Inland Fisheries Ireland Warm Water Protocol Scientific Working Group: Scientific Advice Note for Fishery Managers

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Inland Fisheries Ireland Warm Water Protocol Scientific Working Group (WWPSWG) Advice Note for Fishery Managers related to High Water Temperatures – June 2025.

Science to support IFI's Warm Water Protocol

Background

In recent years, Irish summers have experienced periods of anomalously warm, dry weather conditions, when low water levels and high water temperatures in excess of 20°C have predominated, often for weeks at a time. Future climate projections for Ireland indicate that the climatic conditions that lead to adverse river conditions for inland fish populations may increase in intensity, frequency and duration (Nolan and Flanagan, 2020).

Risk of warm weather conditions for inland fisheries

Periods of low rainfall coupled with settled, sunny weather can see water temperatures in lakes and rivers exceed the thermal tolerances of many fish species, with salmonids (Atlantic salmon and brown/sea trout) amongst the most vulnerable Irish fish species to these conditions (Barry et al. 2022). Prolonged dry spells cause river water levels to drop to baseflow (when the primary source of water comes from subsurface water stored in bedrock and soil), which results in an overall decrease in the total volume of wetted habitat and slow, sluggish river flows. High daytime solar radiation causes high river temperatures which peak in late afternoon but may remain elevated above the thermal tolerance of salmonids overnight, especially in rivers without riparian shading or substantial groundwater inputs (Kelly and Kelly, 2024). In combination, low flows and high water temperatures increase the likelihood that low dissolved oxygen concentrations will also occur, especially in rivers with additional pressures such as poor water quality. In tandem, these conditions can lead to sublethal and ultimately lethal conditions for salmonids and as such, angling practices must be modified to safeguard fish welfare.

Cautionary advice

When to close?

Whilst a single standard water temperature protocol is difficult to define for all species, for Atlantic salmon and brown/sea trout current international best practices indicate that **at water temperatures at or above 20°C recreational angling should cease completely**. This is due in large part to a growing body of scientific literature indicating that angling-related mortality increases dramatically at temperatures above 20°C (e.g. Breau (2012); Havn et al. (2015); Lennox et al. (2017); Van Leeuwen et al. (2020); Van Leeuwen et al. (2023); Van Leeuwen et al. (2024).

When to exercise caution and restricted angling?

Adverse impacts can occur at water temperatures in excess of 18°C and any angling that does take place should carry extra precautions related to angling practices, especially limiting fish exposure to air (avoiding it completely where possible). Furthermore, for Atlantic salmon rivers that are not sufficiently meeting conservation limits to an extent that allows a harvestable surplus (i.e. catch-and-release only rivers), a precautionary advisement would be close recreational fisheries when successive spot checks at or warmer than 18 °C are reached.

When to allow angling without restraint?

Angling related stress and mortality appears to be much reduced when angling is carried out at water temperatures below 18 °C and particularly when fly fishing is practiced (e.g. Gargan et al. 2015).

Recreational angling can generally be carried out *ad libitum* under these conditions where a river is open for angling.

Traffic light system

As such, a "traffic light" system is proposed by the WWPSWG (**Figure 1.**), routinely advised and implemented in other salmonid angling jurisdictions in Canada (e.g. https://0201.nccdn.net/4_2/000/000/017/e75/warm-water-protocol-v5.0.pdf), Scotland (e.g. https://www.adaa.org.uk/commencing-of-angling/) and the United States (https://coloradotu.org/blog/category/Fishing).

