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River Dove Hydro Electric Scheme

PHABSIM Analysis and Report

Client: DCSF

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Contents:

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1. Introduction and Background

The Physical Habitat Simulation System (PHABSIM) is part of a wider conceptual and analytical tool used to assess stream flow management issues, called the Instream Flow Incremental Methodology (IFIM) (Stalnaker *et al*, 1995). The aim of PHABSIM is to quantify the relationship between water flow and the quantity of available physical habitat for fish species within a particular stream system. The outcome from a PHABSIM analysis then provides a way to quantity the differences in instream habitat that will result from proposed alternative instream flow regimes (USGS, 2001).

The technique initially relies on the collection of physical habitat data such as cross-section depth data, cross-section velocity data and bed elevations. This is then combined with daily flow data and linked through habitat suitability curves to generate relationships describing how the Weighted Usable Area (WUA) within a stream channel (essentially the quantity of suitable microhabitat available) changes with flow, typically measured in cumecs (m^3/s). As a result, PHABSIM is often used as a tool when investigating the potential impacts of channel modification and abstraction regimes.

A problem with PHABSIM however is that it is site specific and requires extensive collection of field data. This data then needs to be analysed at length and interpreted. As an alternative to a full PHABSIM analysis, Booker and Acreman (2007) analysed the data from 63 sites in the UK in which PHABSIM had been applied to show that reasonable, quantifiable confidence could be expected for results generated by a PHABSIM analysis utilising the catchment characteristics or cross-sectional measurements taken at only one flow. Full details can be found in Booker and Acreman (2007).

This report presents the results from such a PHABSIM analysis, in which a series of cross-section measurements were taken on the River Dove, in Derbyshire, UK. The site is a stretch of river that is potentially (subject to permission and pending this report) going to be affected by a reduced flow as a result of a proportion of the flow immediately upstream being diverted to power an Archimedean screw hydro-turbine, situated within a leat/bypass channel located parallel to the river reach.

After passing through the turbine, the water will continue down the channel, before flowing back into the main river. The diversion of flow will mean that the river reach (approximately 1200m long) running parallel to the leat will have a lower flow than it would under natural conditions. The PHABSIM analysis was conducted to determine the extent to which different abstraction regimes would affect the quantity of available habitat within the impacted river reach.

2. Methods

Data was collected from five different, representative cross-sections on the river reach at one flow (which was approximately Q85) on the 18/06/08. At each of the five cross-sections, the following data was taken:

- Total width of the river channel
- Depth of the river channel, measured every metre, starting from the true, left bank.
- Water velocity, measured every metre across the channel. This was measured at 0.6 of the depth, or an average of 0.2 and 0.8 for depths over 1m. Velocities were measured using a Valeport 801 flow meter.

Data from these cross-sections was then analysed by Mike Dunbar at the Centre for Ecology and Hydrology (CEH), according to Booker and Acreman (2007). This PHABSIM analysis quantified the relationship between Weighted Usable Area (WUA) and flow for the river reach for four different species life-stages; 0-7cm salmon, 8-20cm salmon, 0-7cm trout and 8-20cm salmon (see figure 1).

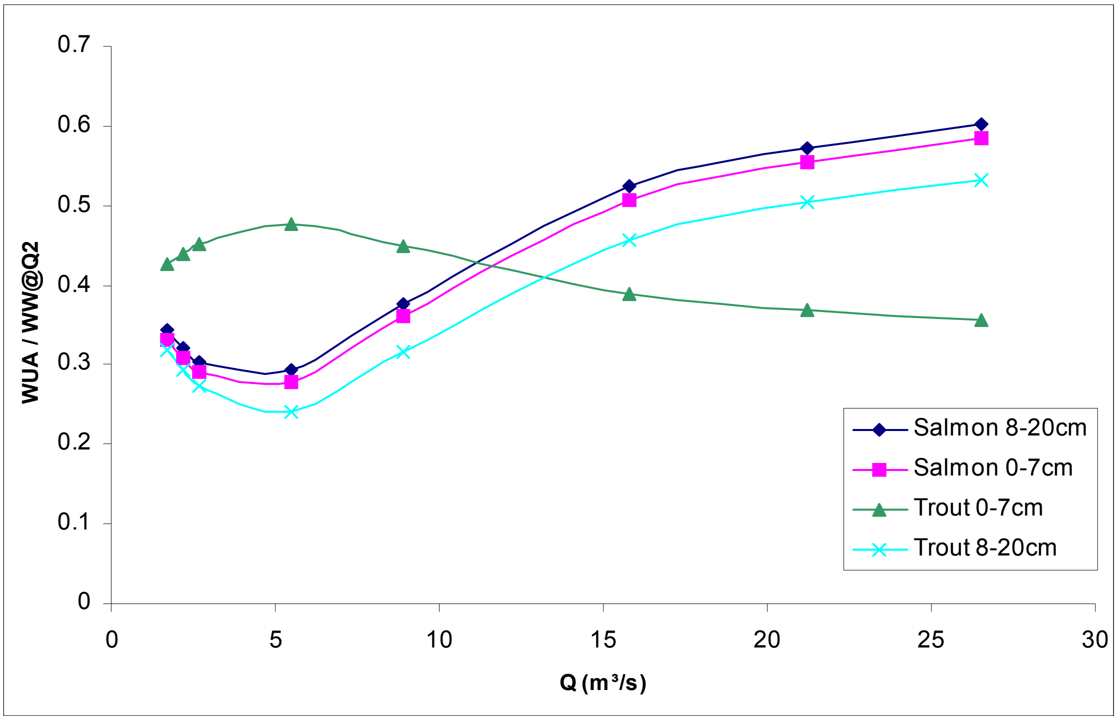


Figure 1: relationship between flow (Q(m^3/s)) and weighted usable area/wetted width at Q2 for the potentially impacted river reach on the River Dove.

These relationships and data on daily flows within the river reach (obtained from the Environment Agency's flow gauging station) were then used to examine how different proportional and maximal takes of water by the turbine would affect the daily weighted usable area within the river reach, relative to the daily weighted usable area under a natural, un-abstracted flow. This was conducted for all abstraction regimes utilising the daily flows from 2006, and a subset of abstraction regimes for the daily flows from 2007. In all cases, the Hands-Off Flow (HOF - the flow below which the turbine stops taking water from the river) was set at Q90. The different turbine abstractions examined are given in table 1:

Table 1: Different potential turbine abstraction regimes that were examined to determine their impact on physical habitat weighted usable area.

Maximum quantity of water taken by turbine	Proportion of water taken from river reach by turbine	Examined for daily flows from years:
2 m^3/s	100%	2006
2 m^3/s	75%	2006
3 m^3/s	100%	2006 and 2007
3 m^3/s	75%	2006 and 2007
3 m^3/s	67%	2006
3 m^3/s	50%	2006
4 m^3/s	100%	2006 and 2007
4 m^3/s	75%	2006 and 2007
4 m^3/s	67%	2006
4 m^3/s	50%	2006

The potential impact of different abstraction regimes on weighted usable area was examined for two species-life stages: 0-7cm salmon and 0-7cm trout. The impact on 8-20cm salmon and 8-20cm trout were not examined, as the flow/WUA relationships for these two species-life stages is very similar to that for 0-7cm salmon.

3. Results

The initial graphs of WUA versus flow generated by the PHABSIM analysis and shown in figure 1 show that for the river reach under consideration, changes in flow have a minimal impact on the WUA (M.Dunbar, CEH, pers. comm.). Changes in flow result in relatively small changes in WUA/Wetted Width at Q2.

The primary output from the analysis examining how different turbine abstraction regimes will impact on the WUA within the river reach are the daily changes in WUA, relative to the WUA under natural flow. In the interests of brevity, these results are given graphically in the Appendix. The results are summarised as an average daily WUA under each abstraction regime and under natural flow in table 2.

Table 2: Average daily WUA for the river reach under varying abstraction regimes and under a natural, un-abstracted flow regime

Maximum quantity of water taken by turbine	Proportion of water taken from river reach by turbine	Year	Life stage	Average daily WUA/WW@Q2	% change in WUA compared to natural
Natural Flow	*Natural Flow*	*2006*	--	*0.447*	--
2 m^3/s	100%	2006	0-7cm trout	0.444	0.6
2 m^3/s	75%	2006	0-7cm trout	0.446	0.2
3 m^3/s	100%	2006	0-7cm trout	0.443	0.8
3 m^3/s	75%	2006	0-7cm trout	0.446	0.0
3 m^3/s	67%	2006	0-7cm trout	0.447	0.2
3 m^3/s	50%	2006	0-7cm trout	0.449	0.7
4 m^3/s	100%	2006	0-7cm trout	0.442	1.0
4 m^3/s	75%	2006	0-7cm trout	0.447	0.1
4 m^3/s	67%	2006	0-7cm trout	0.448	0.4
4 m^3/s	50%	2006	0-7cm trout	0.451	1.0
Natural Flow	*Natural Flow*	*2006*	*0-7cm salmon*	*0.336*	--
2 m^3/s	100%	2006	0-7cm salmon	0.328	2.4
2 m^3/s	75%	2006	0-7cm salmon	0.325	3.3
3 m^3/s	100%	2006	0-7cm salmon	0.325	3.3
3 m^3/s	75%	2006	0-7cm salmon	0.320	4.9
3 m^3/s	67%	2006	0-7cm salmon	0.319	5.2
3 m^3/s	50%	2006	0-7cm salmon	0.318	5.6
4 m^3/s	100%	2006	0-7cm salmon	0.323	4.1
4 m^3/s	75%	2006	0-7cm salmon	0.315	6.3
4 m^3/s	67%	2006	0-7cm salmon	0.314	6.6
4 m^3/s	50%	2006	0-7cm salmon	0.313	7.0
Natural Flow	*Natural Flow*	2007	*0-7cm trout*	*0.444*	--
3 m^3/s	100%	2007	0-7cm trout	0.439	1.0
3 m^3/s	67%	2007	0-7cm trout	0.445	0.2
4 m^3/s	100%	2007	0-7cm trout	0.439	1.1
4 m^3/s	67%	2007	0-7cm trout	0.446	0.5
Natural Flow	*Natural Flow*	2007	*0-7cm salmon*	*0.346*	--
3 m^3/s	100%	2007	0-7cm salmon	0.336	2.6
3 m^3/s	67%	2007	0-7cm salmon	0.329	4.9
4 m^3/s	100%	2007	0-7cm salmon	0.333	3.7
4 m^3/s	67%	2007	0-7cm salmon	0.323	6.4

It is clear from table 2 and the graphs in the appendix that changes in flow in the river reach as a result of turbine abstraction result in relatively small changes in the quantity of physical habitat, expressed as WUA. Average daily WUA for data from

2006 changes only slightly, by between 0-1.0% for 0-7cm trout and 2.4-7.0% for 0-7cm salmon.

The graphs in the appendix plotting daily theoretical changes in WUA as a result of alterations to the flow regime show that changes in flow result in only small shifts in the quantity of physical habitat available. However, from the graphs it is noticeable that for periods of low flow a straight take of 100% leads to a homogenisation of the flow regime and WUA within the river reach. The removal of all water above the HOF of Q90 would therefore result in the river reach flowing at Q90 (2.21 cumecs) for substantial periods of time and as a result, the predicted WUA will remain static with regards to flow.

4. Conclusions

Given the shape of the graphs in figure 2 and the modelled changes in daily WUA as a result of different abstraction regimes given in the Appendix, this PHABSIM analysis has shown that the predicted change in physical microhabitat available to trout and salmon in the affected reach of the River Dove will be relatively minor. Even relatively high maximum abstractions of 4 cumecs only result in a slight change in WUA within the impacted river reach.

With this consideration in mind, and balancing the needs of the all the stake-holders involved, a proportional take of around 67%, up to a maximum of 3 or 4 cumecs, with a HOF of Q90 appears to be feasible for this site, whilst having a minimal impact on the fish population.

5. References

Booker, D.J. and Acreman, M.C. (2007) Generalisation of physical habitat-discharge relationships. *Hydrology and Earth System Sciences*, **11**, 141-157

Stalnaker, C., B. L. Lamb, J. Henriksen, K. Bovee, and J. Bartholow (1995) The Instream Flow Incremental Methodology – A Primer for IFIM. *Biological Report 29, March 1995, U.S. Department of the Interior, National Biological Service, Fort Collins, Colorado*

U.S. Geological Survey (2001) PHABSIM for Windows - user's manual and Exercises. *Midcontinent Ecological Science Center, November 2001.*

6. Appendix

Figure 2 (below) gives the individual daily variations in WUA as a result of varying turbine abstraction regimes. All abstraction regimes were examined initially using flow data from the site from 2006. A subset of the abstraction regimes (given in table 1) was then examined using flow data from the site from 2007. This was to enable the effects of modelling changes in WUA using a different annual flow to be determined. (2006 was a significantly drier year than 2007. Average daily flow was 7.12m^3/s in 2006 and 8.40m^3/s in 2007). In all cases, the changes are compared to the daily WUA under an un-abstracted, natural flow regime.

