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E-Futures

Mini-project report

Effect of a small hydropower scheme on the aquatic macroninvertebrate community

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ASSIGNMENT COVER SHEET 2011/2012

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Mini-Project Mark Sheet

Student: **Grade:** fail/satisfactory/good/very-good/excellent

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Feedback:

	Excellent	Good	Average	Poor	Very Poor	Not Done	Not applicable
Introduction to the problem / subject							
Statement of aims							
Experimental description							
Presentation of results / findings							
Quality and depth of discussion / interpretation							
Relevance of conclusions							
Quality of English							
Use of reference material							
Evidence of external reading							
Quality of presentation							
Use of figures							

Comments:

Effect of a small hydropower scheme on the aquatic macroninvertebrate community

Jim Uttley, University of Sheffield

Abstract

There is currently little empirical evidence available to support claims that microhydropower is environmentally benign. Possible effects include a reduced wetted area and nutrient flow in the depleted stretch which may affect the aquatic ecosystem. In this study macroinvertebrate samples were taken from two upstream locations and a location in the depleted stretch of a picohydropower scheme in North Yorkshire, England. Data suggested macroinvertebrate species diversity was reduced in the depleted stretch compared with the upstream locations, with the Shannon-Wiener index being significantly lower in the depleted stretch compared with the other locations. Although limitations exist with this study due to the unavailability of hydrological data, these findings suggest further research is required to better understand the effect of microhydropower on the aquatic ecosystem and possible causes of such effects.

Introduction

Hydropower has been used for centuries to produce mechanical energy, and, since the 19^{th} century, to produce electricity (Bakis, 2007). It has long been touted as an alternative form of energy generation to help the world make the necessary move away from fossil fuels. Hydropower accounts for 19% of the world's electricity (Paish, 2002), and the IEA predict that global hydropower output will increase from 2,809TWh in 2004 to 4,749TWh in 2030. However, concerns have been raised about the environmental impacts of large hydropower schemes, such as disruption to the transfer of sediment and nutrients, changes to the natural fluctuations in discharge levels, prevention of the flooding of floodplains, and the creation of wider or shallower rivers (de Leaniz, 2006). Concerns have also been raised about the human socio-economic impacts of creating a large hydropower scheme, for example the displacement of communities living in the flooded reservoir area. As a result of these concerns there has been a shift in favour from large hydropower schemes to small hydropower (SHP) schemes. Definitions of SHP vary but it is generally accepted that schemes with a capacity of <10MW can be classed as SHP (e.g. Paish, 2002; SNIFFER, 2011). SHP has been seen as more environmentally acceptable than large hydropower. For example, the BHA (2005) claim SHP is environmentally benign as any dam or barrage is small with little or no water storage and thus not having the same kind of adverse effects as large scale hydro. Paish (2002) also claimed that *"small-scale hydro…is one of the most cost-effective and environmentally benign energy technologies"* (p. 537). The relatively small-scale of SHP has also been claimed as one of the factors that limit its effect on the environment: *"the negative riverine impacts of hydropower dams diminish with plant size…small or micro hydropower systems have extremely minimal riverine impacts"* (Kosnik, 2008, p. 3252). As well as being perceived as environmentally benign, capacity for growth in SHP energy output is significant. For example, global potential capacity for SHP is estimated to be above 100GW, with the UK having 100MW of SHP capacity from around 120 sites (Paish, 2002). As much of the potential for SHP remains untapped and it is perceived to have minimal adverse environmental impacts, many countries are planning to expand the use of SHP significantly (Abbasi and Abbasi, 2011). Some researchers have raised concerns over this planned global expansion in SHP as they claim there is little empirical evidence to support the suggestion that SHP is any more environmentally benign than large hydropower (e.g. Abbasi and Abbasi, 2011).

Ultimately the evidence about the true environmental impacts of SHP is relatively limited, certainly compared to that provided for large hydropower "…there appears to be an acute lack of hard evidence about the impacts of run-of-river schemes on fisheries and other biota" (SNIFFER, 2011).