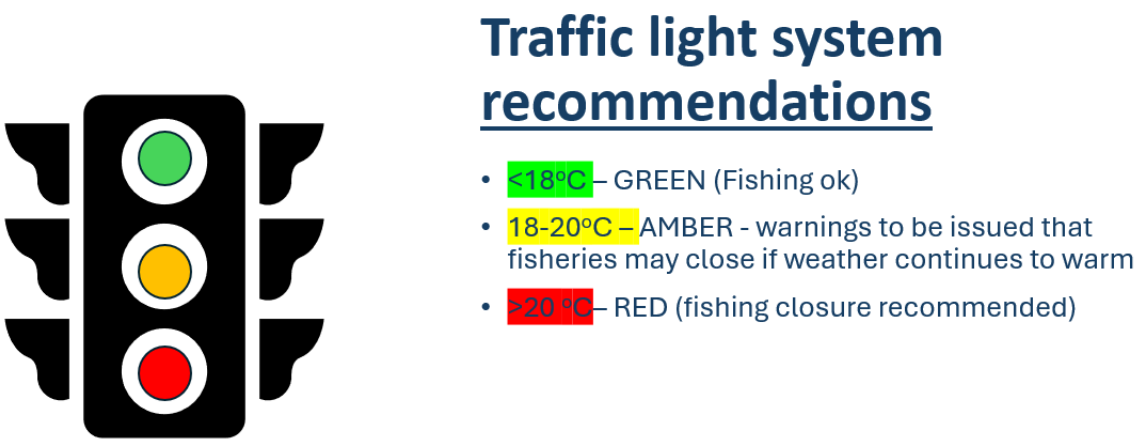

Figure 1. Schematic showing the water temperature bands for which angling practices should be amended.

IFI WWPSWG advise that water temperature at key angling locations (e.g., IFI fisheries) should be monitored regularly during periods of warm weather conditions. The best-case scenario is to utilise near real-time monitoring systems (e.g. water temperature loggers that upload temperature data to an online portal as it is recorded) where fishery management can directly observe water temperatures as they occur and make informed decisions regarding fishery closure.

However, *in lieu* of such infrastructure currently being in place, regular daily temperature 'spot' checks using an accurate water temperature measuring probe should be performed at intervals of approximately 6 hours (i.e. 06:00, 12:00, 18:00). Spot checks should be carried out in an area of the river with thorough flow of water (i.e. avoiding areas of recirculating or slack water which may not be representative of mean channel temperatures). This is due to evolving water temperature changes in response to weather conditions across the day – temperatures may peak above 20 °C in late afternoon/evening but may be cool enough in the morning to allow some angling to occur. In general, the overall trend in water temperatures (decreasing or increasing over successive readings and over consecutive days) is the most pragmatic way to assess when a river should be closed or re-opened, and this will require some judgement by the fishery management team.

These checks must be carried out on individual rivers (and ideally at different fishing locations within individual river systems) – it should not be assumed that closure of one fishery warrants closure of another as various factors dictate the actual water temperature at a single angling location (**Figure 2.**).

Advice should be followed for estuaries in line with freshwater recommendations.

Flows

Low flows often coincide with high temperatures. Extra caution should be exercised when elevated temperatures occur alongside very low flows. For rivers that have live flow readings available, flows at or below the Q95 statistic could be considered in closure criteria, as such low flow conditions may further exacerbate any thermal stress for salmonids. For rivers stocks assessed as being below their conservation limit, flow conditions below summer low flows (e.g., Q95 level) may warrant closure at a more conservative temperature threshold (e.g. >18 °C as opposed to >20 °C). However, if high temperatures are recorded during normal or even higher flow conditions, the 20 °C closure criteria should still apply, as thermal stress takes precedence over flow levels.

