Drift net performance for larval fish sampling in rivers.

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Drift Net Performance for Larval Fish Sampling in Rivers

1.1 Abstract

Deploying small-mesh drift nets in rivers is a well-established method for sampling drifting fish larvae and eggs. Quantitative comparisons are sometimes made on the basis of numbers of larvae captured per unit volume or time. In this study a GoPro ™ camera was mounted inside the drift net to record the change in flow over time (1 to 5 minute intervals for 3 hours) at the same time flow was measured using an analog flow meter. Although a small number of net nights (7 nights at 3 locations) were sampled, variance in the change in flow within and between sites was observed – even during soak times as little as 2 hours. In one case there was almost no change in flow over 180 minutes but at the most extreme, the flow dropped from 8.9 m^3/min to 1.5 m^3/min in just 160 minutes. Variance is probably caused by the level of suspended particulates at different sites or times. If volumetric or temporal estimates are made on the basis of total flow through the net only, they could in some cases be misleading and at worst make comparisons almost meaningless. While there are dedicated data logging flow meters available they are prohibitively expensive for routine sampling. Researchers could consider the method used in this study to cost effectively assess the decay in net performance during sampling.

1.2 Introduction

Freshwater larval fish sampling often uses drift nets suspended in a flowing river to sample larval fish and few studies take into account error that may arise because of clogging (Faulkner & Copp, 2001). The nets are set for various periods, ranging from less than one 1 hour to 24 hours depending on the situation and species targeted. Quantitative spatial and temporal conclusions have been drawn from studies using this method (Tonkin, King, & Mahoney, 2007) (Humphries, 2005). For example some larval fish are believed to drift at night or at particular times of night and so drift nets are specifically deployed to measure such variation.

Some investigations have been conducted on soak duration (Culp & Garry, 1994) and net performance and modification to nets to increase capture of stronger swimming species (Tonkin et al., 2007). Nevertheless it remains the case that the error associated with clogging and decay in drift net performance is rarely considered in detail and could be improved with sampling protocol changes to minimise variance.

Sample volume and its effect on drift density measurements was described by Culp et al in 1994 who showed that larger sample volumes from longer samples produced drift density estimates with lower sample variation than shorter sample durations. However, clogging also needs to be minimised because it can reduce velocities and cause error in volume calculations and therefore drift density (Faulkner & Copp, 2001) . (Culp & Garry, 1994) also noted that longer sample durations may lead to more sample and so raise the cost of sample processing.

1.2.1 Classifying Type of Performance Decay

As would be expected the nets catch material drifting down the river such as algae, leaves, suspended mineral particles, periphyton and plankton which over time have the effect of slowing the rate of flow and therefore the volume filtered by the net and in turn any derived calculations such as catch per unit effort (CPUE). This decay in net performance over time (net filtration rate) might be linear, accelerating or decelerating (Figure 1).

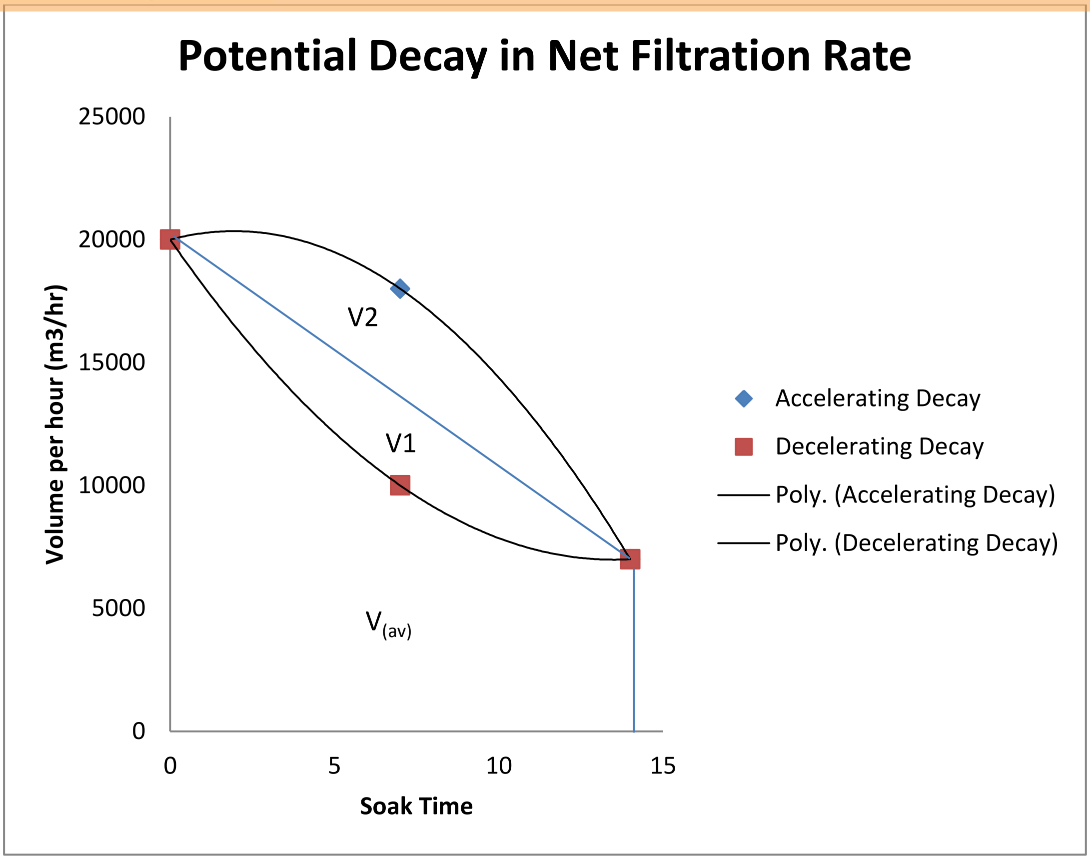

Figure 1: Potential decay paths showing potentially non-trivial variation that may arise in total volume filtered if decay in net filtration rate is assumed to be linear.

