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Research Paper

Moving from multiple pass depletion to single pass timed electrofishing for fish community assessment in wadeable streams

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ABSTRACT

Area-delineated multiple-pass depletion electrofishing (ADEF) can be resource-intensive. It may not capture fish community state when resource limitations mean that the number of sites sampled in a system is insufficient to account for ecological heterogeneity. Rapid assessment techniques such as single-pass timed electrofishing could be more efficient and support increased sample size, but it is important to understand how resulting catches will relate to existing ADEF data/time series. Paired ADEF (3-pass) and single-pass timed (10-min) electrofishing (TEF) samples were collected for sites in the River Barrow catchment (Ireland) in 2015. Paired samples were used to derive species-specific size-based conversion factors (*CF*) for extrapolating TEF catch up to a predicted ADEF Pass 1 catch. Applying these *CF* to a set of independent 'validation' TEF samples (2008–2013) produced fish catch estimates similar to observed ADEF Pass 1 catches (2008–2015). Species size-distributions in extrapolated TEF data were also similar to those in paired ADEF Pass 1 samples. Pass 2 and Pass 3 catches by species were then predicted from extrapolated validation TEF catches using a regression model. Cumulative catch curves fitted to these predicted catches were similar to those fitted to observed ADEF catch data for most species. TEF samples provide estimates of fish species catch and size-distribution that can be extrapolated following a simple protocol and compared with ADEF data for small streams measuring up to 10 m in width.

1. Introduction

Fish communities are widely used for assessing the ecological state of rivers and streams (Fausch et al., 1984; Angermeier and Karr, 1986; FAME CONSORTIUM, 2004). Biomonitoring of European aquatic ecosystems using fish and other biological quality elements has developed substantially since the implementation of the Water Framework Directive (WFD) in 2000 (2000/60/EEC) (Birk et al., 2012). The WFD requires European Union (EU) member states to conduct on-going assessment of the ecological status of surface waters. Assessing change in state typically requires standardised sampling methods that can provide consistent and measurable metrics of fish community (e.g. species diversity and abundance). Standardized survey protocols attempt to ensure that sampling is repeatable, that estimated metrics are comparable among years and systems, and that measurement uncertainty can be expressed. Metrics estimated with standardized sampling can be invaluable for identifying vulnerable populations, monitoring changes in state related to the management of specified pressures, communicating with stakeholders and providing direction for more in-depth assessments. Large-scale standardized surveys, such as those used for the fish community element of the WFD, can be resource-intensive (Foley et al., 2015; Kelly et al., 2007; Meador et al., 2003). Economic and staff resources may limit the spatial coverage of sampling, including survey stretch length (Foley et al., 2015; Meador et al., 2003), the number of sites that can be sampled and the extent of complementary data collection, including abiotic measurements.

When designing a sampling and assessment programme, a balance is required between objectives, available resources and the importance of results (Kelly et al., 2007). Achieving such a balance can involve a trade-off between sampling effort and adequately recording species diversity and a measure of species abundance or density. Ideally, any sampling method should maximize the return of information with the minimum effort. Electrofishing is a well-established technique used by fishery biologists for sampling river fishes and it is frequently the most non-destructive, effective and cost-efficient approach. The effectiveness of electrofishing surveys depend on many different factors including power output and frequency, gear configuration (number of sets and operators), the shape and size of the electrodes, conductivity and the size of the channel being surveyed (Beaumont et al., 2002).

The optimum sample size for estimating species richness may be that after which species richness reaches an asymptote; a number of methods have been deemed effective for this purpose (Angermeier and

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Smogor, 1995; Lyons, 1992; Paller, 1995). Attaining sufficient samples to reach the asymptote can be achieved by adding additional sites (Bateman et al., 2005; Paller, 1995; Wyatt, 2002) or by increasing the length of the surveyed stretch (Hughes et al., 2002; Temple and Pearsons, 2003). The number of fished sites that must be sampled to reach a richness asymptote is low in Irish rivers due to limited species diversity and this makes the possibility of reaching an asymptote much greater than it would be in much more diverse systems elsewhere (Chao et al., 2009) or in systems where there are many rare species (Gotelli and Colwell, 2011). Therefore, for species diversity alone in these systems, less resource intensive sampling efforts can suffice. Assessment of fish abundance or density at a given site is usually conducted by removing fish in a series of successive passes. The added sampling effort increases the chances of recording species missed during previous passes within the system and also increases the likelihood of achieving a species richness asymptote. The quantitative area-delineated multiple pass depletion method of electrofishing (ADEF) (Zippin, 1956; Bohlin et al., 1989) has been used for over 60 years to support such assessment of river fish communities (Schmutz et al., 2007; Teixeira-de Mello et al., 2014). When applying the ADEF, sampling sites are isolated using stop nets up- and down-stream. The method is highly effective but resource intensive, particularly on wider streams. A simpler electrofishing sampling approach is the semi-quantitative single pass electrofishing survey, which uses the fish caught in one pass to calculate a minimum estimate of the fish population. For more specific fish assessments, such as the assessment of juvenile salmonids at the catchment scale, a rapid semi-quantitative timed electrofishing method (TEF) may be used, such as that developed by Crozier and Kennedy (1994). Such a technique has been used to undertake catchment wide surveys of juvenile *Salmo salar* and *Salmo trutta* (0+) fry (e.g. Crozier and Kennedy, 1995; Gargan and Roche, 2011). The use of a standard unit of time generates an abundance index that can be compared among sites. Semi-quantitative timed (10 min pass) electrofishing was adapted by Inland Fisheries Ireland (IFI, 2009) to monitor salmonid and other fish species and to cover all morphological features (riffle/glide pool) present at a given site.