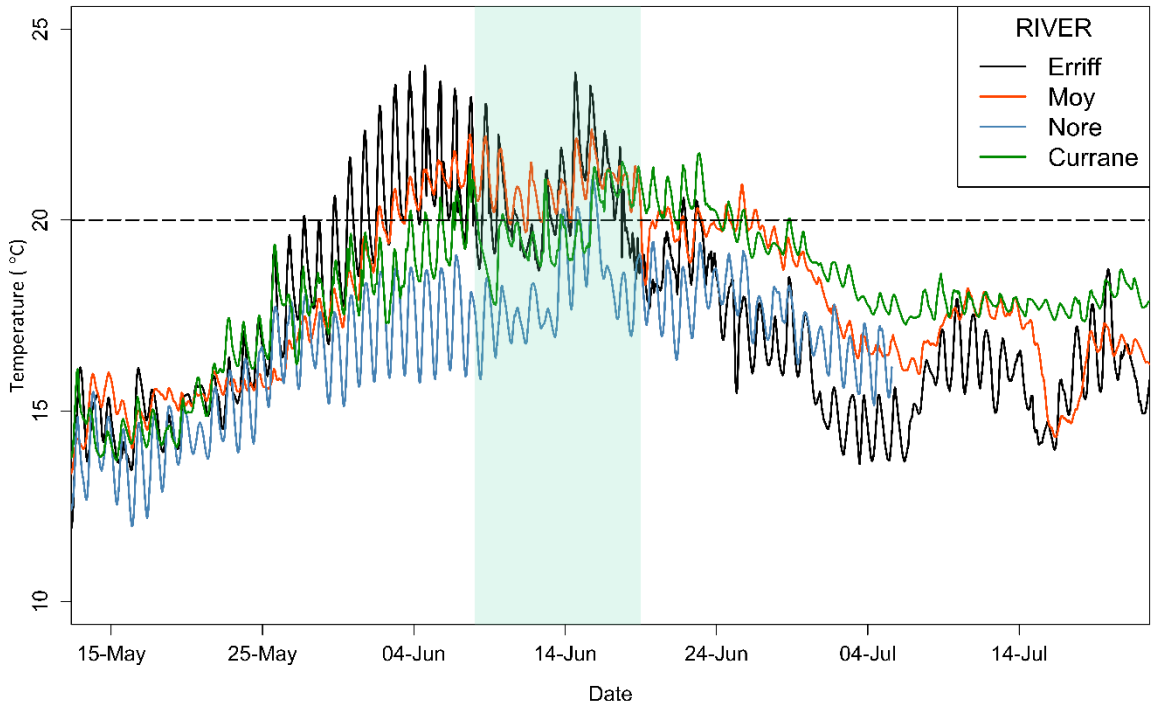

Figure 2. River water temperatures in four Irish salmonid angling rivers during summer 2023. Dashed horizontal line denotes 20 °C threshold. Note that all four rivers show variable temperature patterns, with the Currane and Nore fishery not reaching the same warm water temperatures during the first warm climate event compared to the Erriff or Moy. The green shaded area denotes when the IFI Corrib, Moy and Erriff fisheries were officially closed, however both the Moy and Erriff recorded water temperatures far in excess of 20 °C consistently for several days prior to this management closure.

Closure criteria

Regular monitoring (multiple daily spot checks)

For scenarios where 3 daily water temperature spot checks are taken, fishery management should initiate a fishery closure **when two individual spot checks record water temperature at or in excess of 20 °C in a single 24-hour period.** When water temperatures are at or warmer than 18 °C, especially successive spot checks, or if 18°C is reached during any spot check on consecutive days, management should advise that angling be performed with extra care in regards fish welfare and minimal handling and advice should be issued to prospective anglers that a fishery closure may be imminent (particularly if weather forecasts are indicating a continuation of warm weather conditions in the following days).

Practical example for closure using regular temperature spot checks – water temperatures >20 °C reached in successive days (i.e. within a single 24 hour period) initiates fishery closure:

	Day 1			Day 2			Day 3		
Time	06:00	12:00	18:00	06:00	12:00	18:00	06:00	12:00	18:00
Temp	17.4°C	18.1°C	19.4°C	17.8°C	18.7°C	20.7°C	18.2°C	19.0°C	20.1°C
Advice	Open	Caution	Caution	Caution	Caution	Caution	Caution	Caution	**Close**

Re-opening criteria

Regular monitoring (multiple daily spot checks)

Once a fishery has been closed in accordance with the warm water protocol outlined above, re-opening should be conditional on at least two successive water temperature readings (i.e. 6 hours apart) of less than 18 °C.