1.2.2 Using Set and Pull Flow Rates to Predict Volumes

During a study of larval fish movement in the Murrumbidgee River, Australia the question arose regarding the change in net performance arose after comparing the measured volume that passed through the net, to that which might be predicted using point flow measurements at set and pull times, using an analog flow meter deployed in the mouth of the net. Set and pull flow rates are commonly used for volume calculations. The large disparity between the two suggested that the relationship may not be linear.

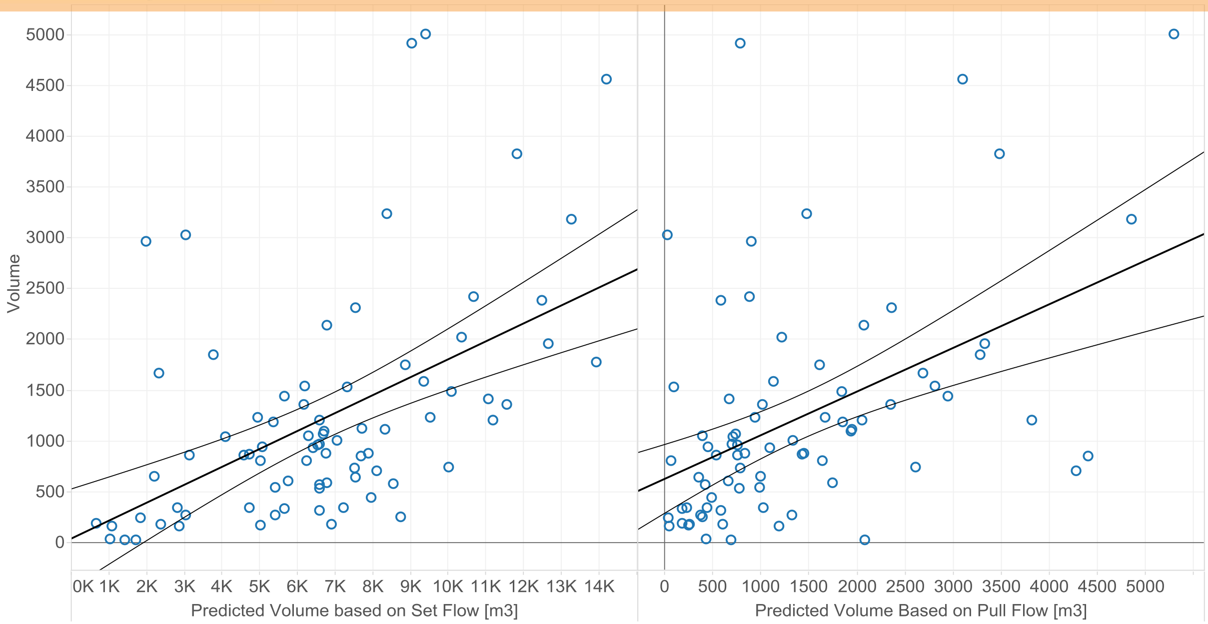

Figure 2: Relationship between the predicted volume passing through the net based on set or pull readings and the true volume passing through the net. The true volume was determined according to the manufacturer's instructions and the total number of turns of the analog flow meter for the soak period. Set or pull readings are shown on the X axes, against the true volume on the Y axes.

The flow rate at pull Volume= 0.43*Predicted Volume from Pull Flow + 625, r^2=0.22, P<0.0001) is a poorer predictor of total volume than the flow rate at set Volume= 0.17*Predicted Volume from Set Flow + 37.6 (r^2=0.26, P<0.0001) (Figure 2). The average of both the flow rate at set and pull is an even better predictor of total volume. While using the average leads to a better estimate of total volume filtered it also assumes a linear decay in the performance of the net Figure 3. However, it may be that as the net becomes clogged, it becomes more clogged more quickly because the holes in the filter are effectively reduced in size potentially trapping smaller particles in the water (accelerating clogging, decelerating decay in filtration rate). Alternatively it may be that the net slows in clogging over time because the diminishing throughput of water, and therefore diminishing amount of flotsam entering the net (decelerating clogging, accelerating decay). Either can change the total volume of water filtered by a non-trivial amount (Figure 1).

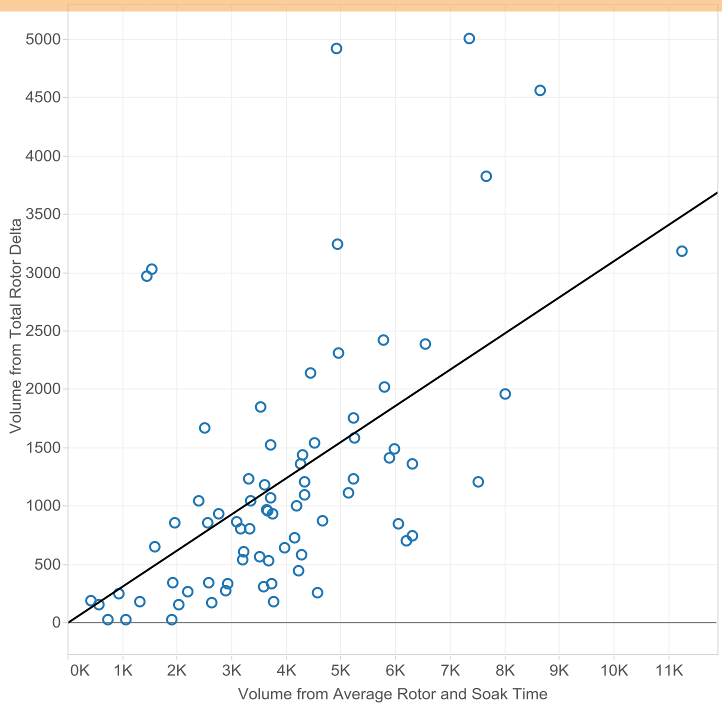

Figure 3: Actual volume measured by the flow meter in 2012 sampling and the predicted volume using the average of the point flow measurements at set and at pull, for the duration of the soak.)

