichopterans. Baetids were over three times less abundant in fishless stream riffles than glides, and not significantly more numerous than in trout streams. Leptophlebiid mayflies were four times less abundant in trout than fishless streams, stoneflies three times less abundant.
- Pool habitats were dominated by chironomids and larval scirtids. Large bodied taxa were relatively rare, with baetids being very low in abundance. Stoneflies and leptophlebiids were also proportionately rarer than in glides or riffles, but were still significantly reduced in trout than fishless streams.

Conclusions:

Macroinvertebrate habitat preferences influence the effects of trout in streams. Large bodied, mobile taxa that are vulnerable to trout predation, in particular baetid mayflies, show preference for glide habitats, however, they are also most vulnerable to trout in these sections. Even when abundant, small-bodied taxa appear to occupy a size refuge from trout predation.

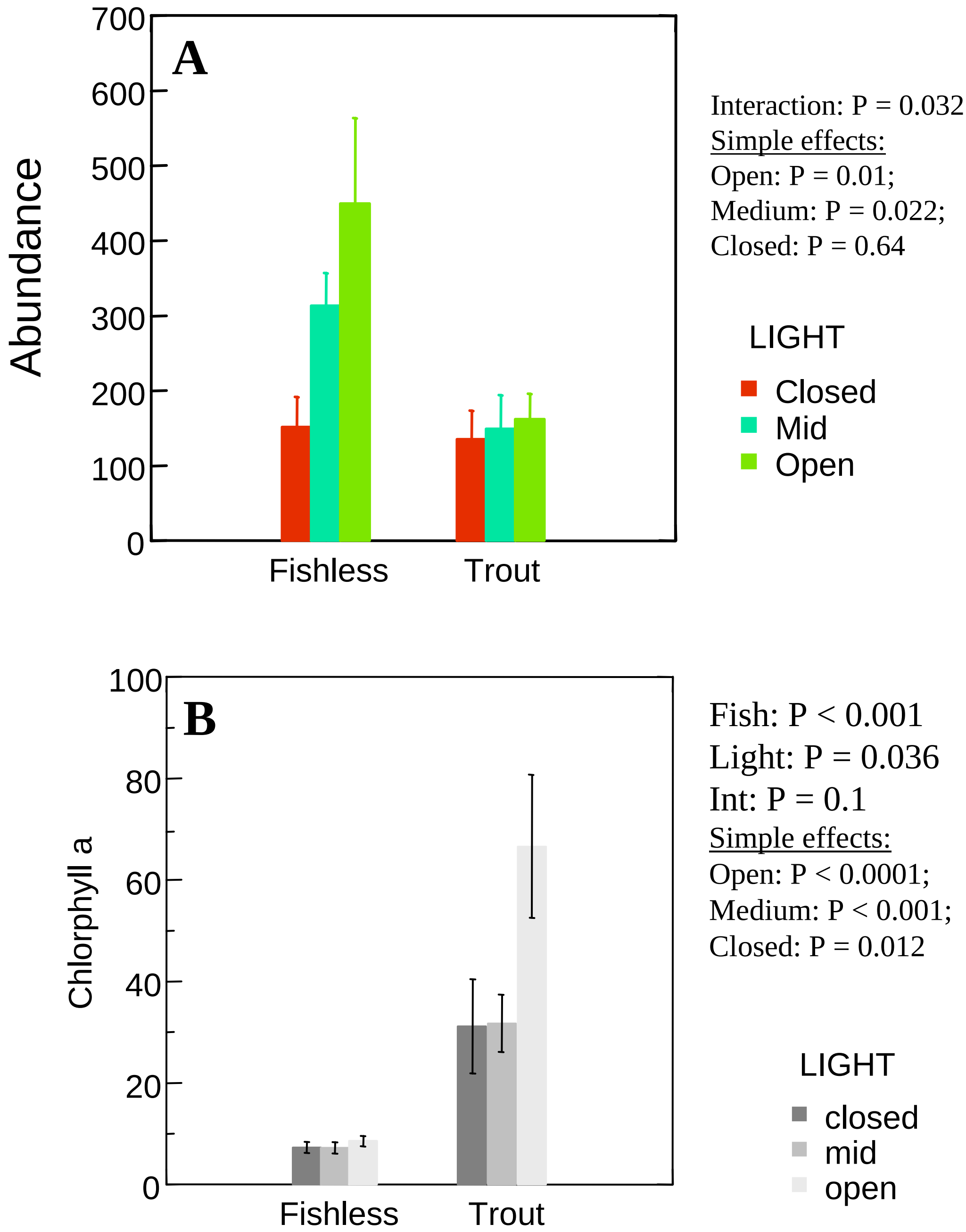

Figure 1. Epifaunal baetid abundance (A) and algal standing crop (B) in Tasmanian upland streams containing trout, compared with fishless streams, and interaction with level of shading.

b) Effect of trout on the diel substrate positioning and drift behaviour of macroinvertebrates:

- Drift was strongly nocturnal in trout streams and aperiodic in the fishless streams, particularly for large taxa such as baetids, stoneflies and leptophlebs.
- The effects of trout were greater on the epibenthic than infaunal macroinvertebrates.