Practical example for re-opening using regular temperature spot checks, coming out of a period when "red" readings have been recorded previously but very hot weather conditions have begun to subside – two successive temperature readings < 18 °C initiates reopening of the fishery:

	Day 1			Day 2			Day 3		
Time	06:00	12:00	18:00	06:00	12:00	18:00	06:00	12:00	18:00
Temp	18.8°C	18.9°C	19.6°C	17.7°C	18.1°C	18.5°C	16.8°C	17.7°C	19.5°C
Advice	Close	Close	Close	Close	Close	Close	Close	**Open**	Caution

In the example above, the fishery could be opened for angling the following day (if the weather forecast indicates that favourable (cooler) weather conditions will continue to prevail) but water temperatures should still be monitored closely and the necessary advice regarding extra judicious angling practices should continue to be observed.

The temperature data used in the practical examples above are taken from filtering a timeseries of high-frequency temperature readings on the River Nore during a warm period in 2022 to the 6-hour spot check intervals (shown below in Figure 2.), illustrating in this instance the period when it is advised that the recreational fishery should be closed and re-opened.

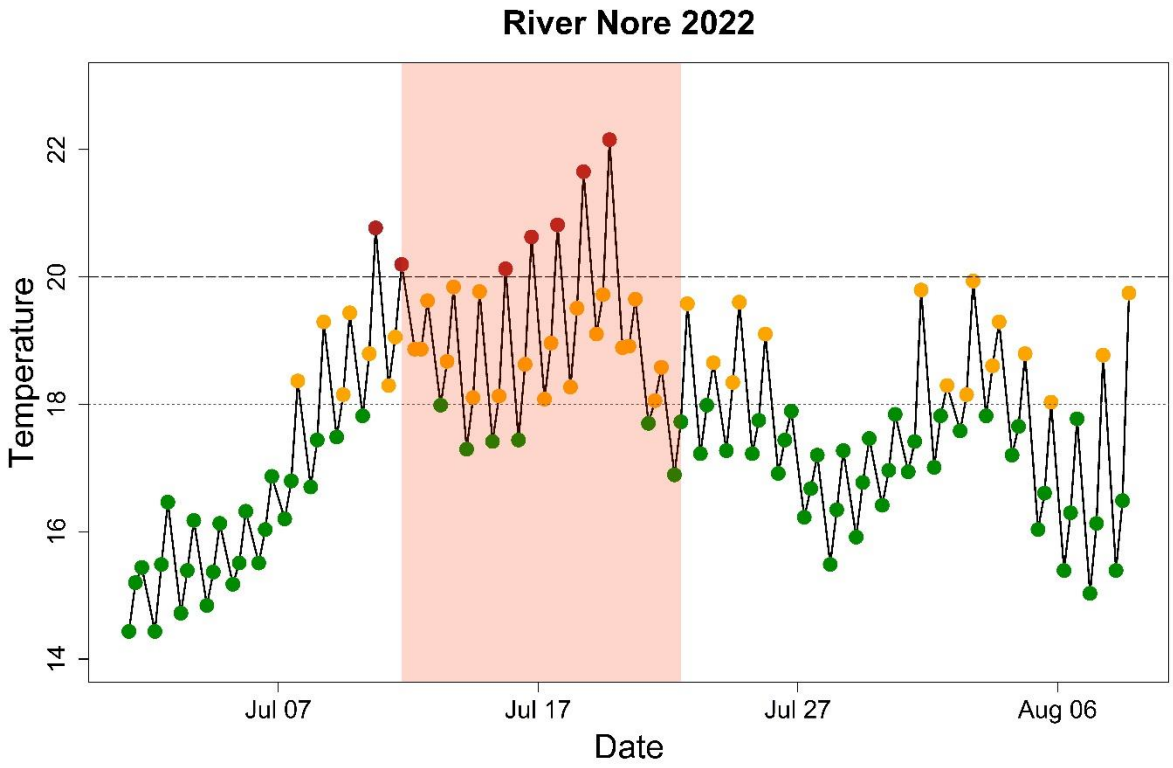

Figure 2. Timeseries of 6-hourly temperature spot-checks for the River Nore during summer 2022, with the shaded pink area highlighting when the recreational fishery is advised to close based on recording two individual spot checks with water temperatures exceeding 20 °C within a single 24-hour period and not re-open until two successive spot checks record water temperatures cooler than 18 °C. Despite instances of single <18 °C water temperature spot checks in the early morning in subsequent days following the advised closure, afternoon and evening temperatures were shown to continue to exceed 18-20 °C for several days and were therefore in excess of thermally tolerable conditions for salmonids. Two successive <18 °C spot checks (for reopening) therefore represents a more precautionary approach and are indicative of an overall cooling trend in river water temperatures.

Further Background Information

Thermal biology of salmonids

Brown trout

Brown trout (*Salmo trutta*), and by extension sea trout, generally exhibit a preference for environmental water temperatures lower than approximately 19 °C (Elliott and Elliott 2010) and will actively avoid areas of warmer water temperatures when possible (Santiago et al. 2015). This is largely due to their preference for feeding and the occurrence of optimal growth in a temperature range below 19°C (reviewed in Elliott and Elliott 2010). Once water temperatures exceed 20 °C brown trout will begin to incur metabolic stress and in juvenile trout the critical thermal maximum (temperature at which onset of mortality is rapid) is as low as 26 °C. Generally, the thermal tolerance decreases with exposure length, with field-based observations indicating that the upper thermal tolerance of brown trout to mean daily water temperatures decreases from >25 °C after 1 day to <23 °C after 14 days (Wehrly et al. 2007). Thus, as a heatwave event persists in duration, trout will become increasingly vulnerable at lower temperatures.