We can see from the regression equation for the line in Figure 3 (Volume= 0.34*Predicted Volume -142.195 (r^2=0.34, P<0.0001) that the total volume filtered is only about one third of that which is predicted using the average of the flow as measured at set and pull. This could be because the net clogs and slows quickly (decelerating decay in net filtration rate) or that the reading obtained at pull time is a poor proxy measure for the total volume filtered because of the disturbance causing a poor measure of flow. It is likely a combination of these two factors.

To measure the decay in net filtration rate during net deployment and get a better appreciation for when during the soak time the water is filtered, a flow meter that sequentially logs flow and time would be required. Unfortunately most affordable flow meters are not data loggers. There are a couple of approaches to solve this issue in an affordable manner and obtain a better estimate of volume filtered by the net and therefore a more accurate estimate of CPUE. One approach is to capture continuous flow rate data for the whole period. There are flow meters with data loggers built in (Valeport, 2014) but unfortunately these tend to be prohibitively expensive. This preliminary study describes a novel but simple method to cost effectively measure the change of performance of drift nets deployed in rivers over time.

Better understanding of the net performance decay may have implications for deciding optimal flow rate, appropriate soak durations and minimum acceptable flow rate to prevent loss of target species. In turn this could lead to better catch per unit effort (CPUE) calculations, making more valid spatial or other comparisons using data from drift net sampling. This is particularly so when drawing density or temporal conclusions about larval drift from data collected with drift nets.

1.3 Method

1.3.1 Netting

A drift net (0.5mm mesh) was suspended on a chain across the river and below a riffle at three separate sites on two or three nights over a three week period in December 2014 in the Murrumbidgee River. The sites were selected to ensure sufficient flow for the net function and flow meter (3-9 m^3/min). Most drift net protocols make an estimate for flow over the period by deploying a flow meter in the mouth of the net to measure the rate at which water enters the net and from this a volume can be calculated knowing the diameter of the net to calculate the volume of the 'cylinder' of water that has been filtered.

1.3.2 Flow

The net had a General Oceanic's flow meter (Figure 4) suspended in the opening to measure the flow rate, which, given a known area of the opening of the net ($0.2m^2$) was used to calculate the volume of water that has passed through the net according to the following formulae:

Given, Standard Speed Rotor Constant = 26,873 (manufacturer ("General Oceanics Flowmeter," 2012)) then the:

DISTANCE in meters = Difference in COUNTS (X) Rotor Constant/999999

VOLUME cubic meters = 3.14 (X) (Net Diameter)² (X) Distance/4

Thus in this case where net diameter =0.5 m, the equation applied was:

$$Vol(m^3) = (3.141*0.5 * 0.5 * \Delta count * 26873/999999)/4$$

$$Vol(m^3) = \Delta count * 0.00527$$

$$Vol(ML) = \Delta count * 0.00527/1000 \quad (1)$$

1.3.3 Camera

We set up an underwater video camera (GoPro™) to periodically record the meter readings. By mounting the camera on the frame of the net a series of images of the meter were made, each with a time stamp.

A GoPro Hero 3 camera was attached to the drift net rim with cable ties ensuring it was pointing towards the counter on the centrally mounted flow meter. It was configured to record one image per minute. The light sensitivity of the camera is high allowing acceptable image quality even under somewhat turbid conditions. The total soak time was between 16 and 18 hours, but image data was collected for the first 180-220 minutes of the soak. This time during which data was collected was limited as a function of the unmodified battery life of the camera. The net was rinsed between each netting event.