Figure 2(i) to (x) were modelled using the WUA versus flow data for 0-7cm trout and the flow data from 2006. Figure 2(xi) to (xx) were modelled using the WUA versus flow data for 0-7cm salmon and the flow data from 2006. Figure 2(xxi) to (xxiv) were modelled using the WUA versus flow data for 0-7cm trout and the flow data from 2007. Figure 2(xxv) to (xxviii) were modelled using the WUA versus flow data for 0-7cm salmon and the flow data from 2007.

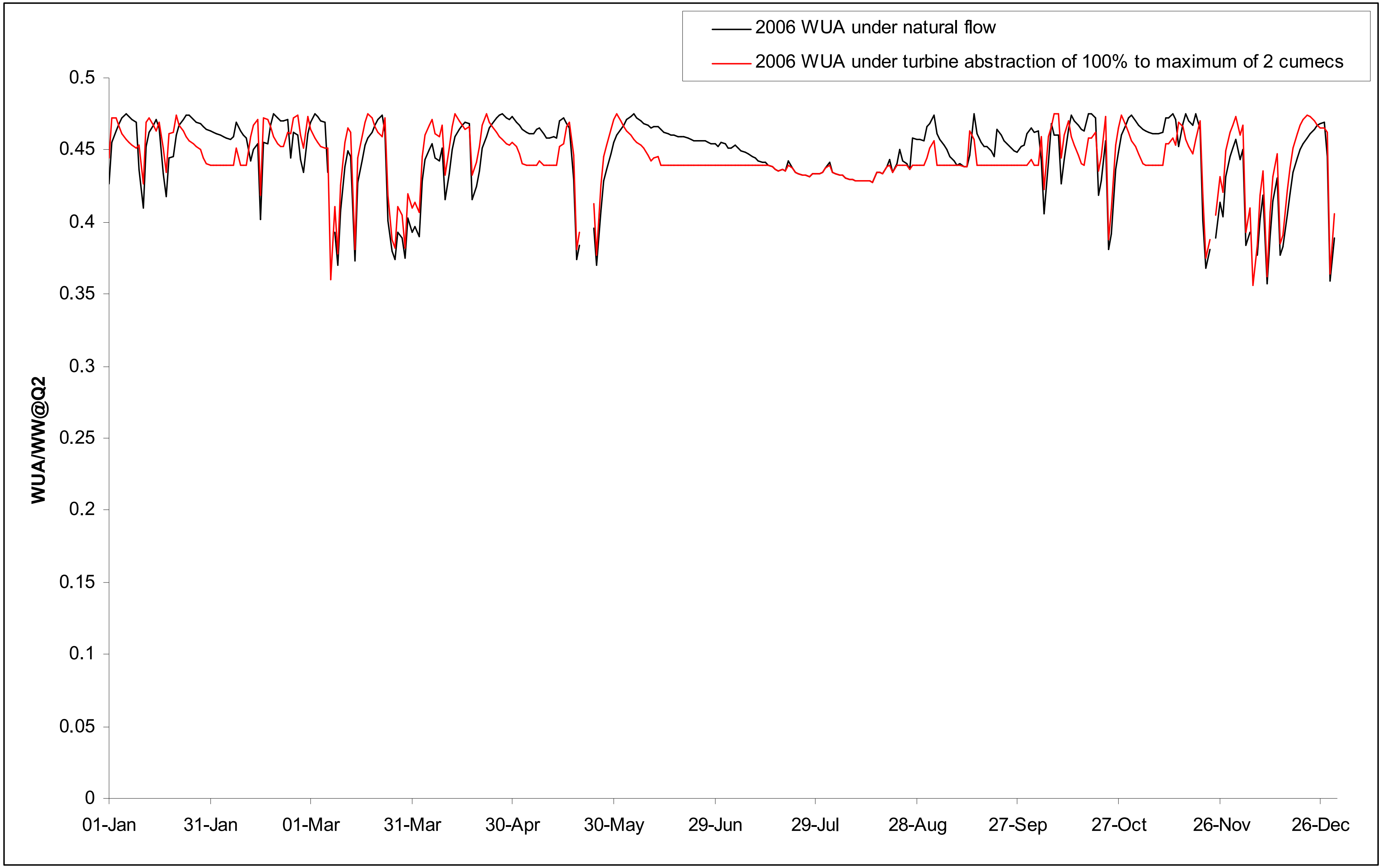
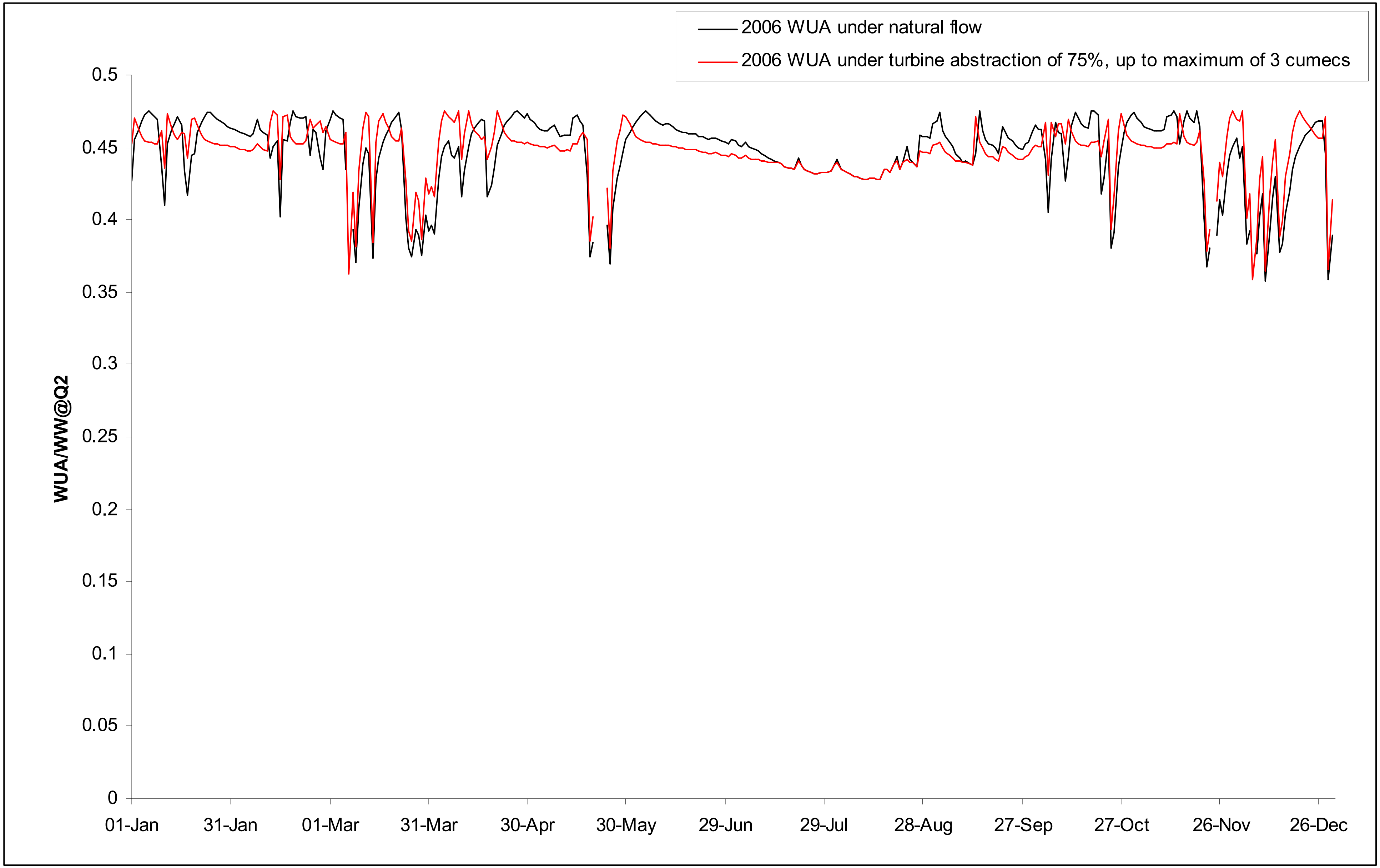


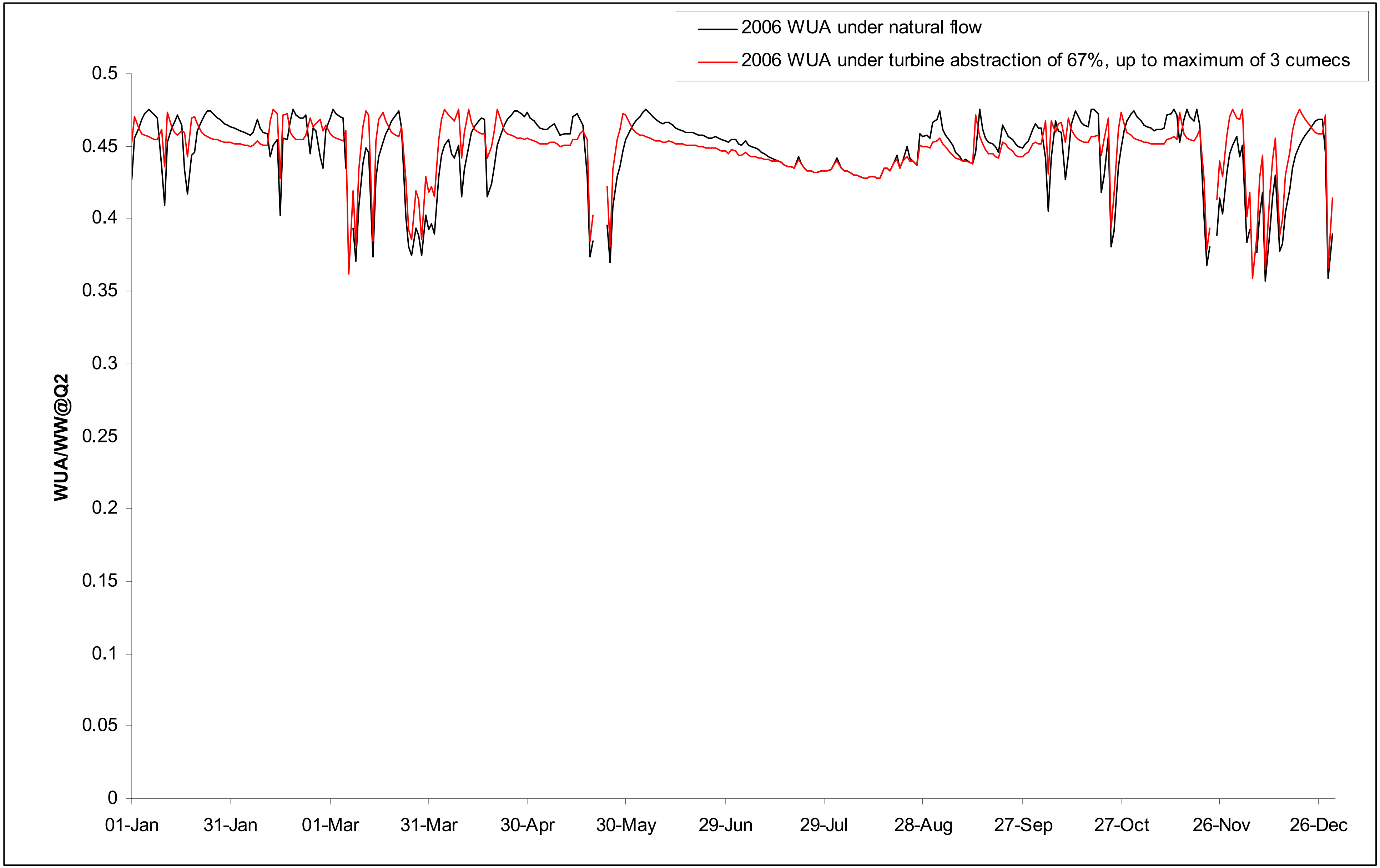
Figure 2(i): Impact of a turbine take of 100% of river flow above Q90 in 2006, up to a maximum of 2 cumecs, on the WUA/WW@Q2 for 0-7cm trout.

(ii) Impact of a turbine take of 75% of river flow above Q90 in 2006, up to a maximum of 2 cumecs, on the WUA/WW@Q2 for 0-7cm trout.