Atlantic salmon

Whilst juvenile Atlantic salmon (*Salmo salar*) generally exhibit higher tolerance to water temperature compared to juvenile brown trout (Elliott and Elliott 2010), few studies on the thermal tolerance of wild adult Atlantic salmon are available and most current information comes primarily from aquaculture populations in sea cages. Information from aquaculture studies indicates that adult salmon actively avoid water temperatures at and above 20.1 °C (Stehfest et al. 2017) and metabolic stress is invoked above 19 °C (Karus et al. 2024). Notwithstanding the caveats associated with extrapolating physiological performance from farmed salmon in marine cages to wild salmon in river settings, these values appear to be broadly consistent with the aforementioned findings of numerous studies that angling-related mortality increases dramatically in wild salmon at temperatures in excess of 18-20 °C as well as broadly consistent with the thermal tolerances of the very closely related brown trout. A comprehensive overview of the thermal tolerance of adult Atlantic salmon in the context of additional angling stress with justification for a 20 °C cut-off is available in Breau (2012).

Relevance to angling warm water protocol

The general consensus from the studies listed on the thermal biology of salmonids as well as the angling studies on water temperature effects on angling mortalities provides a foundation for nominally setting the warm water temperature protocol at 18 °C for exhibiting extra caution and at 20 °C for complete cessation of angling. While salmon and trout will only begin to incur substantial metabolic stress above 20 °C and lethal temperatures occur several °C higher than this, it must be noted that any additional physiological stress or injury as typically occurs through standard angling practices could compound otherwise tolerable temperatures of 18-20 °C in wild salmonids and in effect render trout and salmon even more thermally sensitive. As salmonids cope with elevated temperatures by increasing metabolic rate, the capacity for salmonids to fully recover from exhaustive exercise and major increases in anaerobic metabolism during angling encounters will be greatly diminished in thermally taxing water conditions, even if those temperatures would otherwise only have invoked mild physiological stress in isolation. Thus in line with the precautionary principle, it is advised that angling practices are modified or stopped completely as water temperatures begin to encroach on levels known to be metabolically taxing to salmon and trout.