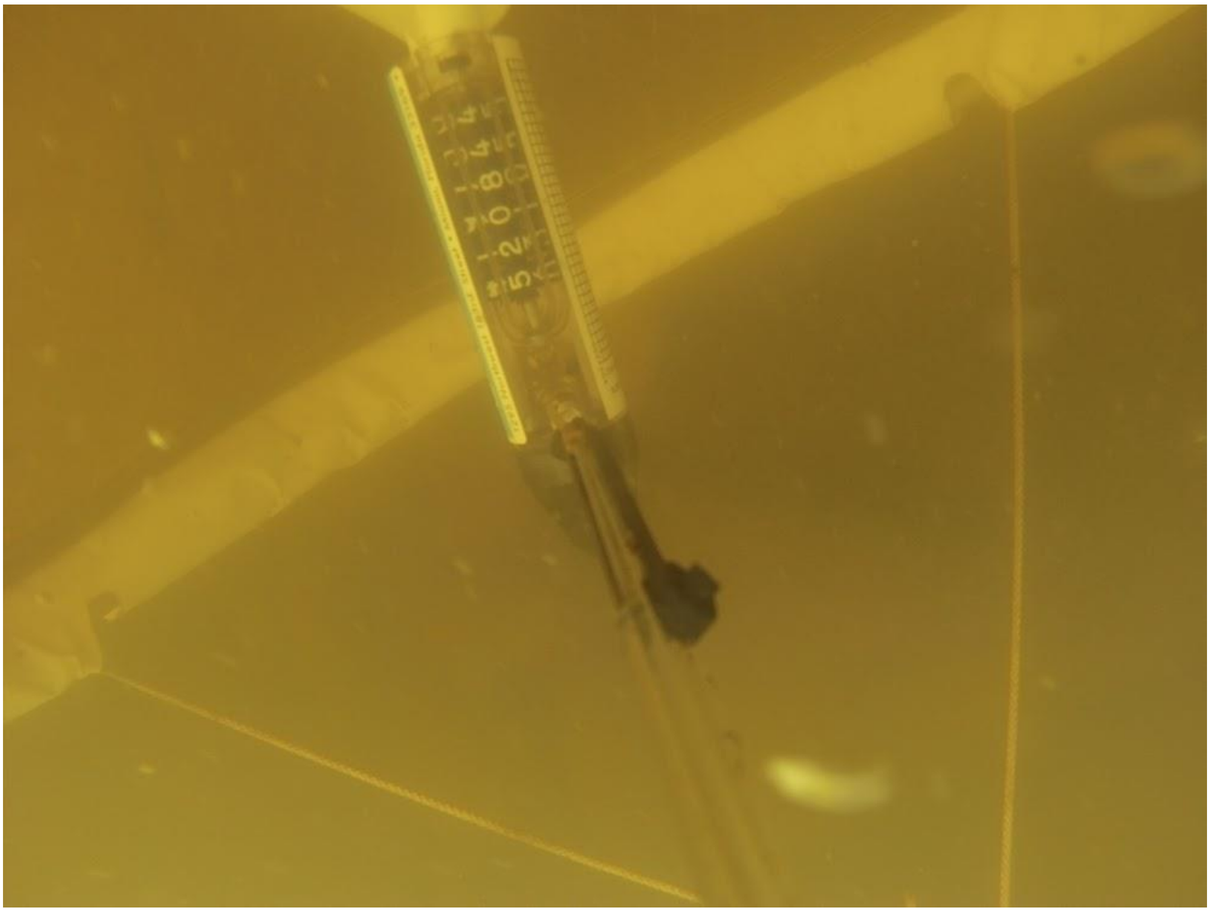

Figure 4: Image from camera mounted inside drift net to record flow meter readings each minute for first three hours of soak period.

The flow meter count from images at 5 minute intervals was recorded and converted to flow and volume using equation (1) and (2) and graphed to visualise change over time. Data cleansing was performed with MS Excel, and calculations, statistics and graphs were done using Tableau and R. From this 5 minute periodic data a decay curve was plotted.

The first three hours (180 minutes) was used to compare volumes within and between sites for netting events. The volume filtered after 180 minutes until the end of soak was calculated using above formulae and by 'numerical integration' (Roy Haggerty, n.d.) which assumes a linear decay model for this portion as there is no intermediate data.

1.3.4 Turbulence

Net Turbulence may also indicate change in flow pattern during the sampling period.

The angle of the flow meter to the net were measured using Universal Desktop Ruler (AVPSoft, 2014) between the front line of the net frame and the line of the flow meter (Figure 5)Figure 5: Measuring angle from images as a proxy for turbulence inside the net. . Angles were converted to a ± Ø° for plotting. In this way 90° below became 0° deviation from the net flow.

Figure 5: Measuring angle from images as a proxy for turbulence inside the net.

1.4 Results

1.4.1 The First Three Hours of Soak Time

Despite the small sample size (n=7) it appears that there is variation in the rate of net performance decay within and between sites over the first 180 minutes of soak time (Table 1).

The time to sample half volume ranged from 50 minutes to 96 minutes (mean= 75 minutes). If it was linear net performance decay we would expect 50% of the volume to be sampled at 90 minutes. Comparing the mean 75 minutes, with the expected mean of 90 minutes using a one sample t-test suggest there is only a 6% chance that this difference is due to chance. It appears likely therefore that decelerating decay in filtration rate rather than liner decay is most common during the first 3 hours.

Table 1: A disproportionately large portion of the total sample is sampled within the first 3 hours of the soak duration.

Site Name	**Date**	**Volume Sampled (m^3)**	**Soak Time (min)**	**Time to sample 50% of volume (min)**	**Time to Sample %age**
Nerreman	2/12/2013	413	180	50	28
Lanyon	4/12/2013	693	180	80	44
Bullen	5/12/2013	928	180	56	31
Lanyon	12/12/2013	366	180	96	53
Bullen	13/12/2013	958	180	80	44
Nerreman	16/12/2013	424	180	75	42
Lanyon	18/12/2013	566	180	90	50