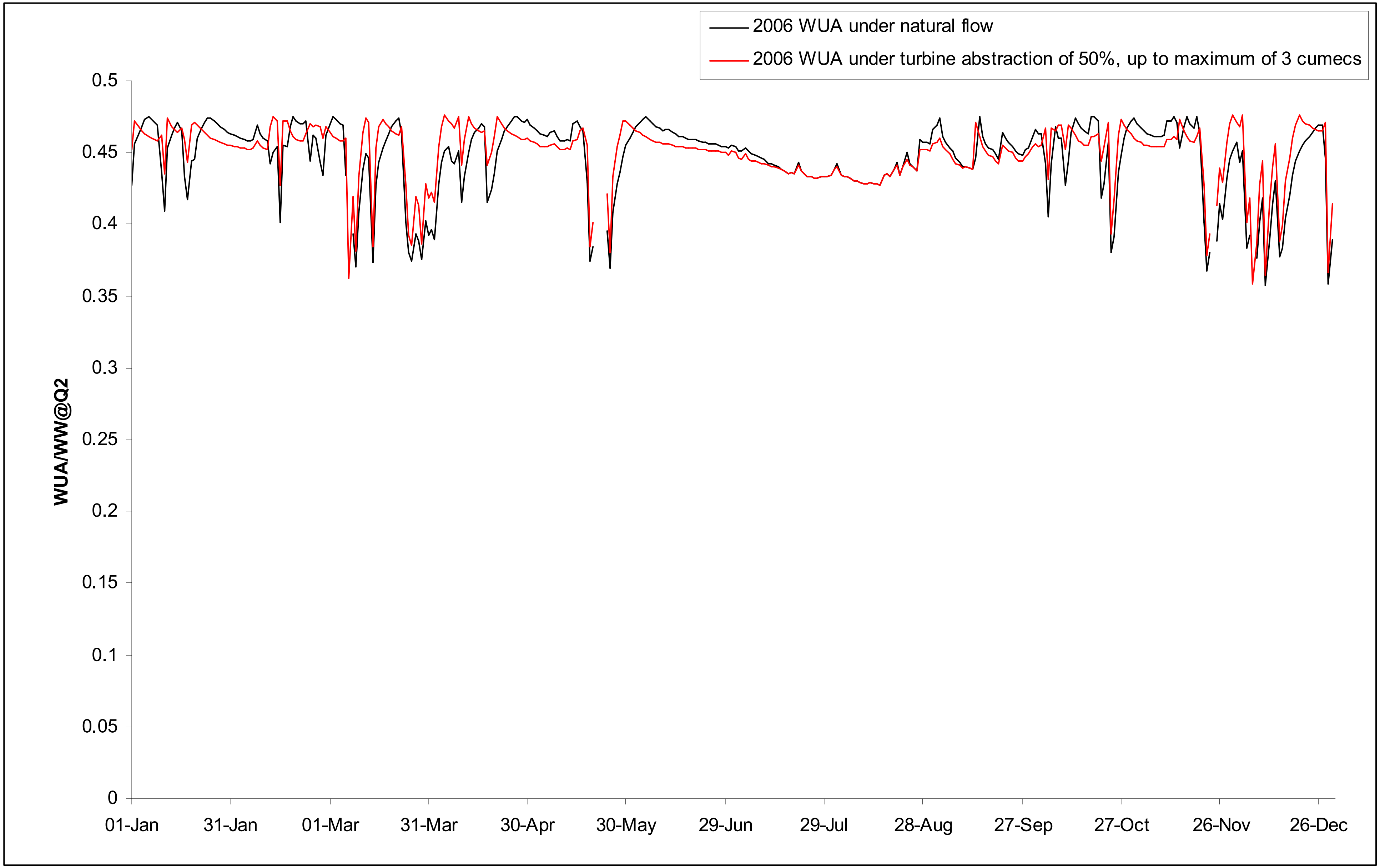
(iii) Impact of a turbine take of 100% of river flow above Q90 in 2006, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm trout.



(iv) Impact of a turbine take of 75% of river flow above Q90 in 2006, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm trout.



(v) Impact of a turbine take of 67% of river flow above Q90 in 2006, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm trout.

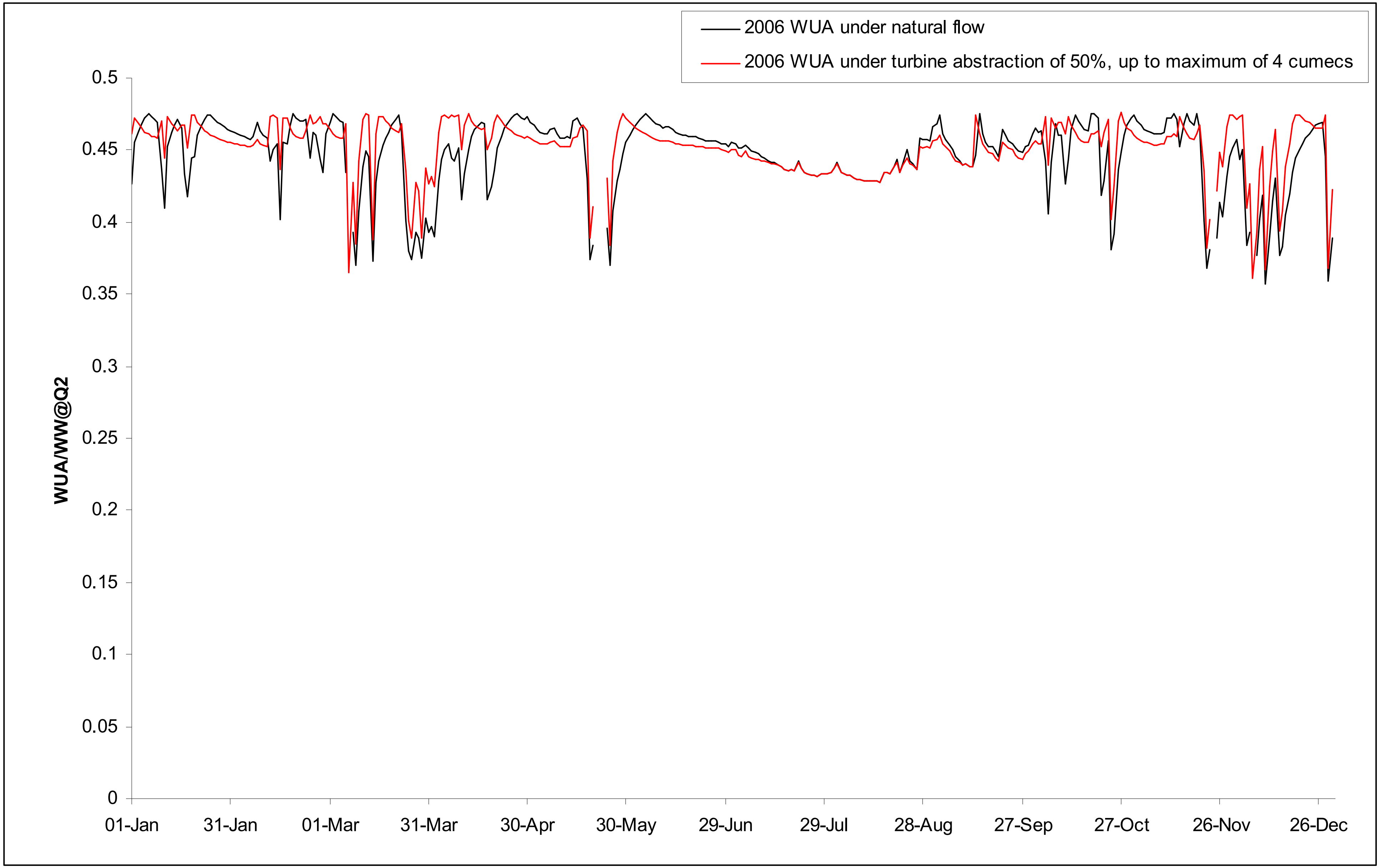


(vi) Impact of a turbine take of 50% of river flow above Q90 in 2006, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm trout.

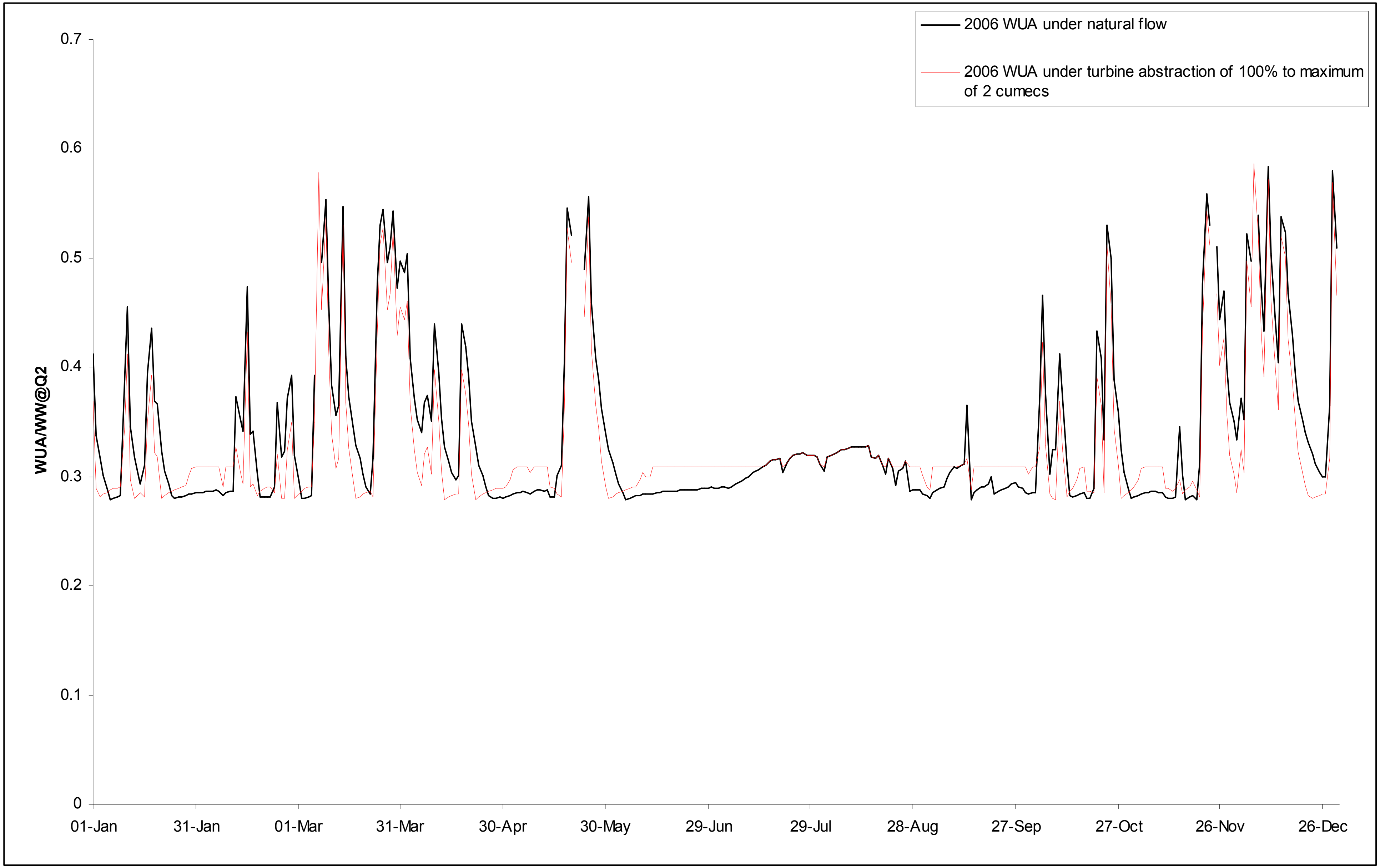
(vii) Impact of a turbine take of 100% of river flow above Q90 in 2006, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm trout.

(viii) Impact of a turbine take of 75% of river flow above Q90 in 2006, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm trout.