There are a number of possible effects SHP can have on a river and its ecosystem. The initial construction of the scheme is likely to cause issues such as noise, visual intrusion, increases in suspended matter and turbidity and disruptions to river flora and fauna (IEA, 1998). SHP generally relies on a small impoundment to control river flow and this can cause various issues such as preventing fish migration (Lucas et al, 2009), disruption of sediment dynamics, alterations to the diversity and abundance of biota in the river (Renofalt et al, 2010) and reductions in access to breeding, feeding and nursery habitats (Mader and Maier, 2008). The impoundment or weir also creates an upstream backwater with increased sedimentation, altered habitats and reductions in dissolved oxygen, all of which affect the river ecosystem. SHP creates a depleted stretch of river between the point of abstraction and the point at which the water is returned. The depleted stretch will have less wetted area and a resulting reduction in aquatic habitat (Kubecka et al, 1997). SHP also potentially alters the river's flow regime which will have a major impact on the aquatic environment, as flow is a major determinant of a river's ecological characteristics and the biodiversity of its aquatic organisms (Gilvear et al, 2002; Enders et al, 2009). Reductions in flow caused by SHP potentially also result in a number of changes to the river hydrology, including water velocity, sediment transport, turbidity, bed and bank stability, wetted width and water depth and temperature (SNIFFER, 2011).

Despite the range of potential effects SHP can have on a river and its ecosystem, the subject has not been studied in great depth. The current study aimed to examine the effect of a SHP scheme on the ecosystem of the river on which it was sited, specifically looking at the macroinvertebrate population. Macroninvertebrates are a useful indicator of river quality and ecological health. The structure of the invertebrate community reflects the health of the wider ecosystem (Reice and Wohlenberg, 1993), invertebrates for example are a food source for many other aquatic species (Fette et al, 2007). Invertebrates can also be used as a biological indicator of important river variables, such as water pollution (e.g. Hawkes, 1998) or flow characteristics (Extence et al, 1999).

Method

The SHP site chosen for this study was Bonfield Ghyll in North Yorkshire. Bonfield Ghyll is a picohydropower scheme providing 1kW of power to a farmhouse not connected to the grid. Three minute kick sampling was used to obtain invertebrate samples from locations upstream of the hydropower scheme, in the depleted stretch, and downstream of the depleted stretch and leat outfall. At each location the sampling comprised of six 30-second collections in selected areas in order to provide a representation of the habitats at that cross-section of the river. Samples were collected by a postgraduate student (Catherine Leonard, University of Sheffield) and due to time constraints with the current project only samples from Upstream 1, Upstream 2 and Depleted Stretch locations were analysed. Two upstream locations were included in the study to provide a baseline for the 'natural' river but also to examine whether the SHP scheme had any effect on ecosystem health before the river reaches the weir, leat and depleted stretch. Upstream 2 was further upstream than Upstream 1 in order to determine how far up the river any effect from the SHP may have reached. Unfortunately one of the current study's limitations is that data regarding the sampling locations, such as distance from the weir or weir pool, was not available and cannot be reported.

Samples collected from the Upstream 1, Upstream 2 and Depleted Stretch locations were identified to family level using appropriate keys (Croft, 1986; Merritt et al, 2008).

Results

Six replicates were analysed for each of the locations sampled (Upstream 1, Upstream 2 and Depleted Stretch). Each location acted as an independent variable, n = 6. A mean of 101 invertebrate specimens were collected in each sample (s.d. = 73), the mean numbers of invertebrates collected at each location did not differ significantly. The most abundant invertebrate family was *chironimidae* in all but one replicate. Invertebrate samples were analysed using a number of metrics. Species diversity was measured using the total number of unique families and the Shannon-Wiener index. Water pollution was measured using the British Monitoring Working Party score (see Hawkes, 1998) and Average Score Per Taxon. River flow regime was measured using the Lotic Invertebrate index for Flow Evaluation (Extence et al, 1999).