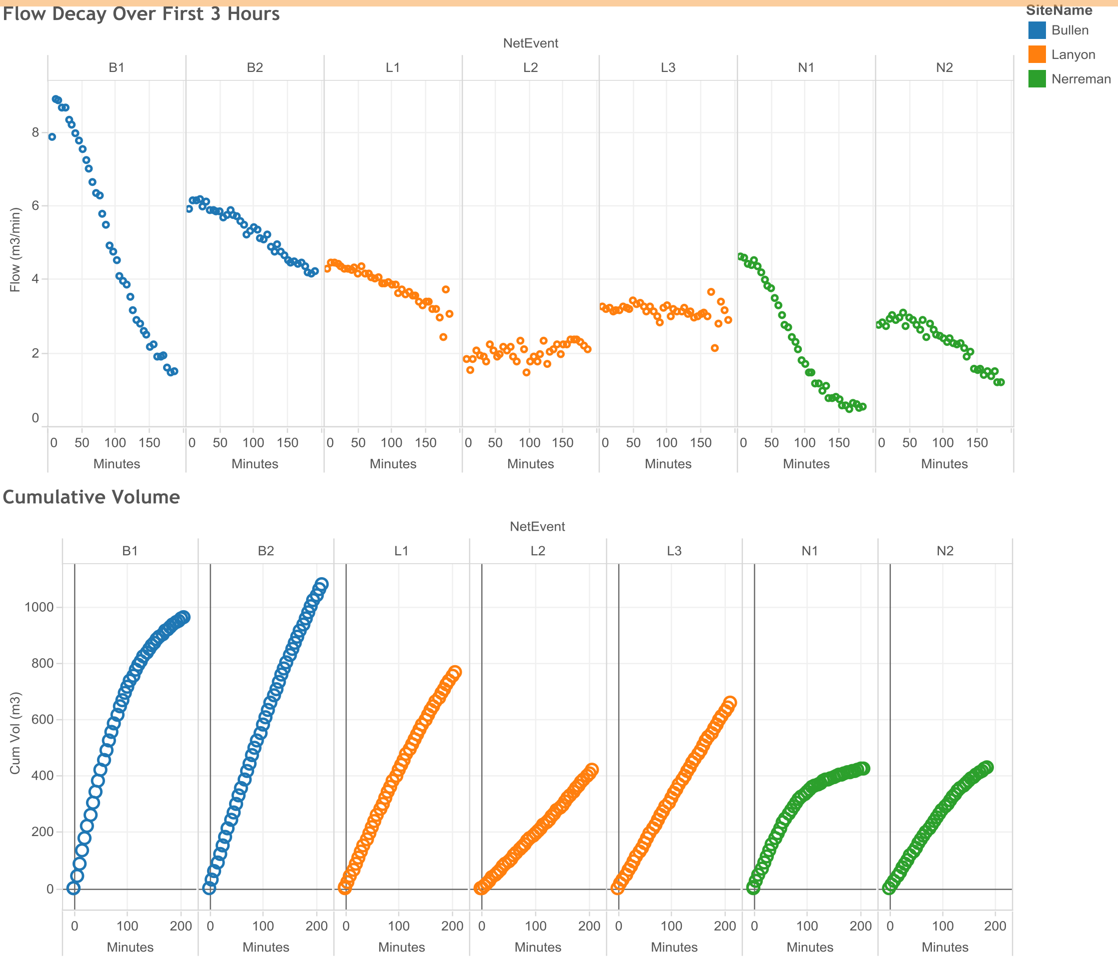

Figure 6: Net performance decay curves differ between three sites and differ at the same sites on different days.

In Figure 6 it can be seen that the net performance decay curves differ between sites and differ at the same sites on different days. Examples of no performance decay (L2), accelerating (N2), decelerating (B1) and linear net performance decay (L1) are apparent within the first 3 hours of filtration.

1.4.2 Total Soak Time

Over the total soak time all cases indicate that the decay in filtration rate is decelerating as on average 43% of the total volume is sampled by 3 hours (just 15% of the soak time). There is a significance difference between the proportion of the total volume sampled in 180 minutes with that which would be expected after 180 minutes if the decay had been linear (two-tailed t-test, $p = 0.0021$). While it is unsurprising that there is decay in net performance over time, or even that the decay is decelerating, it is useful to observe how quickly it occurs when sampling and particularly the variance that occurs between and within sites.

Table 2: A disproportionately large volume of water is sampled in the first three hours which is about 16% of total soak duration.

Site Name	Date	Volume Sampled (m^3)	Soak Time (min)	Time to sample 50% of volume (min)	Time to Sample (%age)	% of sample completed in three hours
Nerreman	2/12/2013	730	1110	115	10	57
Lanyon	4/12/2013	2321	1080	>200	-	30
Bullen	5/12/2013	1843	1199	176	15	50
Lanyon	12/12/2013	2003	1105	>230	-	18
Bullen	13/12/2013	1868	1192	175	15	51
Nerreman	16/12/2013	621	1087	185	11	68
Lanyon	18/12/2013	2264	1064	>217	-	25

There is a high variability between sites and between netting events at the same site. A disproportionately large volume of water is filtered early in the soak period in all cases (Table 2).

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Figure 7: Net performance decay curves differ between sites and differ at the same sites on different days over the whole soak period..

In Figure 7 it can be seen that the net performance decay curves differ between sites and differ at the same sites on different days over the whole soak period. For the whole soak time all appear to show decelerating decay with the possible exception of L2.

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1.4.3 Flow Angle – Also Varies Over Time

Net Turbulence may also indicate change in flow pattern during the sampling period.

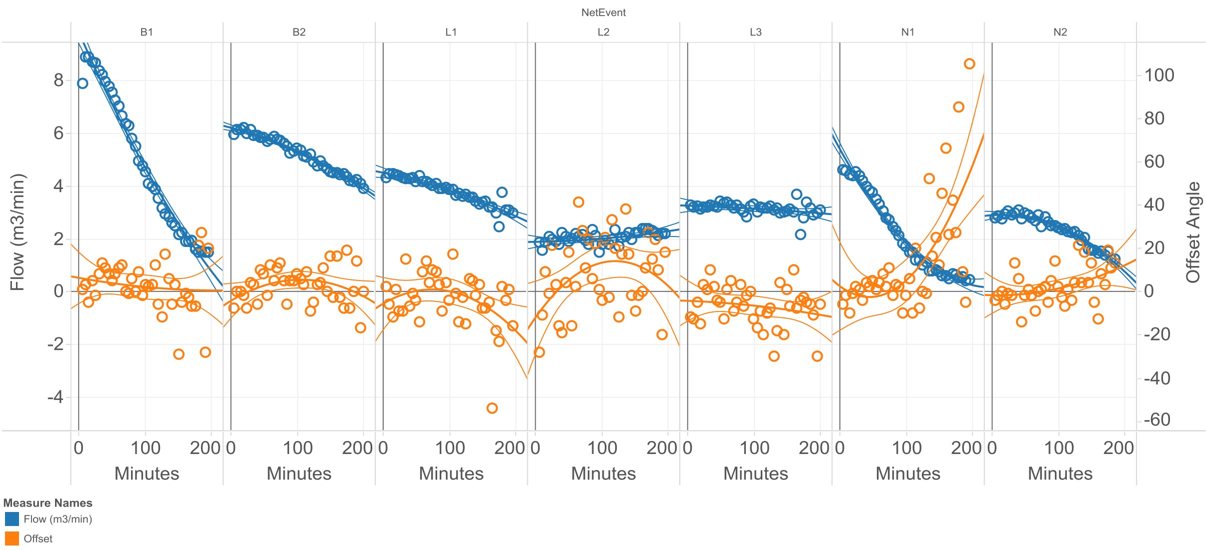

Figure 8: Turbulence change during the first three hours of a netting period.