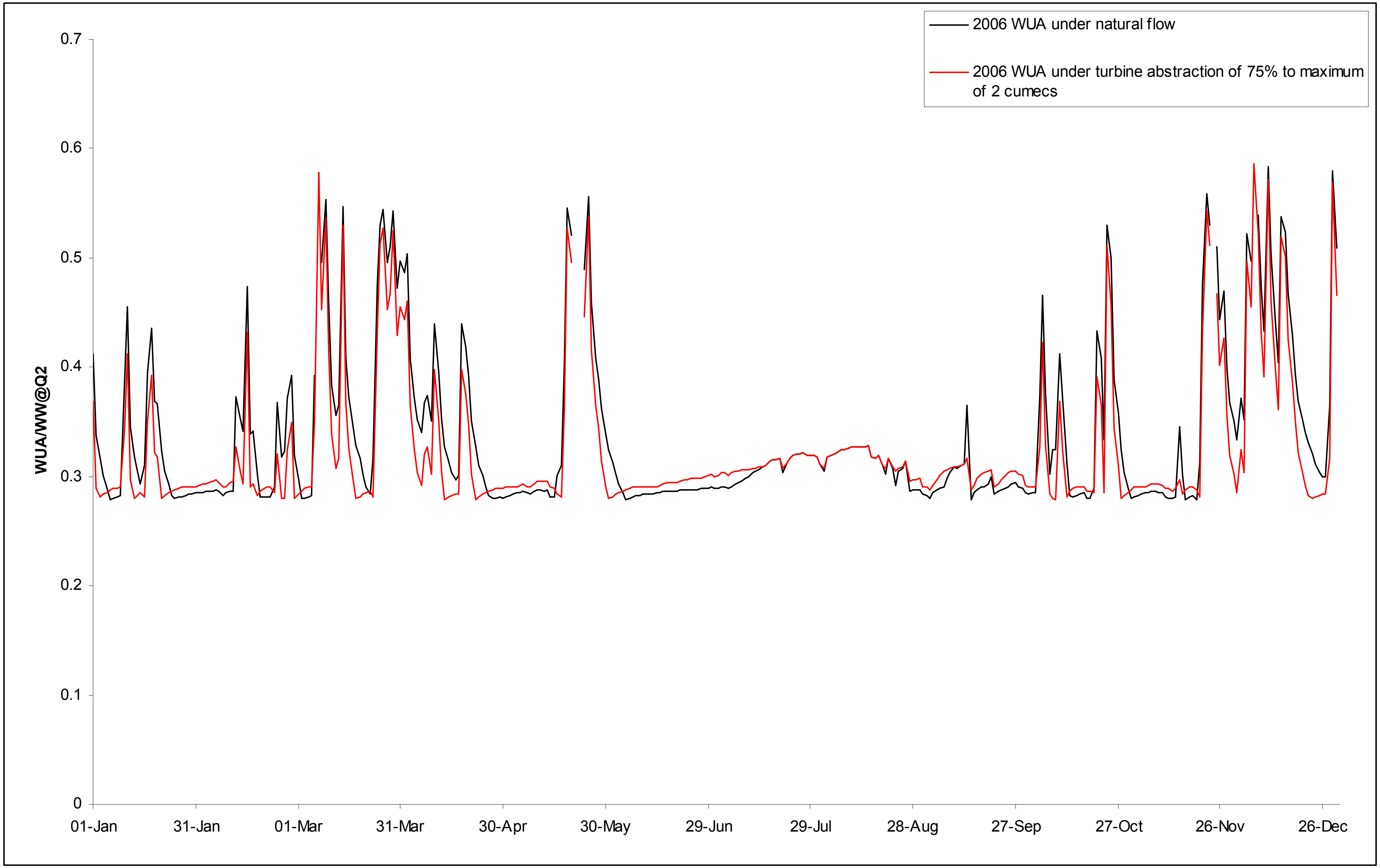
(ix) Impact of a turbine take of 67% of river flow above Q90 in 2006, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm trout.



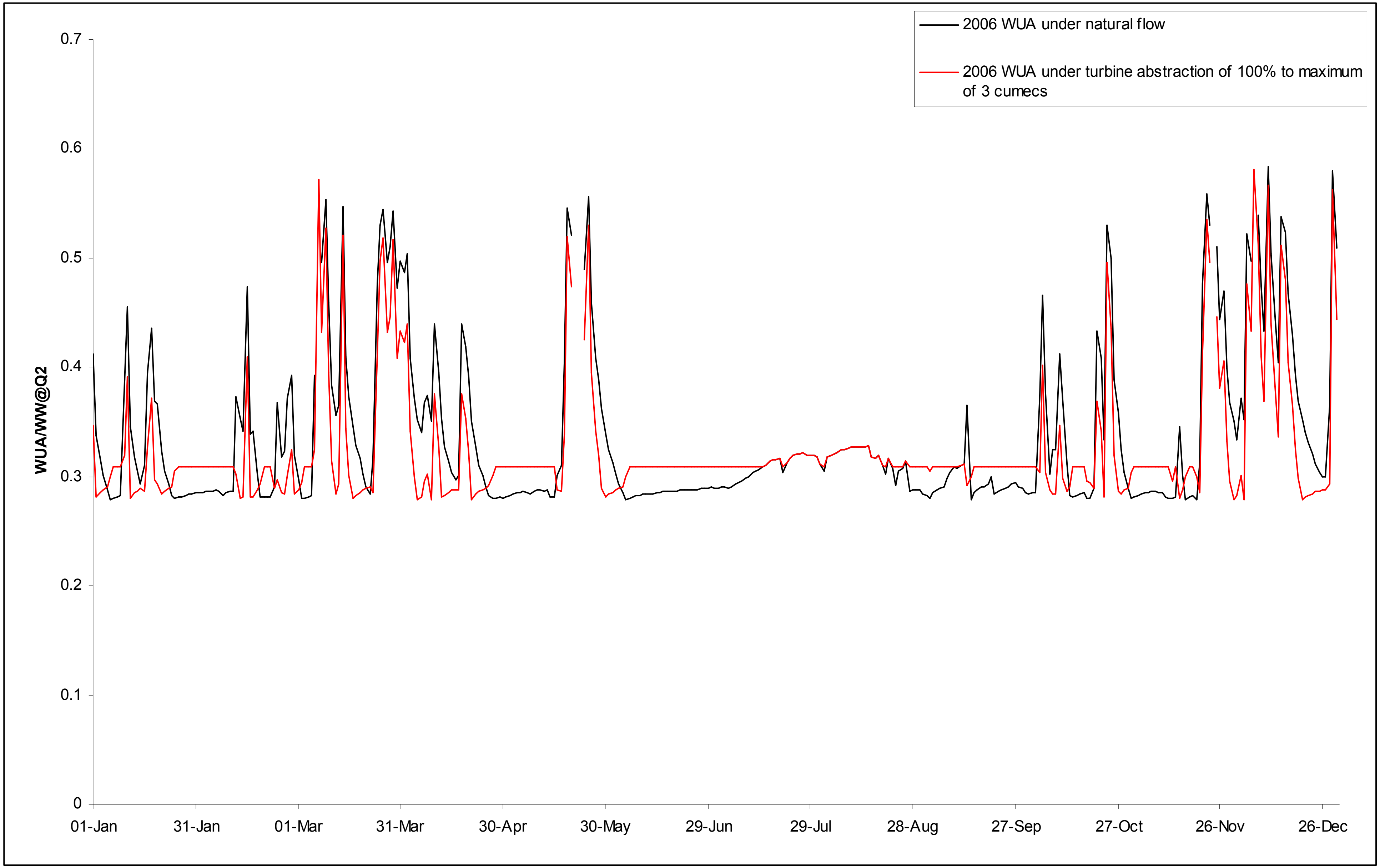
(x) Impact of a turbine take of 50% of river flow above Q90 in 2006, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm trout.



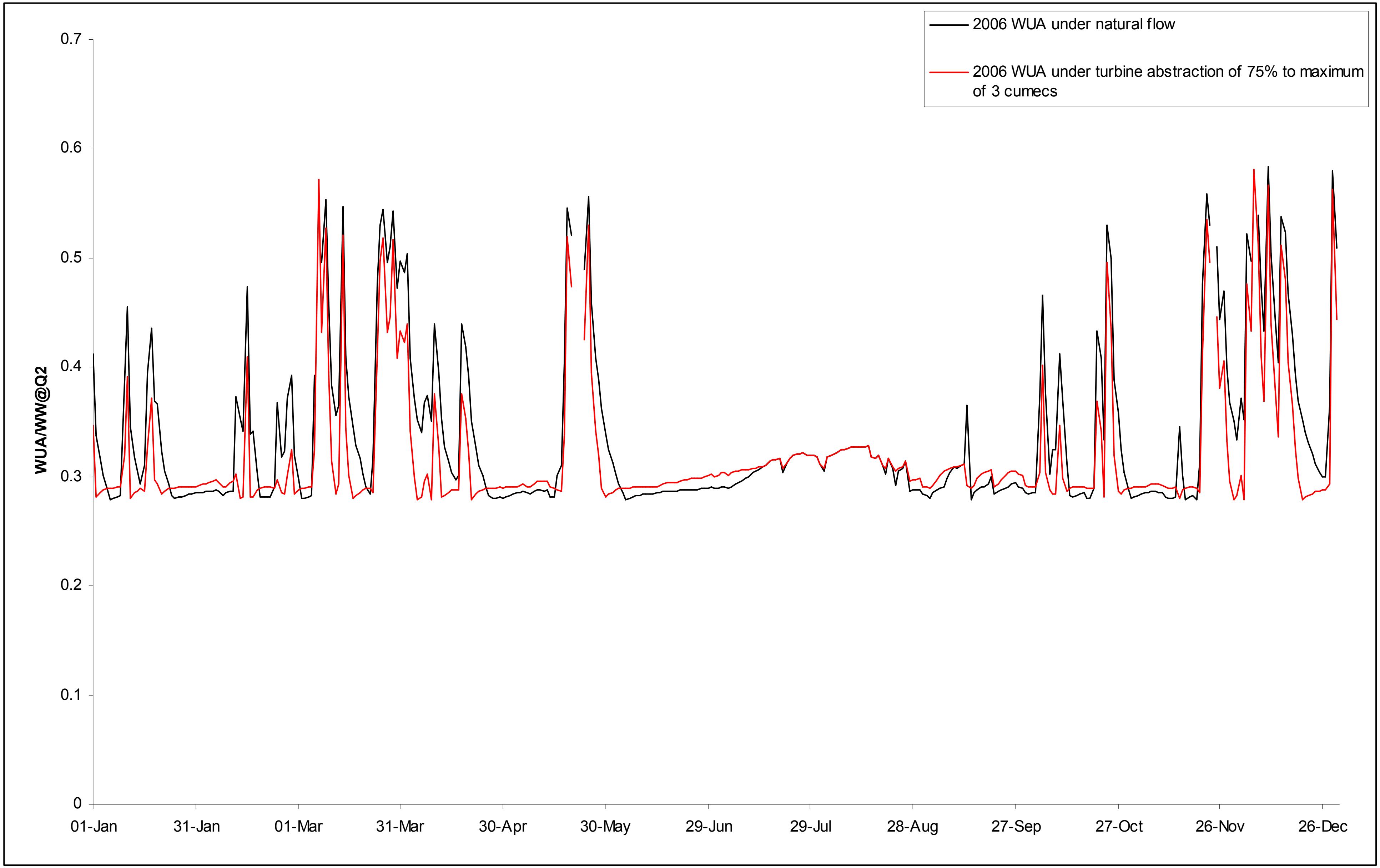
(xi) Impact of a turbine take of 100% of river flow above Q90 in 2006, up to a maximum of 2 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



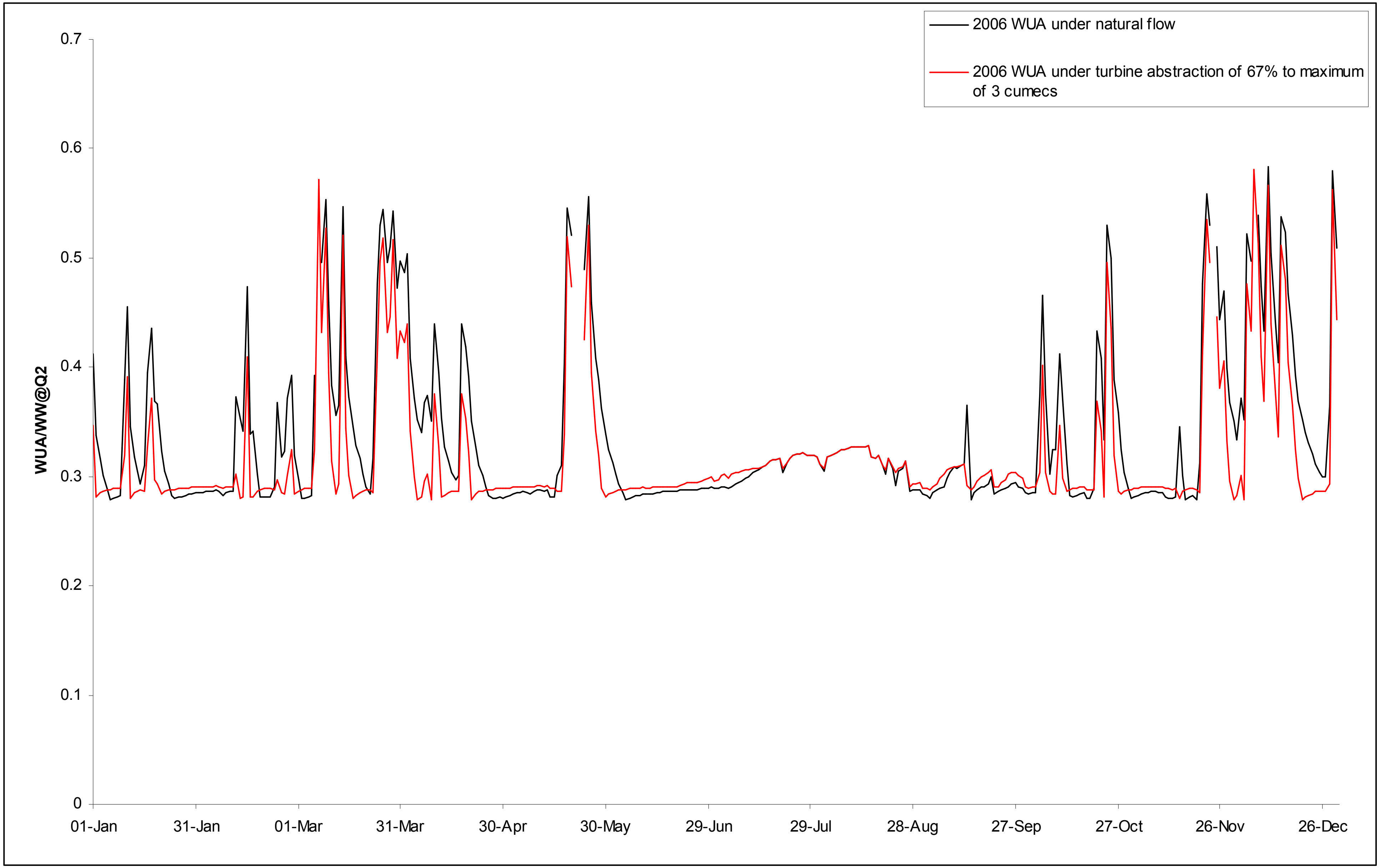
(xii) Impact of a turbine take of 75% of river flow above Q90 in 2006, up to a maximum of 2 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