Figure 1 – Mean S-W index by location

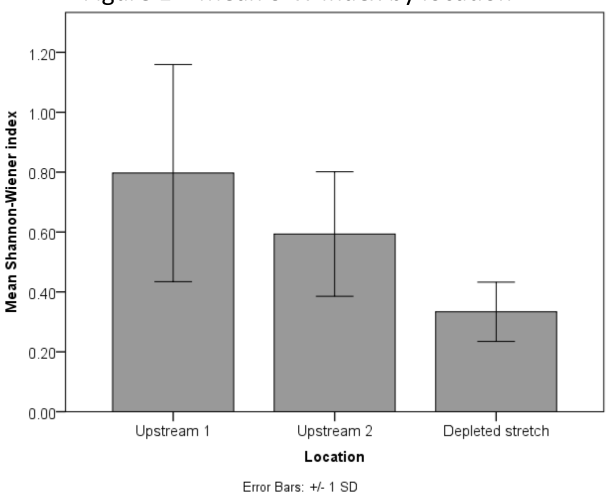

Figure 2 – Mean number of families by location

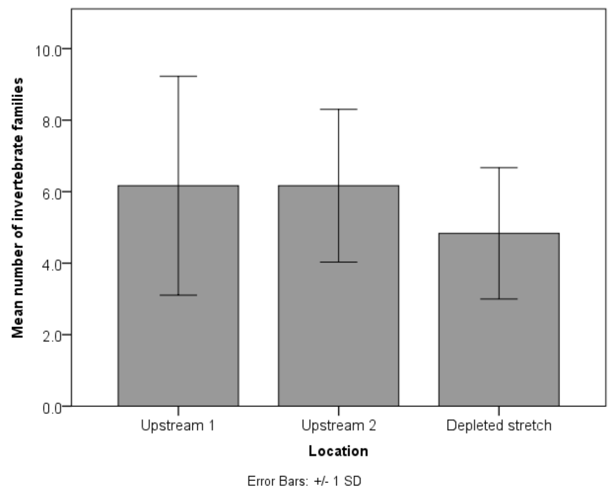

Table 1 in the Appendix shows the mean scores on each of these indicators. As the data was normally distributed for each indicator a one-way ANOVA was carried out for each of the indicators to determine whether the scores differed significantly between locations. The only difference between locations was on the Shannon-Wiener index ($F(2,15) = 5.26$, $p<.05$). Post hoc tests revealed that the Depleted stretch location had a significantly lower Shannon-Wiener index (M = 0.33, s.d. = 0.10) than the Upstream 1 location (M = 0.80, s.d. = 0.36) – see Figure 1. Like the Shannon-Wiener index, the number of unique families found at each location is a measure of species diversity. This indicator was also suggestive of differences between the depleted stretch and the upstream locations, as illustrated in Figure 2, although this difference wasn't found to be significant.

Discussion

Bonfield Ghyll is a very small hydropower scheme providing 1kW of power output. The current study examined the macroinvertebrate community in locations upstream of the hydropower scheme and in the depleted stretch of river after the point of abstraction. The aim was to draw conclusions about the impact a hydropower scheme has on macroinvertebrates and, by extension, the river as a wider ecological system. The study found that species diversity, as measured by the Shannon-Wiener index, was significantly reduced in the depleted stretch compared with a location upstream of the hydropower scheme. No difference was found between locations for other indicators. The BMWP score and ASPT are indicators of pollution levels. If pollution was present upstream of the SHP scheme it could be argued that this may be concentrated in the depleted stretch due to the reduction in water volume. However, if pollution levels are minimal upstream to begin with we would expect no noticeable increase in the depleted stretch. As the Bonfield Ghyll site is in a very rural and relatively isolated area it's likely that pollution levels upstream are minimal, thus resulting in no difference in pollution indicators for the upstream and depleted stretch locations. Upstream and depleted stretch locations also showed no significant difference on the LIFE score suggesting no great changes in the flow regime of the river. It is difficult to ascertain reasons for this without physical, hydrological measurements from the site, which were unavailable for the current study.