In some cases turbulence increase late in the period, in others it peaks in the middle and in others there is no apparent change across the first three hours of a netting period (Figure 8).

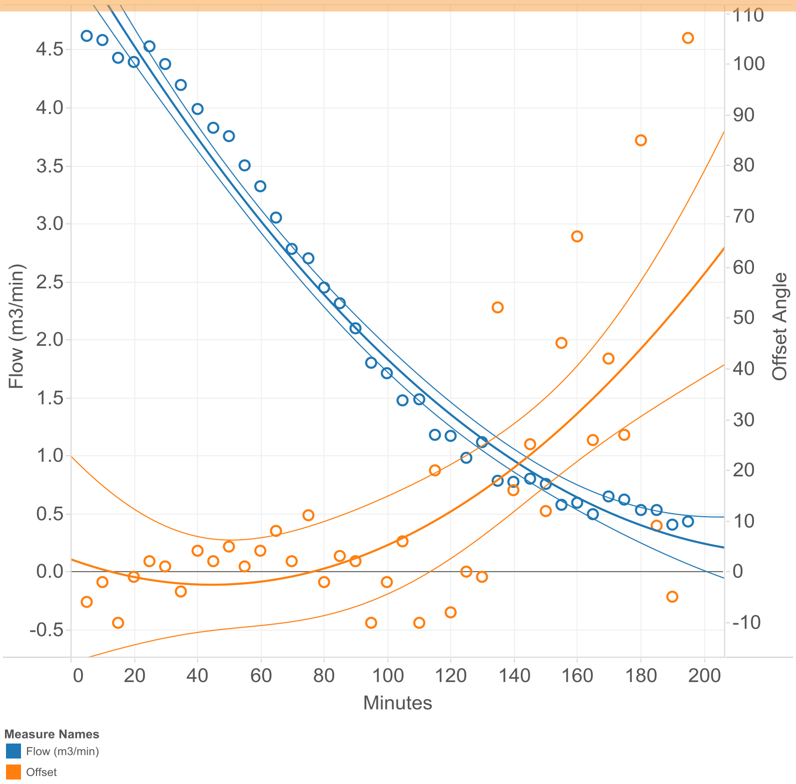

Figure 9: Diversion from the laminar flow expected in a drift net over three hours for netting event N1.

The example in Figure 9 from one example netting event starts with laminar flow with the flow meter angle at about 0° for about 100 minutes. This represents the flow meter in line with the net as would be expected when the water is passing smoothly through the mesh. After about 120 minutes the flow becomes non-laminar or rough. In this case the flow was diverted mostly to one side in some cases the turbulence diverts the flow meter in both directions Figure 10.

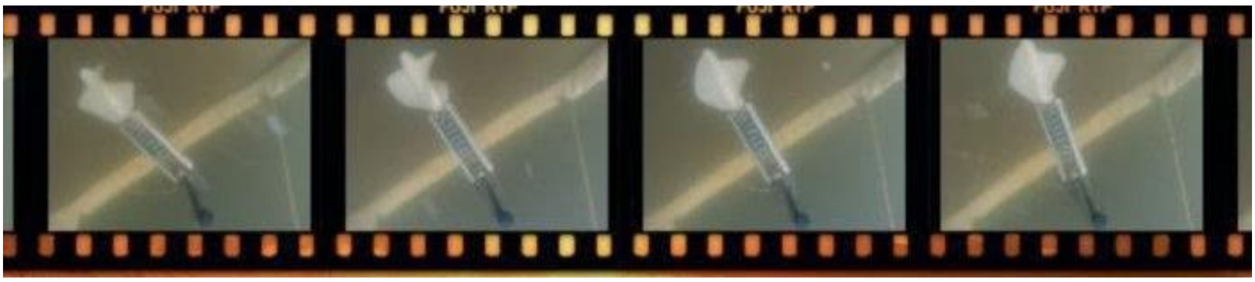

Figure 10: Examples of Turbulence as indicated by angle of the flow meter in the net mouth.

Turbulence provides some measure of change in flow but over 3 hours it does not provide as much information in all cases as flow speed. It may be worth measuring turbulence over the entire period or towards the end of the soak time when most disruption to flow and net performance is likely.

1.4.4 An example case – further explored.

In some cases net performance drops of rapidly – approaching asymptote in as little as 3 hours. This will have has a major impact on volume calculations and therefore any derived catch per unit effort calculations if the larvae do not drift with approximately the same frequency throughout the sample period. For example if the larvae only drift at night, or at dusk or dawn, the volumes of water sampled in total will not give a reliable estimate of density of the sample.