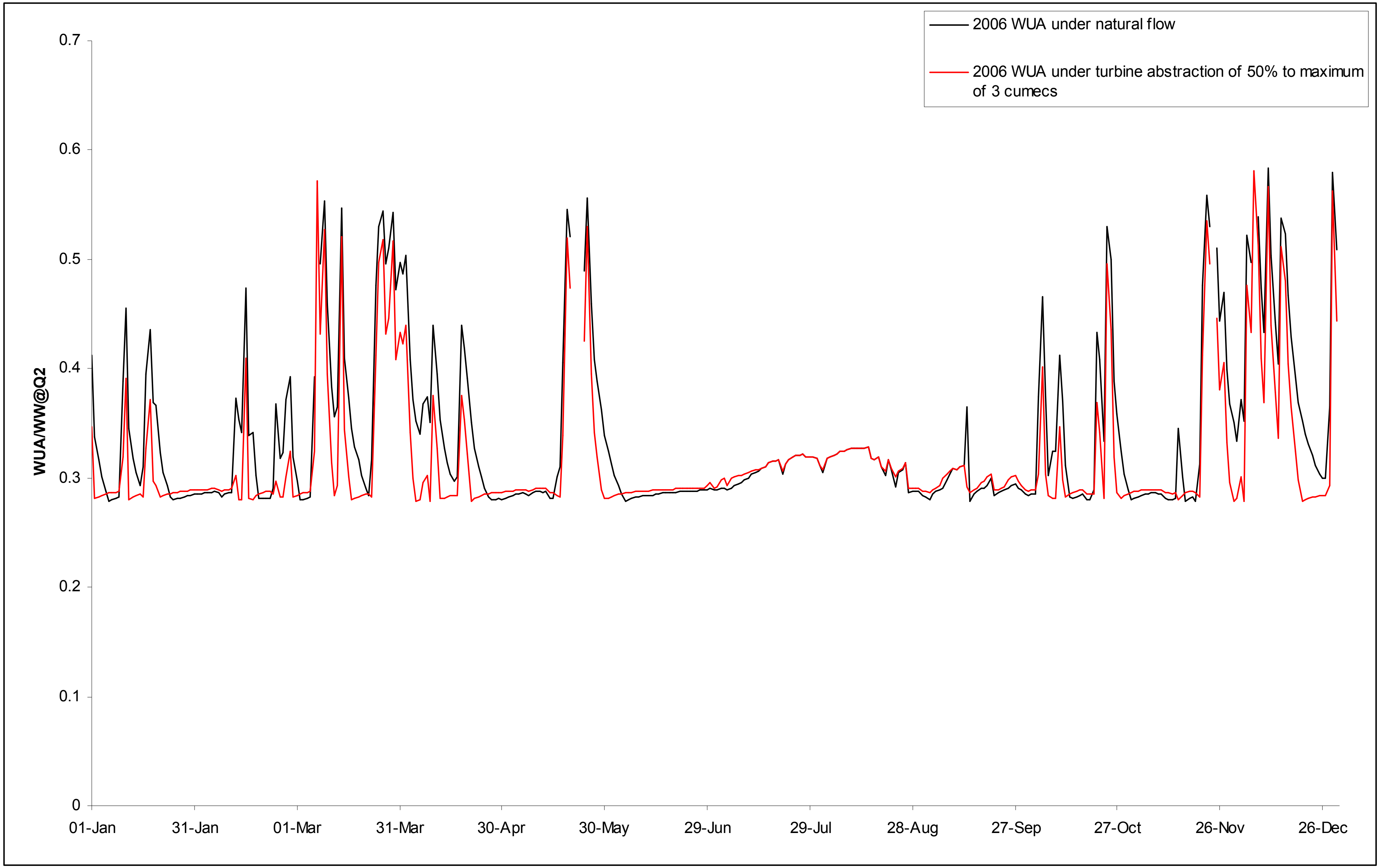
(xiii) Impact of a turbine take of 100% of river flow above Q90 in 2006, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



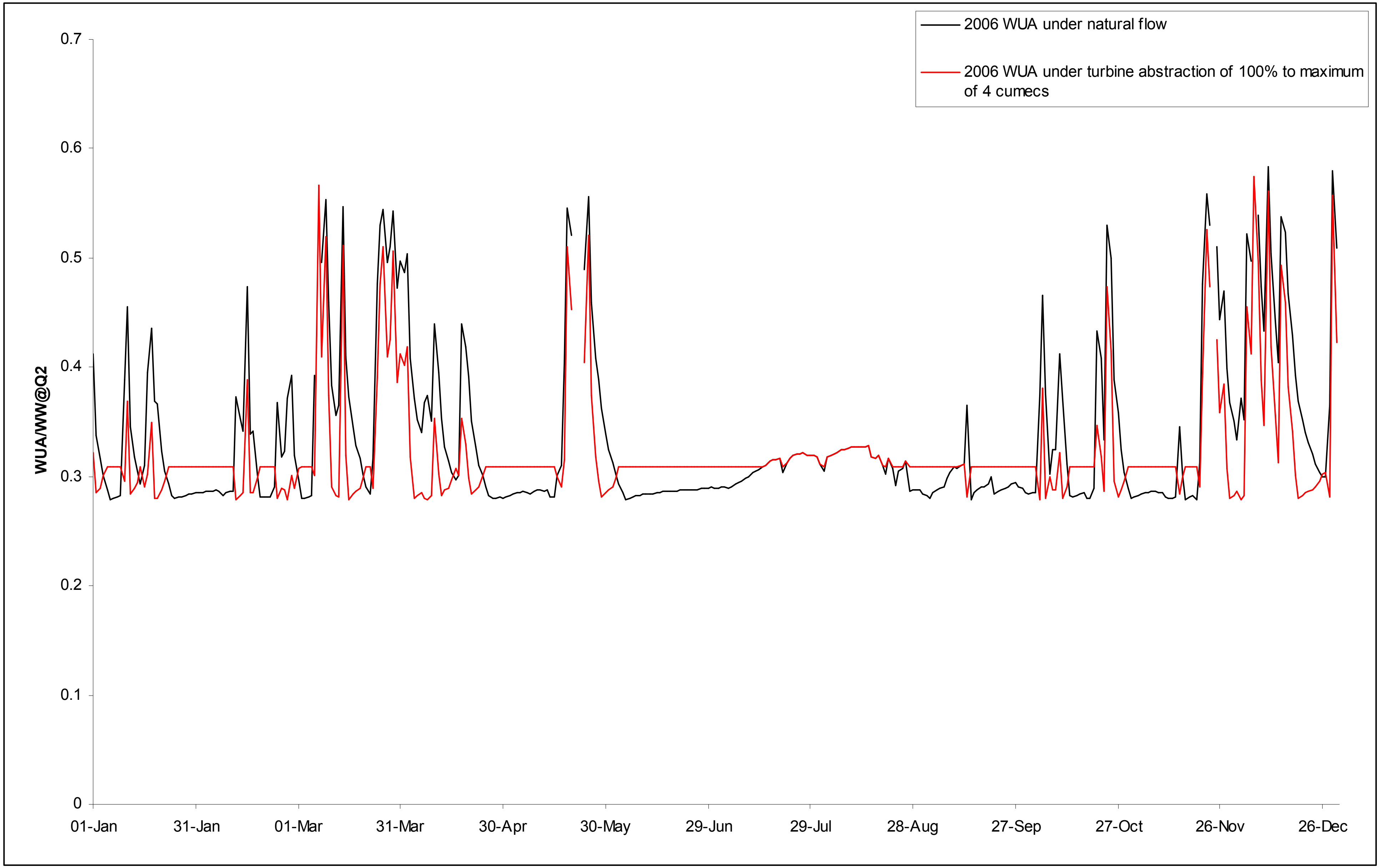
(xiv) Impact of a turbine take of 75% of river flow above Q90 in 2006, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



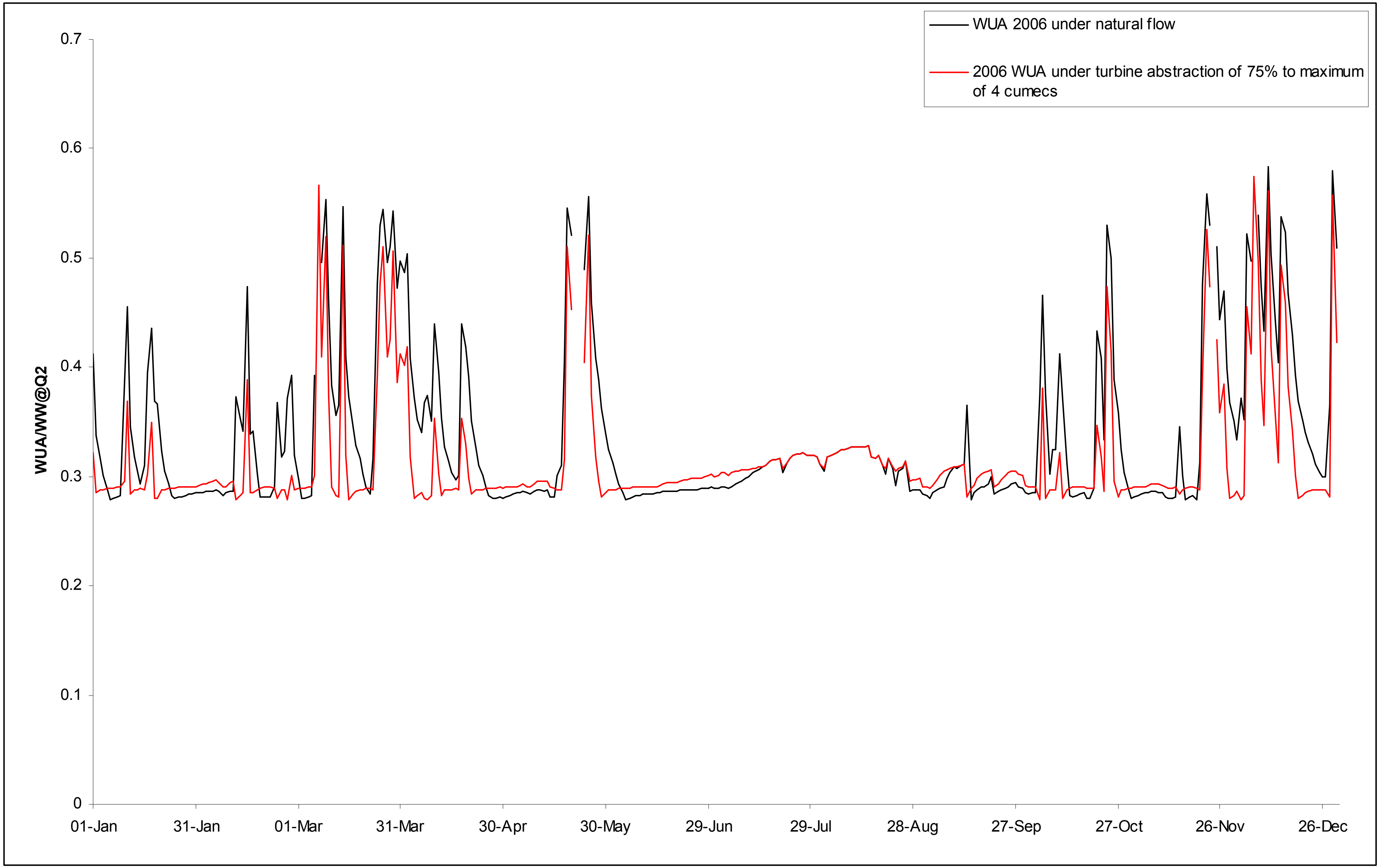
(xv) Impact of a turbine take of 67% of river flow above Q90 in 2006, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



