Practice change and water quality response

TEAGASC took part in an international research review which examined how long it takes for water quality to improve after changing a potentially polluting agricultural practice or introducing a set of mitigation measures.

A global question

The time between the introduction of mitigation measures and a water quality response occurring is called time lag. How long it takes is a big question and an important one for farmers, as well as policy makers. Two components of time lag are, firstly, the physical movement of water and pollutants (hydrological time lag) and, secondly, the transformation of these pollutants before they affect water quality (biogeochemical time lags). Within agricultural catchments these time lag components interact and are influenced by the soil, the subsoil and the geology. To guide our expectations for water quality improvement in Irish river catchments, we looked at experiences from around the world for issues around phosphorus (P), nitrogen (N), suspended sediment (SS) and river biology.

International catchment studies

A literature review was undertaken on 25 previous studies from across Europe, USA, New Zealand and Brazil, which were conducted in medium-sized river catchments (1-100km^2) where mitigation measures had been implemented to improve water quality. For the review, we also defined the aspects of time lag:

- response time – how long does it take for the practice or measure to have been implemented before a change in water quality starts to emerge?
- measurement time – how much monitoring is required, including beyond the emergence of the change in water quality, to say for certain that change has definitely happened? This is in order to statistically separate signals or responses from environmental noise.
- implementation lag – the time it takes for practice change to reach a maximum or threshold rate of implementation.

Positive effects and catchment scale

Positive effects on one or more water quality indicators were measured in 17 of the 25 studies reviewed. These positive effects occurred one to ten years after practices were implemented (**Figure 1**). In contrast, four to 20 years were needed to statistically detect the positive effects on water quality (**Figure 1**). The longer times appeared to have a relationship with scale. The larger the catchment scale, the longer it took to respond to practice change and subsequently measure a water quality change. The review indicated that there was also a tendency for the response time to increase as the travel time of the pollutant flow pathway increased. For example, SS and P transport, which occurs predominantly via the overland flow pathway, had opportunities to be remediated quickly, whereas N leached via subsurface flow pathways took longer to remediate (**Figure 2**).

Implementation lag times ranged from 0.5-14 years, tended to increase with catchment size up to about 20km^2, and were not always shorter when practice change was mandatory. A caveat in most of the studies was that nutrient management practice data,

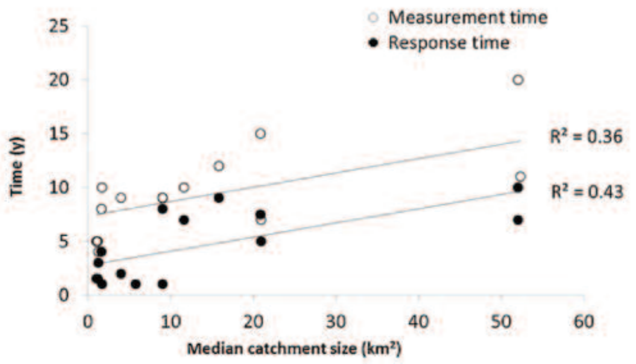

FIGURE 1: *Response times and measurement times for positive effects on water quality following practice change – indicating a relationship with catchment scale and showing the extra time needed to detect a statistically significant change through monitoring.*

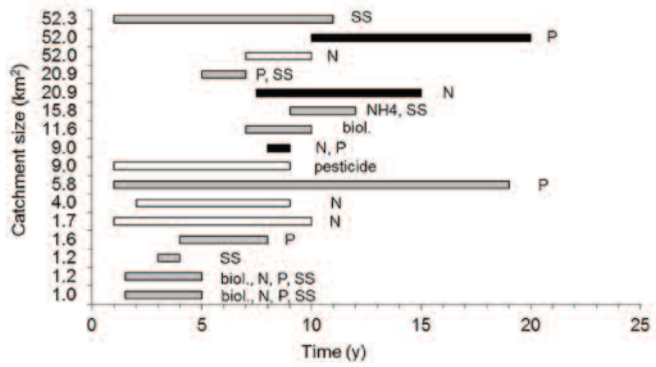

FIGURE 2: *A comparison of catchment size and main water flow pathway against positive water quality response and measurement times. Left extent of bar = response time, right extent of bar = measurement time. Water quality indicators are also annotated as biol. (biological indicator), N (nitrogen species), NH_4 (ammonium only), P (phosphorus species) and SS (suspended sediment). The transport pathway contributing most to the state of the water quality indicator is represented as surface (grey bars), subsurface tile drains (un-shaded bars) or subsurface/groundwater (black bars).*

such as the timing of fertiliser application, were often not as complete as water quality data, despite their importance in identifying cause–effect relationships.

There were also examples of simultaneous negative or immeasurable effects. For example, a study in New Zealand found positive effects for P and SS (and also faecal indicators), but no measured change was found in stream macroinvertebrate indicators, and river N loads increased. Important lessons can be learned here as both surface and subsurface flows transported farm pollutants in the catchment. The increased river N load was explained by higher N leaching losses owing to higher N fertiliser and supplementary feed inputs to the catchment over the period of measurement, whereas the positive effects were realised via mitigation of surface flow pathways.

The neutral effect on stream macroinvertebrates was attributed to the short timeframe of the study (five years), poor recolonisation potential and non-limiting water temperatures prior to stream habitat restoration.

The long-term view

The review highlighted that to measure water quality change in medium-sized catchments, scientists should account for long time lags, from four to 20 years, when designing measurement programmes. Scientists should also:

- highlight any ineffective practices (including pollution swapping);
- identify the degree to which water quality targets are likely to be achieved;
- estimate the temporal and spatial scale of effectiveness of practice change, because the appropriate monitoring period and location varies for different indicators of improved water quality; and,
- calculate the ratio of costs to benefits due to practice change.

The review indicates the need to consider the limitations of combining response data from multiple catchment scales and over multiple soil, subsurface and geological conditions, when gauging the effectiveness of practice change policies on water quality.

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