Further considerations

Whilst water temperature is the primary variable to focus on in relation to closure of recreational angling, additional factors need to be considered that will not always be as apparent from observations of water temperature alone. As water temperature rises, the solubility of dissolved oxygen (i.e. how much oxygen the water can hold) decreases. The combination of high water temperatures and low dissolved oxygen creates conditions of "oxythermal stress" for fish. Fish adapt to increasingly stressful water temperatures by increasing their metabolic rate (i.e. increasing oxygen uptake) and avoiding metabolically-taxing activities (e.g. feeding, rapid swimming). An angling event, in which a fish may be physically stressed for upwards of 20 minutes while hooked, requires an immense increase in metabolic output and the time taken to recover from such exhaustive exercise is largely dependent on the rate at which fish can replenish depleted tissue oxygen reserves. Therefore, whilst water temperatures in the range 18-20 °C may seem to be tolerable for salmonids at rest, the oxygen-debt incurred following an angling event and the overall decrease in ambient dissolved oxygen levels at such water temperatures, represent a compounded situation for salmon and trout and the ability of hooked fish to recover post-release is greatly compromised. In addition, dissolved oxygen levels are typically lowest early in the morning due to the natural daily cycle of biological oxygen production and consumption that occurs in aquatic settings (Figure 3.). Plants and algae in the river consume oxygen during darkness, meaning that dissolved oxygen is gradually depleted overnight. Therefore, the early morning hours can still represent a period of high oxythermal stress, even if river water temperatures have cooled. The more prolonged a period of warm, dry weather, the more severe the extent of oxythermal stress. Therefore, as a heatwave-type event continues for multiple days or weeks the overall tolerance of salmonids to warm temperatures and the stress of angling events decreases and these considerations should be incorporated into management decisions in relation to reopening (e.g. a threshold of 18 °C may be adapted for warm weather spells that persist for more than a couple of days).

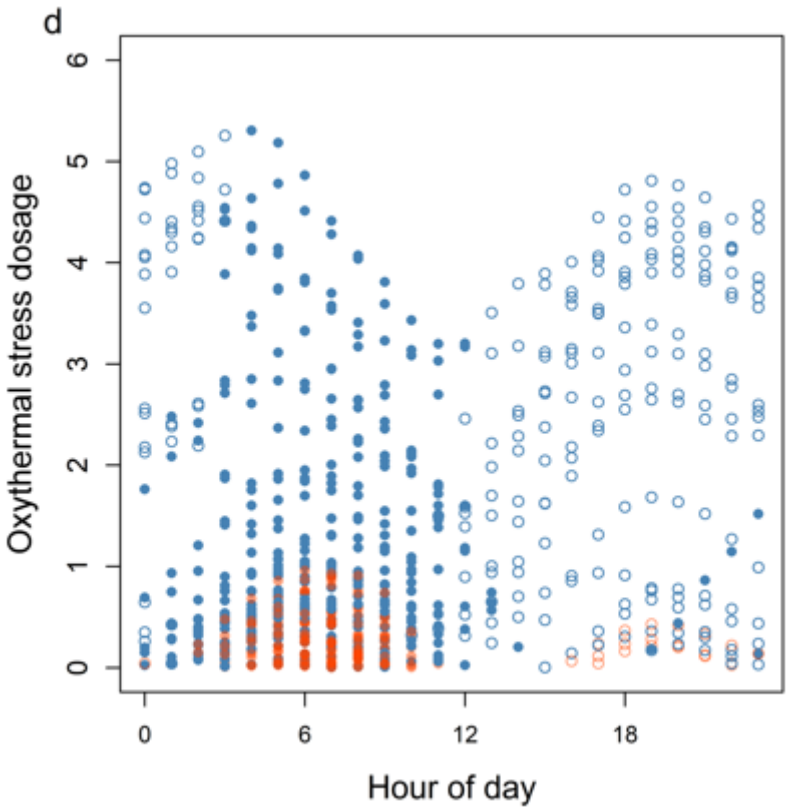

Figure 3. Pattern of summer oxythermal stress incurred by salmonids in river settings over the course of 24 hours (0 representing midnight). Higher values represent times of higher oxythermal stress due to high water temperature, low dissolved oxygen or a combination of both. Peak periods for oxythermal stress are early morning hours and from midday into evening time.

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