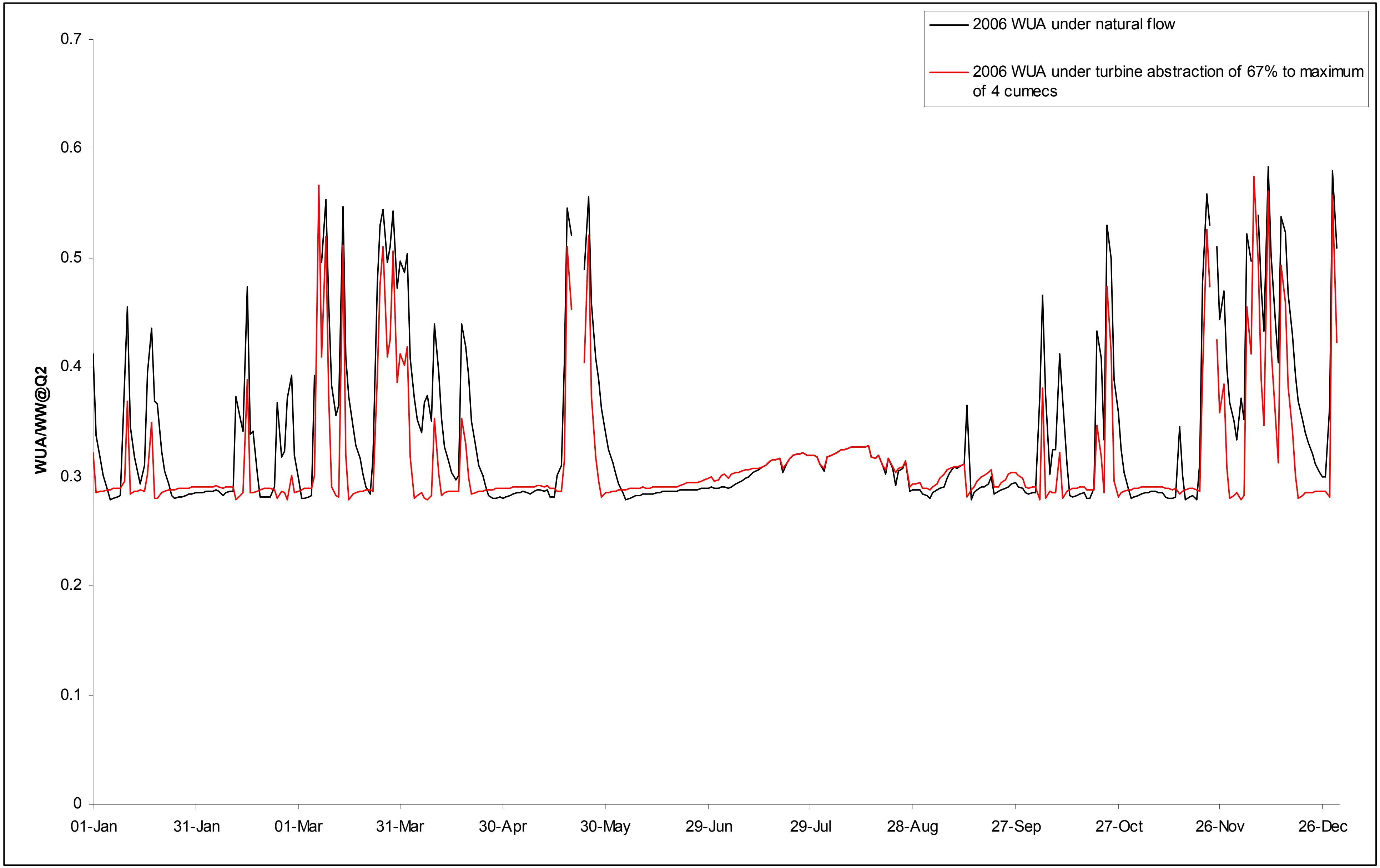
(xvi) Impact of a turbine take of 50% of river flow above Q90 in 2006, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



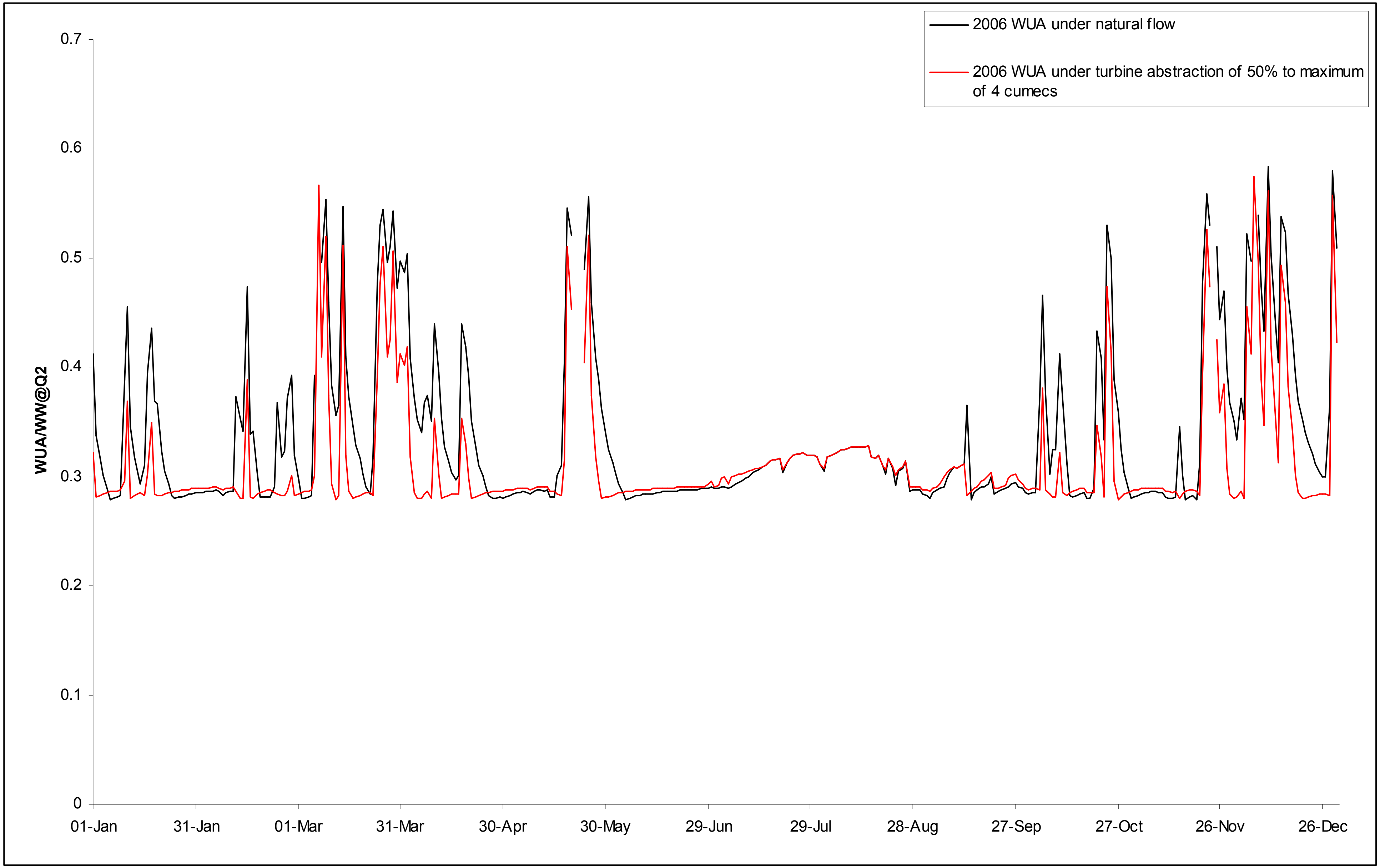
(xvii) Impact of a turbine take of 100% of river flow above Q90 in 2006, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



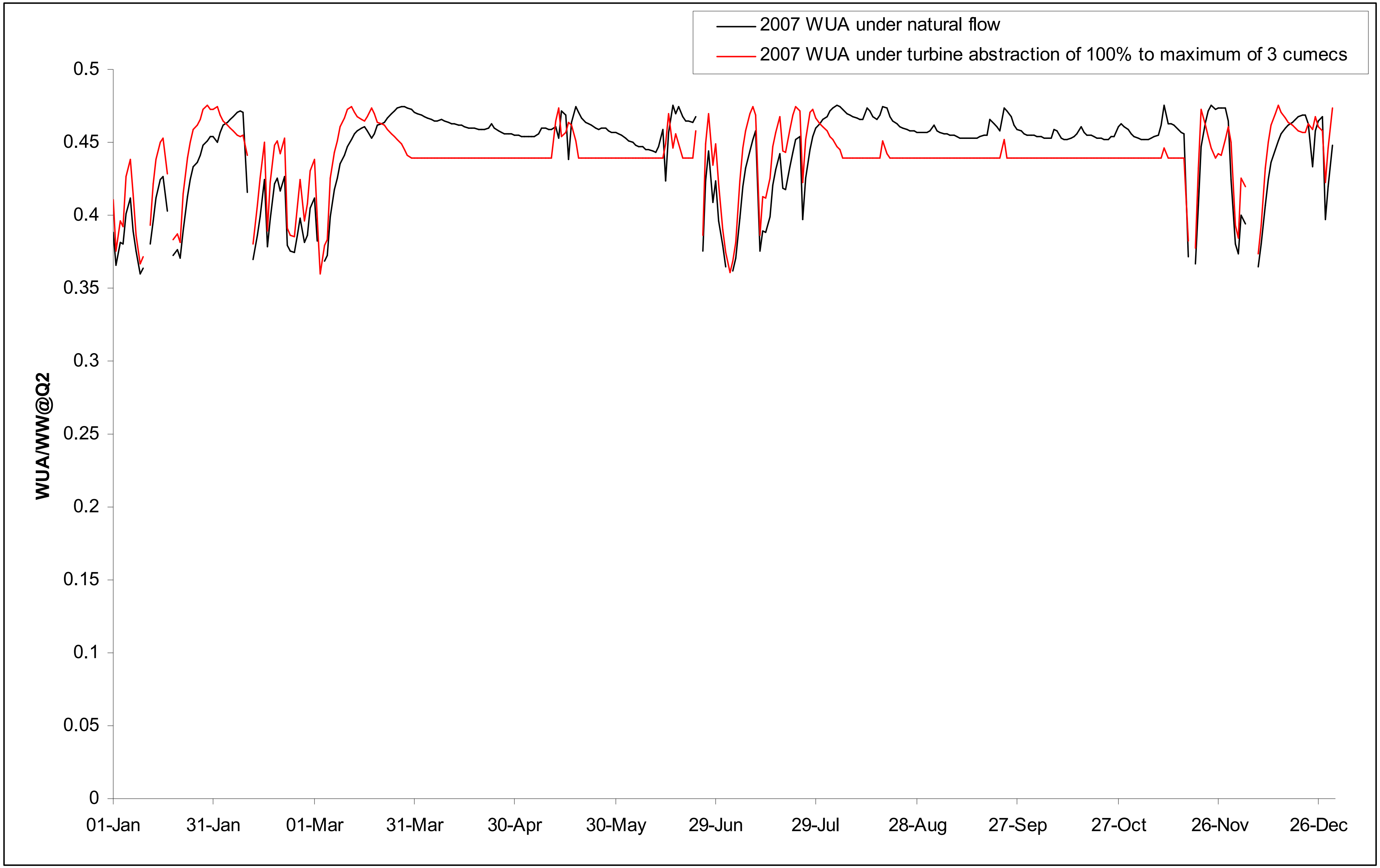
(xviii) Impact of a turbine take of 75% of river flow above Q90 in 2006, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