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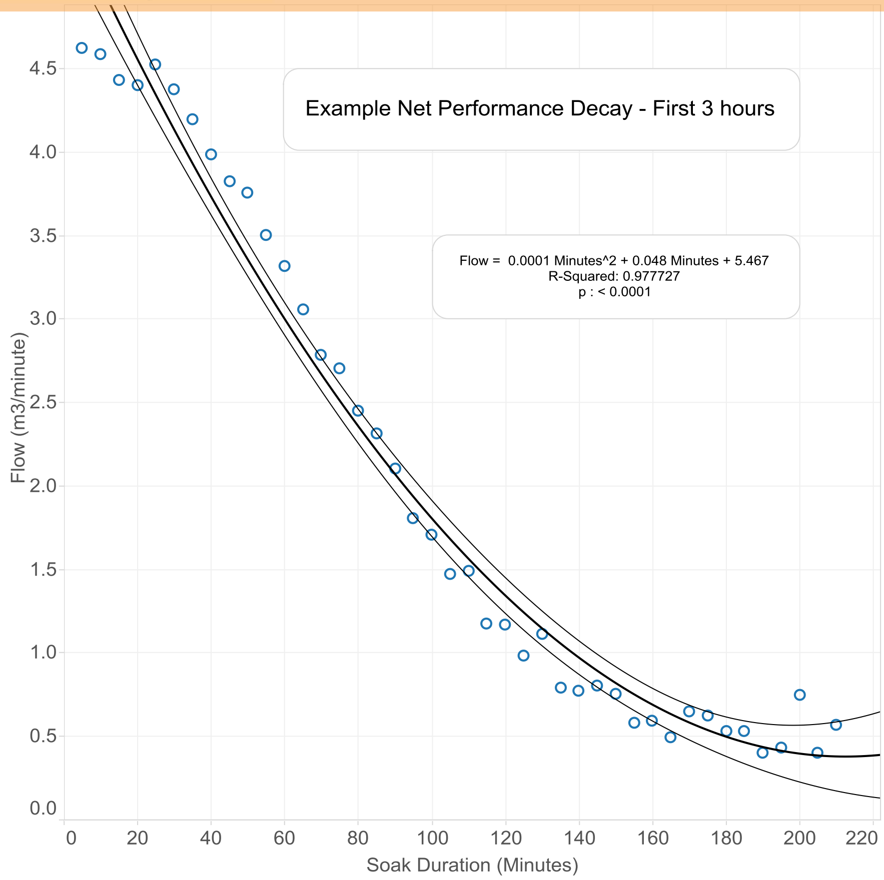

Figure 11: Decay in net performance over the first 3 hours at site N1 on 2 December 2013.

In this case 50 % of the total water filtered in the first 3 hours is done in the first 50 minutes. In total 58% of the water filtered is done in the first 3 hours. If no decay was occurring 16% would be expected to have been sampled in the first three hours.

When we consider the total volume, 730 m^3 in this case, much of it (443 m^3) was filtered before the sun set at 20:04 hours (approximately at 267 minutes after net set). Allowing also for the portion of the volume that was sampled after the sun rose 05:42 hours (265 min before net was pulled - another 120 m^3) means only about 290 m^3 was sampled during the night hours. This would have a major impact on any larval density calculations that assume night-time drift.

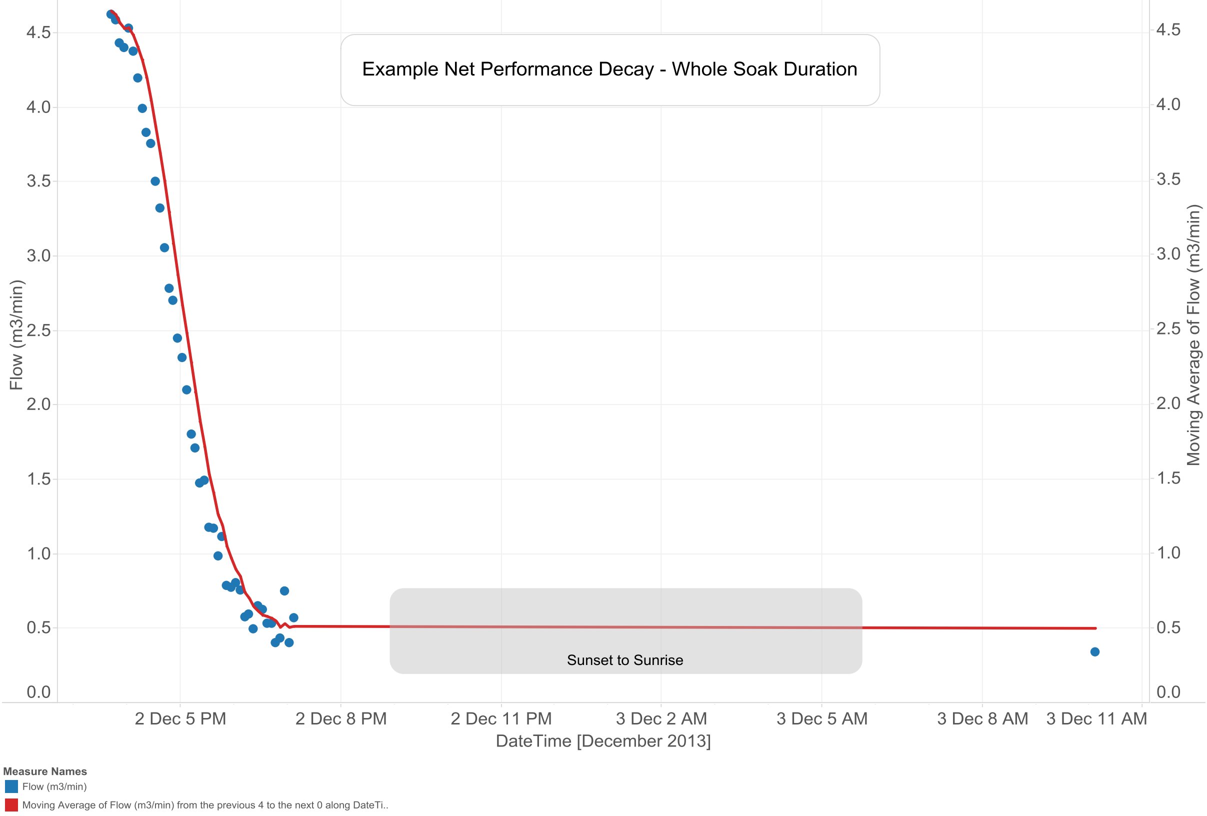

Figure 12: Decay in net performance over the whole soak duration at site N1 on 2 December 2013.