- The effect of riparian shading on the top-down effects of trout on macroinvertebrates and algae:

- Trout and shading effects were largely limited to baetid mayflies and benthic algae. Grazing fauna was dominated by baetid mayflies which formed 70% of the total epifauna.
- In the fishless streams: baetids track decreasing shade, and therefore increasing algal productivity and the algae were grazed to low levels regardless of shade conditions.
- In the trout streams: baetids did not track decreasing shade and were generally reduced in abundance in comparison to fishless streams. However, the magnitude of this difference was affected by shading, with no difference under heavy shade, 2.1 times lower under medium shade and 2.8 times lower under light shade. The biomass of algae was four times higher in trout than fishless streams under heavy and medium shade, and eight times higher under light shade.

Conclusions:
Trout and baetids exert strong top-down control in these streams. The lower density of baetids and higher standing biomass of algae in trout than fishless streams is consistent with a trophic cascade. However, these communities are simultaneously limited by the effects of shading on the supply of resources. That is, shading influenced the strength of top-down control with the greatest difference in the abundance of baetids and biomass of algae seen under the lowest level of shading. Variation in shading, and hence variation in the productivity of benthic algae, influenced trophic interactions by affecting the behaviour and distribution of baetid mayflies.

Mesocosm experiment

- The fauna of the stream channels was dominated by detritivorous fauna, small in body size and rarely present in the drift.
- Highly vulnerable taxa such as highly mobile, large bodied mayflies were relatively rare.
- The top-down effects of fish were generally weak, the three most numerous taxa *Riethia* sp. (Chironomidae: Pseudochironomini), and the mayflies *Nousia* sp. and *Tasmanocoenis* sp. were unaffected or weakly reduced in the presence of trout.
- A small trophic cascade was recorded with the biomass of benthic algae 1.4 fold higher in trout than fishless channels; however, the size of the trophic cascade was not significantly affected by shading.
- The effects of shading had a greater effect on algae than trout did with biomass two fold higher under open than shaded channels.

Conclusions:
Our prediction that a greater trophic cascade would occur in the unshaded channels was not supported. We suggest that the depositional habitat in the channels resulted in a detrital, rather than algal, dominated food web that dampened strong top-down interactions. This dampening probably occurred through suppressing the growth of algae via self shading, particularly in the unshaded channels, and by influencing the

identity of the prey community, with a low proportion of the large bodied mayfly taxa usually associated with trophic cascades in streams. The importance of cascading interactions in stream communities may, therefore, be subject to both heterogeneity in habitat conditions and to the identity of the prey community.

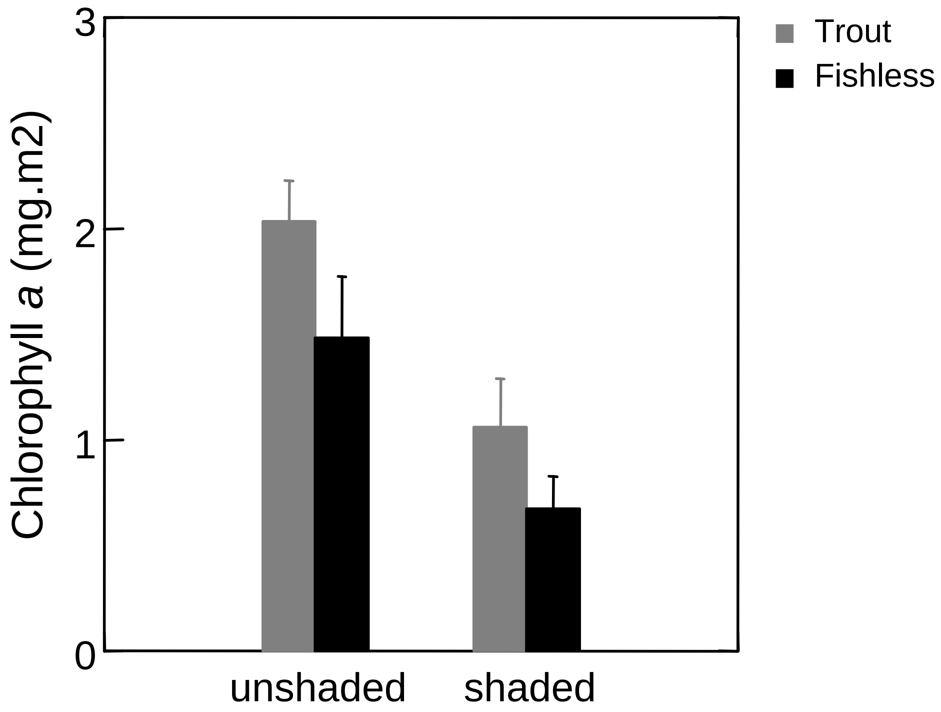

Figure 3. Mean benthic biomass of algae at the end of the mesocosm experiment in unshaded channels with trout, unshaded channels without trout, shaded channels with trout, and shaded channels without trout.

Communication activities

Seminars

Attended joint conference of Australian Society of Limnology and the New Zealand Society of Limonology in New Zealand (1999): presented talk on mesocosm experiment. Attended International Society of Limnology conference in Melbourne (2001): presented talk on mesocosm and survey data.

Publications in preparation

All PhD Thesis data chapters are being written as papers. Mesocosm experiment draft has been submitted to Canadian Journal of Fisheries and Aquatic Science. Shade survey chapter in preparation for submission to Canadian Journal of Fisheries and Aquatic Science. Remaining chapters will be submitted to Oecologia.