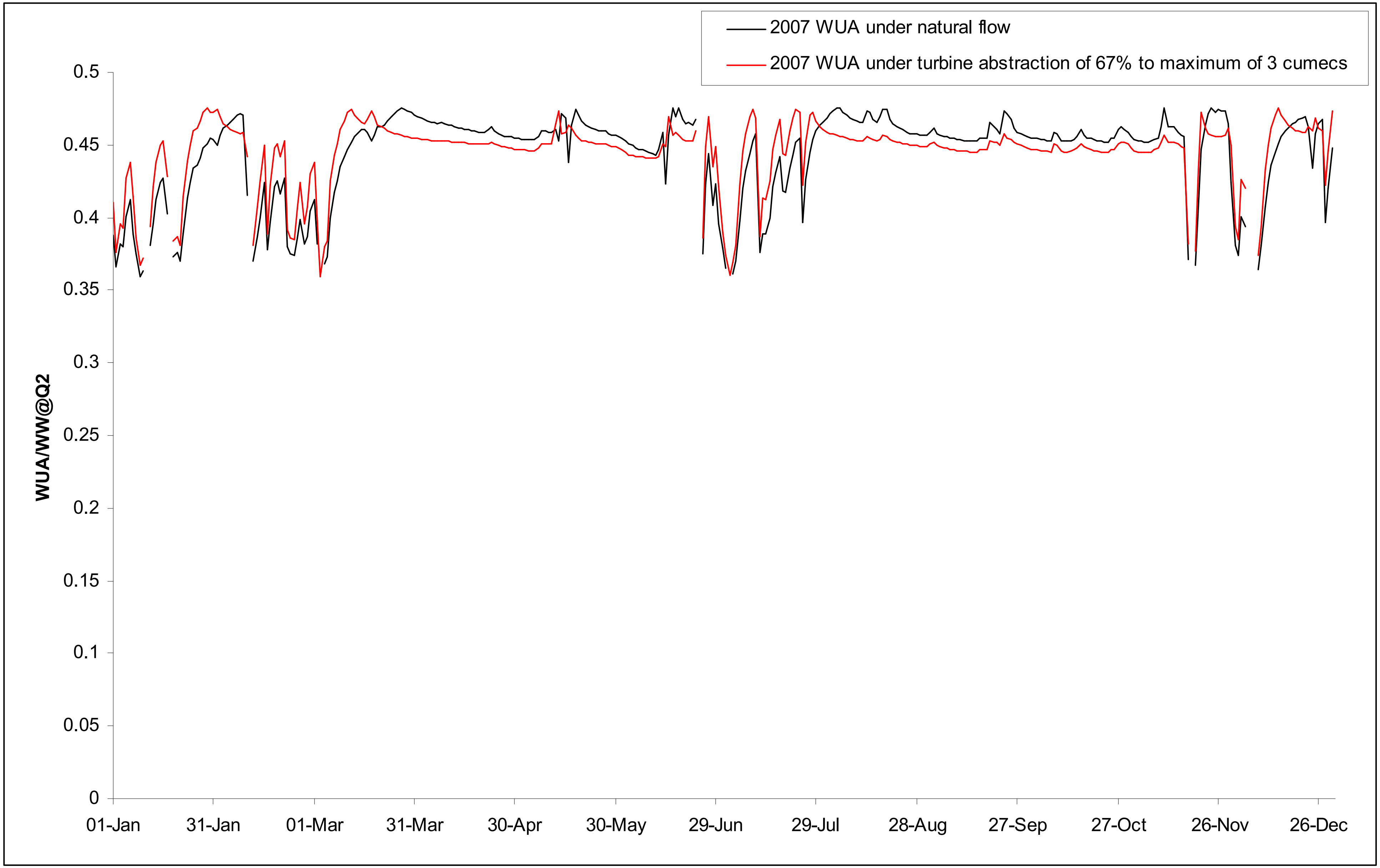
(xix) Impact of a turbine take of 67% of river flow above Q90 in 2006, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



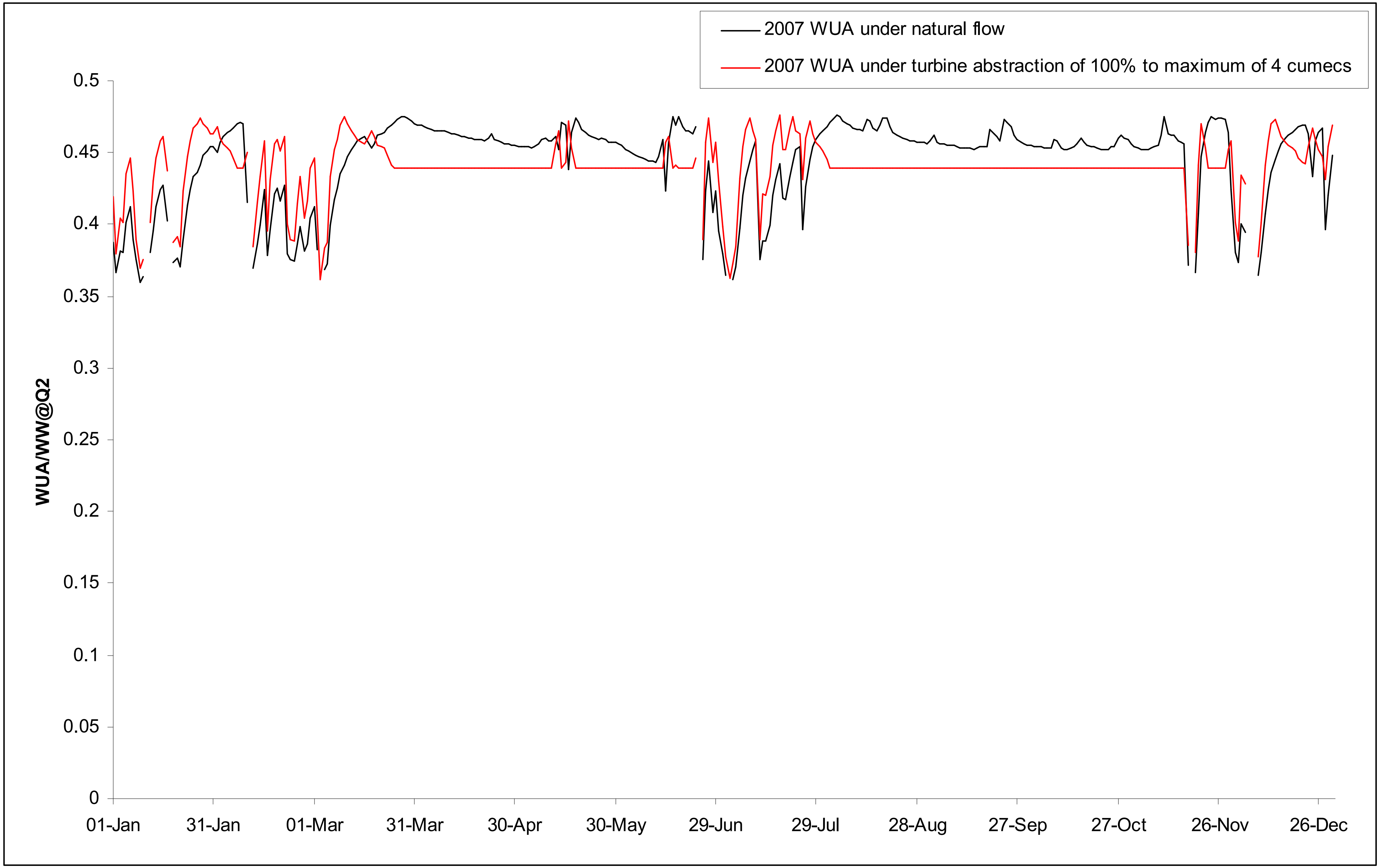
(xx) Impact of a turbine take of 50% of river flow above Q90 in 2006, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



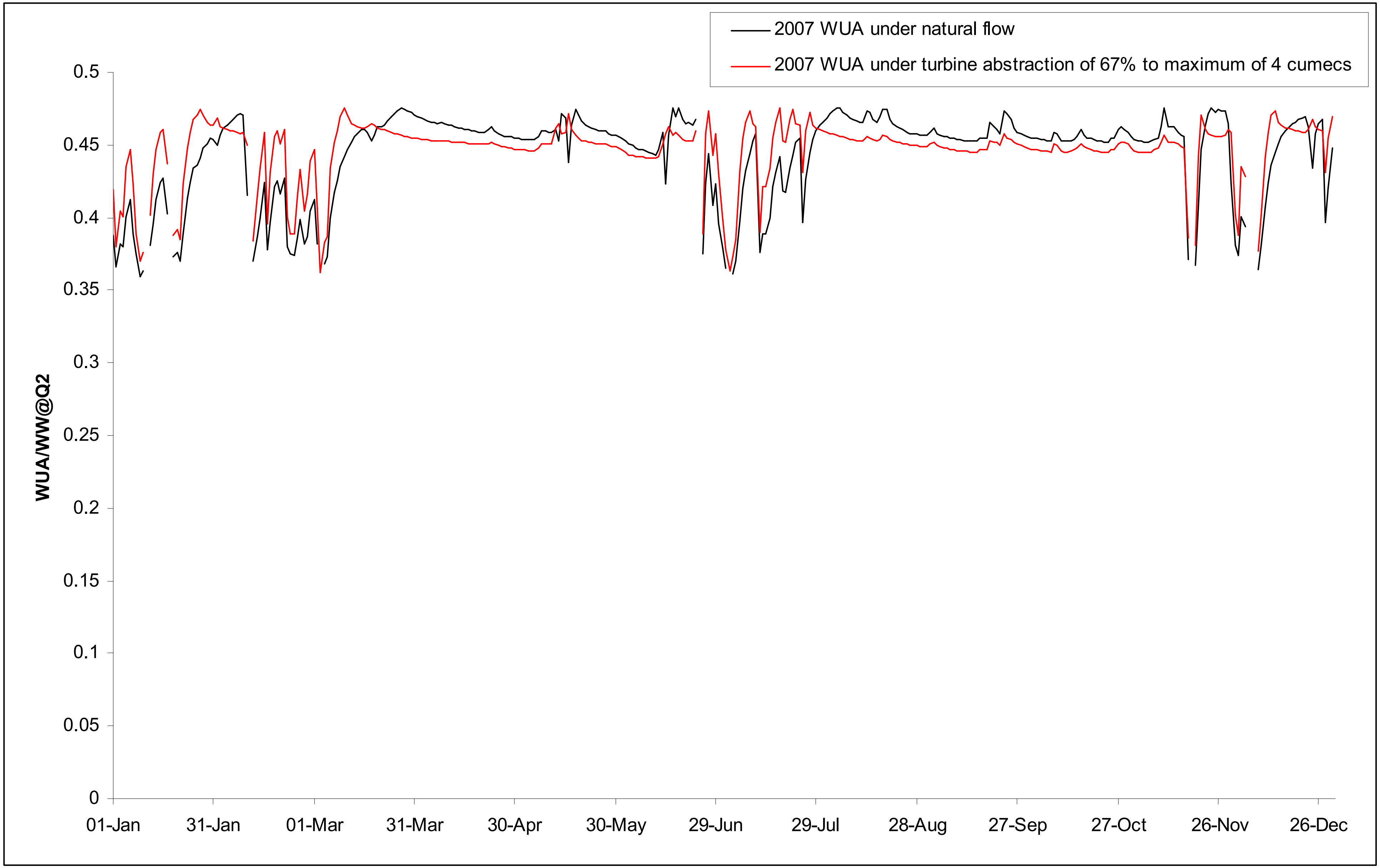
(xxi) Impact of a turbine take of 100% of river flow above Q90 in 2007, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm trout



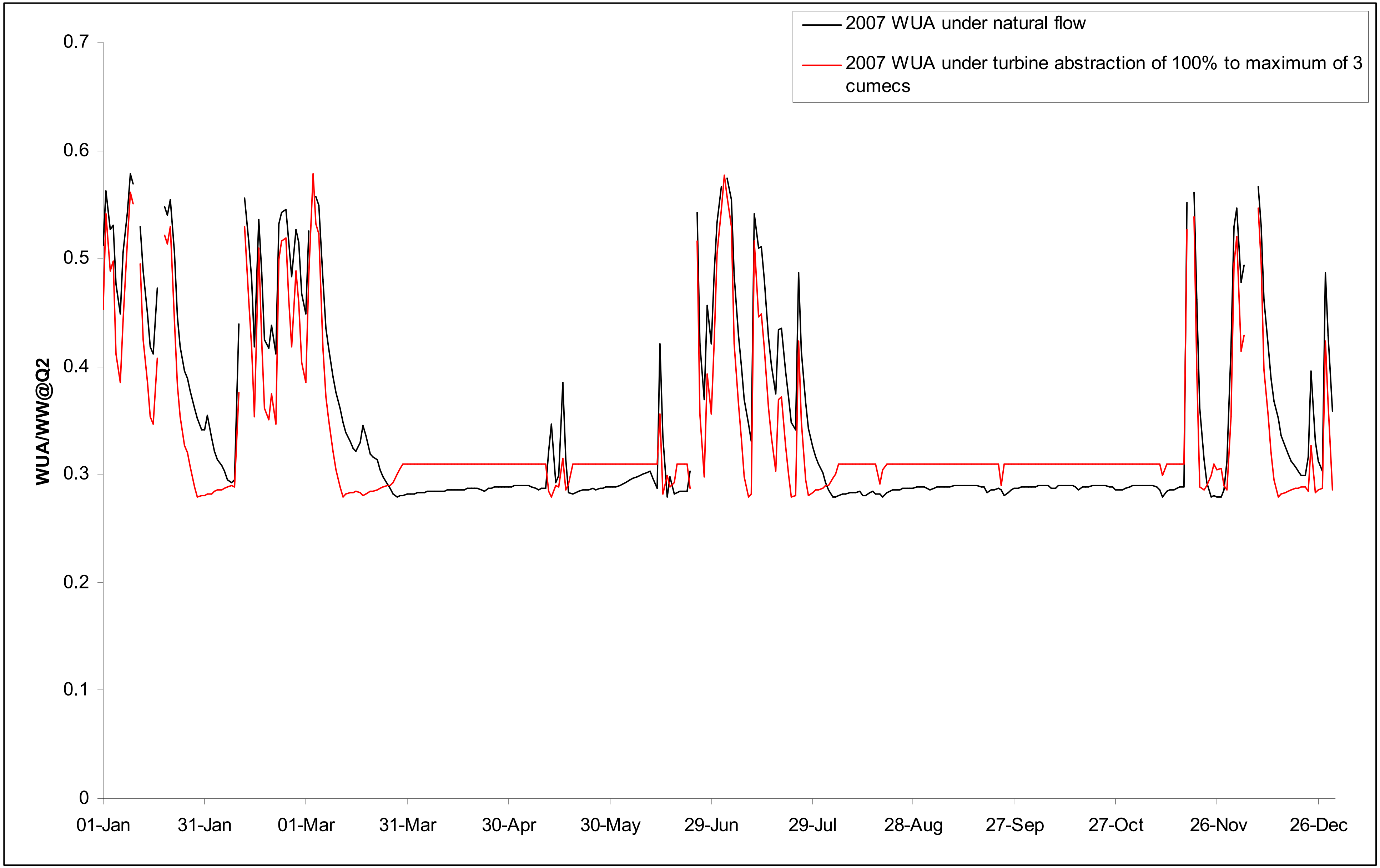
(xxii) Impact of a turbine take of 67% of river flow above Q90 in 2007, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm trout