1.4.5 Hypothetical larval Drift

It may be helpful to consider the potential effect of flow variability on numbers expected in a sample using a hypothetical example. If, for the aforementioned sites, volumes and durations the density of larvae is 40 larvae per 1000 ML and that when they drift they do so in accordance with a normal Poisson distribution. The larvae could drift evenly throughout the day, drift during the day only or drift during the night only. This allows us to calculate an estimate of the number of larvae we could expect to catch during these netting events with these variables and there is considerable variation.

Table 3: Number of larvae expected under three hypothetical conditions of drift.

Site	Even Drift (50:50)	Day Drift	Night Drift
N1	32	21	11
L1	106	44	62

B1	81	50	32
L2	84	33	51
B2	180	83	96
N2	36	18	18
L3	110	40	70

Table 3 provides estimates of larvae that would be expected to be caught. If we standardise to the same volumes for each of the sites the effect is more apparent Table 4.

Table 4: Number of larvae expected under three hypothetical conditions of drift after standardising for volume.

Site	Even Drift (50:50)	Day Drift	Night Drift
N1	40	26	14
L1	40	17	23
B1	40	25	15
L2	40	16	24
B2	40	19	21
N2	40	20	20
L3	40	14	26

1.5 Discussion

The present study suggests that a greater proportion of the volume filtered by a drift net set in a river will occur early in set period if there is any material in the water that can clog the net. This has implications for the temporal and spatial conclusions that may be drawn from the use of drift nets without considering the changing flow rate over the duration of the net soak. It has been observed previously that open mouth of the passive drift nets may allow fish with good swimming abilities, particularly in slow-flowing areas, to escape the net (Tonkin et al., 2007). Performance decay of nets could therefore reduce the efficacy of the net at times during the soak period which would further confound findings if the sampled species exhibited temporal patterns to their drift.

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The decay curve from these sampling events from one river suggest that there is high variability between sites, but also variability at the same site on separate occasions. Clearly understanding the decay in net performance as each sampling occurs will help researchers better assess volume and therefore catch per unit effort. This particularly indicates care is required about drawing conclusions about timing of larval drift using a total flow, rather than considering the changing flow during a netting event.

The skewed flow in drift nets may even be worse than observed here. In at least some cases the flow meter was pointing in the wrong direction at the end of the soak duration thus measuring flow out of the net likely due to standing waves causing backwash (Allan & Russek, 1985) inside the net. The flow meter was therefore measuring water flow but not flow that was passing through the net. This also suggests that a further over estimate of the flow occurs on some net events and thus the volume which in turn would lead to further error in volumetric calculations.

Turbulence as an indicator of net performance when collected in the manner described has some potential but, at least in the early part of the soak period is less effective than graphing flow decay. It may be that a turbulence measure during the whole soak period - which would require modification to the equipment described - could provide useful information and may warrant investigation where long duration soaks are required.

It has previously been suggested that low flow through drift nets may allow stronger swimming fish to escape (Tonkin et al., 2007). For this reason too, it is important to know the change in flow rate during the soak period. If the flow towards the end of sampling period decreases too far there is some prospect of strong fish, which may have been sampled at any time during the soak duration, escaping the sample. Indeed there is some evidence collected during this study that such an effect can be seen in Murray cod larvae. (Couch, 2014 unpublished). Murray cod critical swimming speeds range from an average of 11.47 cm.s-1 for preflexion larvae, through to 28.84 cm.s-1 for postflexion larvae according to Kaminskas (2011) who attributed these data to Kopf's (2011) unpublished findings. This corresponds to 2.5 and 5 m^3 per minute respectively. This is right in the zone that the net performance drops to after a couple of hours in most cases, and in all cases after the whole soak period (Calculations shown in appendix A). There is mounting evidence that commonly accepted estimates of swimming performance are low (Castro-santos, Sanz-ronda, & Ruiz-legazpi, 2013).

In recent volumetric studies various approximations are assumed to compensate for apparent anomalies in flow measurements. For example one research group ensured "all propeller counts were analysed as absolute values" even when they were negative, and if zero measurement was detected they assigned a "a propeller count of 1" (Wilson & Ellison, 2010) as compensation. Clearly improvements in volumetric analysis of drift net CPUE are required. Any method to improve sample validity for this sort of sampling needs to be simple to implement and enumerate. Sampling needs to be done cost effectively and as the present study suggests the decay can potentially vary for each sampling event as it depends on a number of biotic and abiotic factors that are each likely to vary widely and often independently. A simple repeatable method to measure and calculate each sampling therefore can save time and money.

Where volume is being taken into account drift net sampling in rivers could be more accurately conducted by taking into account the decay in net performance over the soak duration. This net performance decay can be done reliably and cost effectively by deploying time lapse cameras inside the nets to function as a data logger.

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Appendix A

TableA1: Calculation of water speed in drift net for comparison with larval fish swimming speed.

constant	26873	Provided by manufacturer				
Δcounts	**Time**	**Distance**		**Speed**		**Volume**
	(sec)	(m)		(cm/s)		(m^3/s)
1	60	0.027		0.045		0.005
100	60	2.687		4.479		0.527
200	60	5.375		8.958		1.055
500	60	13.437		22.394		2.637
1000	60	26.873		44.788		5.274
2000	60	53.746		89.577		10.548

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