There are a number of possible explanations for the reduction in species diversity in the depleted stretch. The abstraction of water from the river for use in the hydropower turbine is likely to have created a reduction in wetted area and therefore essential invertebrate habitat (Kubecka et al, 1997). Habitat complexity has been shown to increase with water depth, velocity and cover (Gorman & Karr, 1978; Schlosser, 1982; Felley & Felley, 1987). All these variables are likely to be reduced in the depleted stretch making the river in this area less likely to support a variety of invertebrate species, compared with areas of the natural river regime. It is also likely that the hydropower weir and abstraction of water have altered nutrient dynamics with the potential of a reduction in available nutrients in the depleted stretch to support a range of invertebrate species. The depleted stretch may also have been affected by an increase in temperature, as a result of reduced flow and shallower depths. Invertebrate species that are sensitive to temperature changes may be less likely to thrive in the depleted stretch (e.g. Floodmark et al, 2004), thus contributing to a reduction in the diversity of species found. Changes to the natural river flow may have also contributed to reduced species diversity, as flow can affect the aquatic habitats available and thus the organisms that are present (Lake, 2003; Anderson et al, 2006). However, the LIFE score in the depleted stretch was not significantly different to the upstream locations, and without hydrological measurements (these were unavailable during this study) it is difficult to confirm this as a possible cause of reduced species diversity. Finally, Copeman (1997) suggests an invertebrate community living in a river with low hydrological variability may be more likely to be affected by flow fluctuations caused by a SHP scheme as they will be less adapted to this variability. If the river upon which the Bonfield Ghyll scheme is sited does have low hydrological variability this may be a factor in the reduced species diversity in the depleted stretch. However, without hydrological measurements from the site it is difficult to confirm this as a possible explanation.

The current study has provided some suggestive evidence that a SHP scheme may have a detrimental effect on a river's ecosystem, specifically the diversity of invertebrates in the depleted stretch. However, there are some major limitations to the study which restrict the conclusions that can be drawn. No physical or hydrological measurements of the river were available during the project which has made it difficult to correlate ecological findings with first-order effects on the river, such as flow, wetted area etc. Data from downstream locations (beyond the leat outfall) were also unavailable during the study so longitudinal effects when the river has returned to its 'natural' state could not be ascertained. It is possible species diversity returned to upstream levels downstream of the depleted stretch but this is unknown. The SHP scheme studied is very small (1kW output) and therefore it is not possible to extrapolate findings from this study to other SHP schemes due its unique nature and size. Finally, it's not possible to ascertain a causal link between the SHP scheme and the reduction in species diversity in the depleted stretch as other factors may be involved that have not been controlled for, such as naturally lower flow rates in this area of the river.

Despite the limitations present in this study it does support the view of other researchers (e.g. Abbasi and Abbasi, 2011) that the environmental neutrality of small microhydropower should not be taken for granted and further research is required to determine the full range of possible effects microhydropower can have on the riverine system and how these could be mitigated.

Appendix

Table 1 – Descriptive data for river quality metrics, by sample location

	Indicator	Invertebrate families	Shannon-Wiener index	BMWP score	ASPT	LIFE index
Depleted stretch	Mean	4.83	0.33	23.50	5.13	6.33
	Standard deviation	1.83	0.10	9.73	0.68	0.52
	Range	3-8	0.20-0.46	14-42	4.6-6.0	6.0-7.0
Upstream 1	Mean	6.17	0.80	25.83	5.02	6.88
	Standard deviation	3.06	0.36	12.88	0.55	0.66
	Range	4-11	0.26-1.15	14-45	4.3-4.6	6.0-8.0
Upstream 2	Mean	6.17	0.59	21.00	4.67	6.75
	Standard deviation	2.14	0.21	9.78	0.76	0.61
	Range	3-9	0.35-0.89	12-34	4.0-5.7	6.0-7.5

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