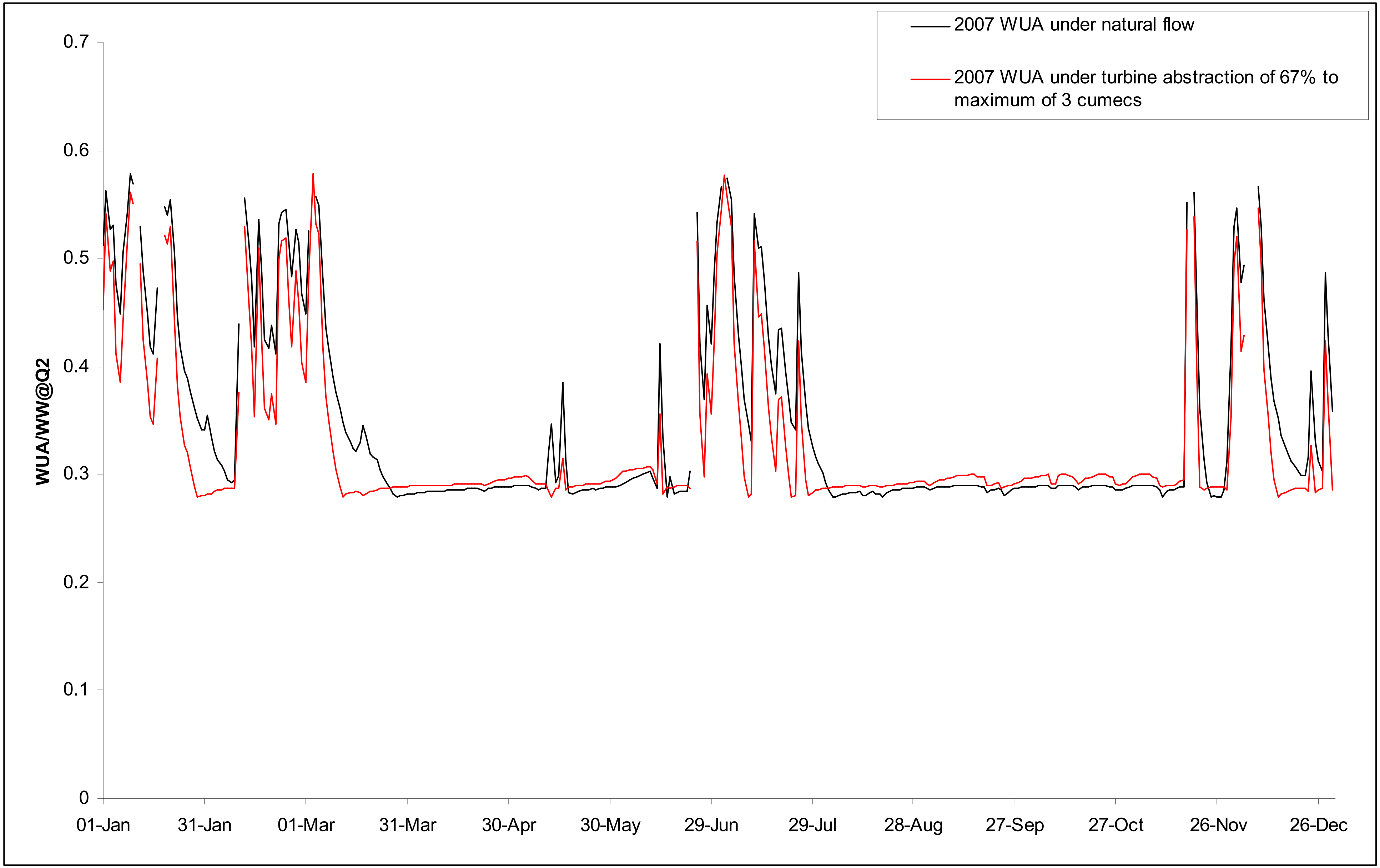
(xxiii) Impact of a turbine take of 100% of river flow above Q90 in 2007, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm trout



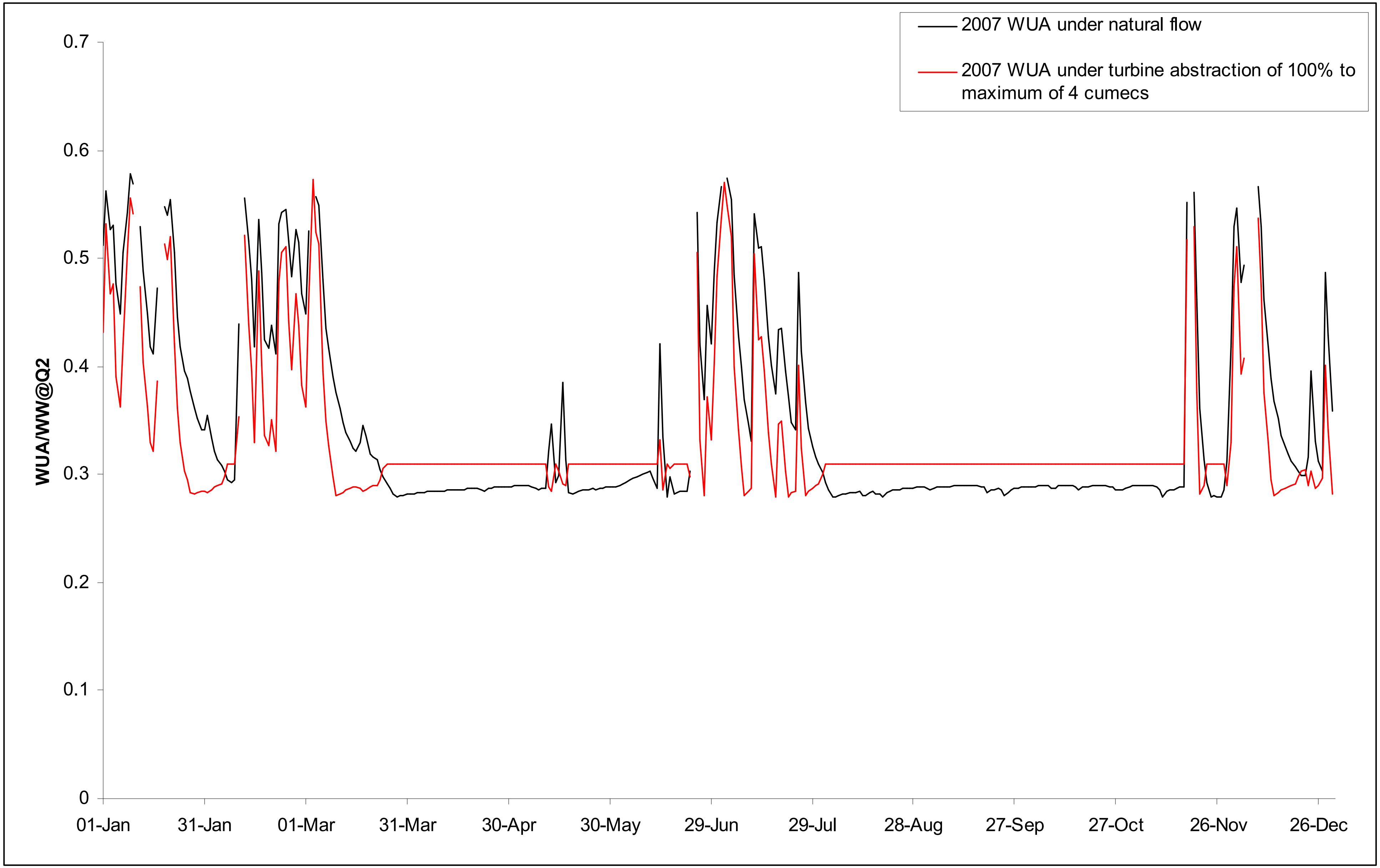
(xxiv) Impact of a turbine take of 67% of river flow above Q90 in 2007, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm trout



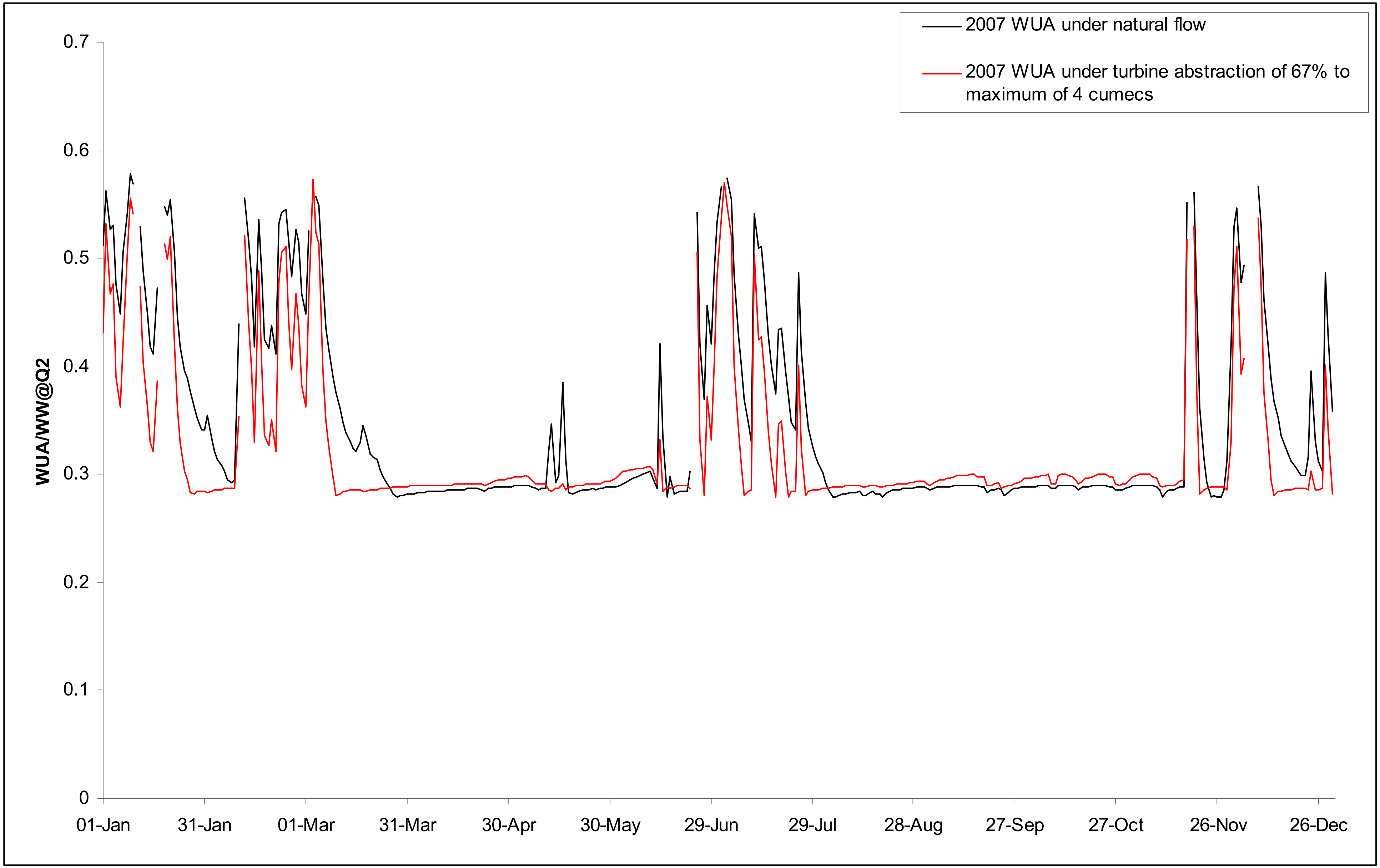
(xxv) Impact of a turbine take of 100% of river flow above Q90 in 2007, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



(xxvi) Impact of a turbine take of 67% of river flow above Q90 in 2007, up to a maximum of 3 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



(xxvii) Impact of a turbine take of 100% of river flow above Q90 in 2007, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm salmon



(xxviii) Impact of a turbine take of 67% of river flow above Q90 in 2007, up to a maximum of 4 cumecs, on the WUA/WW@Q2 for 0-7cm salmon