Multiple pass electrofishing like ADEF involves more staff equipment and time than TEF. ADEF may also have greater environmental impact; electrofishing can affect fish both physiologically and behaviourally depending on the level of exposure and may take up to 24 h to recover (Mesa and Schreck, 1989). Electrofishing mortality rates increase with sampling intensity (Habera et al., 1996; Panek and Densmore, 2013). Reducing the sampling effort by using TEF could help offset some of these negative impacts (Kocovsky et al., 1997; Panek and Densmore, 2013). Both resourcing and environmental impact issues create an incentive to shift towards TEF, and this shift would be acceptable under guidelines within the European standards (CEN 2003). However, there are various issues to be considered before adjusting a sampling programme that contributes to state assessment time series (e.g. WFD). A key potential disadvantage is that TEF may be less efficient than ADEF at catching species or size groups that are rare or that have low catchability (Bertrand et al., 2006; Paller, 1995; Vehanen et al., 2012), which may bias community level assessment metrics. However, research suggests that possible information loss due to reduced precision and accuracy in single-pass electrofishing can be compensated for or even improved upon by the potential to use resource-savings to increase sampling coverage (Bateman et al., 2005; Jones and Stockwell, 1995; Paller, 1995) and/or to sample a more representative range of sites in heterogeneous river systems (Edwards et al., 2003; Bateman et al., 2005; Reid et al., 2008).

When introducing new sampling methods, it is important that the new data can be comparable with existing time series and associated ecological state assessments. Implementation of more efficient TEF methods will benefit from a robust protocol for adjusting catches to support comparison with current ADEF catches. The current study aimed to (1) compare catches between TEF and ADEF methods, and (2) develop a protocol for extrapolating catch from the rapid assessment TEF technique so that it can be compared directly with existing catch time series from the established ADEF method. The proposed TEF method may provide another useful tool for fisheries researchers and managers looking to carry out large sampling programmes in a more cost-effective manner.

2. Material and methods

Paired samples were collected from the River Barrow catchment (Ireland) in 2015, and comprised fish catches at the same site using both ADEF and TEF with sampling events spaced closely in time. These samples were used to support development of a catch extrapolation protocol for expanding observed TEF catch to a predicted ADEF catch. Independent archived data sets from other Irish rivers collected using each of the two electrofishing methods were then used to validate the proposed catch conversion protocol, i.e. to compare observed and predicted ADEF catch.

2.1. Study area and sites

The River Barrow catchment in south-eastern Ireland was chosen as a suitable study area due to its relatively diverse network of tributaries (Fig. 1). The Barrow is Ireland's second longest river measuring over 180 km in length, with a catchment of approximately 3000 km^2. The tributaries of the Barrow catchment include lowland streams draining peatland, streams traversing agricultural and pastureland, and small to high gradient channels. Independent alkalinity data (EPA 2013–2014) from sites on tributaries within the River Barrow catchment range from between 40 and 345 mg/l $CaCO_3$. The underlying geology of the catchment is varied, consisting predominantly of limestone to the west and granite to the east. Of the 36 paired sites (P-Sites), 22 could be classified as having calcareous underlying geology, with the remaining 14 siliceous. The length of each survey site was measured using a measuring tape, from downstream to upstream stop net for ADEF samples and start to finish points for TEF samples. Wetted width was taken as the mean of at least three transects, spaced evenly along the length sampled. Depth was recorded at five locations along each transect, with the mean of all values taken as the mean depth. The maximum depth was taken as the maximum of all depths recorded.

2.2. Fish sampling at paired sites (P-Sites)

Thirty-six sites were surveyed using both ADEF and TEF electrofishing methods at low flow levels during July and August 2015 (Fig. 1). Sites were selected to cover a diverse range of habitats, including riffle, glide and pool. Estimates of recovery time after electrofishing range from 1 to 24 h (Peterson and Cederholm, 1984; Mesa and Schreck, 1989) and are dependent on factors including amount of exposure, number of shocks and handling stress. ADEF and TEF surveys were split between different teams of operators. Both methods were conducted on alternating river sites concurrently but with a minimum gap of two weeks and maximum gap of one month between samples at any given site to enable the fish and river habitat to recover to a normal state. Electrofishing was carried out in an upstream direction using bank-based units (Electracatch International (now Smith-Root) WFC4 units with Honda 10I Inverter generators) set with a typical output of 50 Hz and 100–200 V. All surveys began at the downstream end of a riffle where possible. Differences in physical dimension (depth, width and surface area) were tested using paired *t-t*-tests with alpha = 0.05 (PAST, 2015).

All fish caught were held in buckets of fresh cold oxygenated water until processing, which was carried out promptly after each electrofishing pass. After processing, fish were returned to the river as quickly as possible to avoid further stress. All fish except for lamprey were identified to species level and counted; lampreys were identified to genus. Fish fork-lengths (cm) and weights (to the nearest 0.5 g) were recorded.