**Appendix A. Supplementary material**

Reproductive success of stream fish species in relation to high and low flow patterns: the role of life history strategies and species traits

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*Table A.1: Abundances and occurrences of the 13 selected juvenile species*

|  |  |  |
| --- | --- | --- |
| Species | Total abundance (number of individuals) | Total occurrence (number of sites) |
| Barbatula barbatula | 11684 | 168 |
| Cottus gobio | 10491 | 200 |
| Gasterosteus aculeatus | 13696 | 159 |
| Gobio gobio | 8872 | 119 |
| Lampetra planeri | 47 | 12 |
| Leuciscus leuciscus | 2567 | 49 |
| Perca fluviatilis | 2502 | 96 |
| Phoxinus phoxinus | 7931 | 71 |
| Pungitius pungitius | 814 | 24 |
| Salmo salar | 955 | 9 |
| Salmo trutta | 9020 | 232 |
| Squalius cephalus | 3776 | 81 |
| Thymallus thymallus | 289 | 34 |

*Table A.2: Life-history traits used to follow the opportunistic periodic-equilibrium trichotomy fish life-history strategies: opportunistic (O), periodic (P), equilibrium (E), according to Winemiller and Rose (1992). Trait categories not falling strictly into one of the three life strategies were indicated with potentially suitable multiple strategies.*

|  |  |  |  |
| --- | --- | --- | --- |
| Trait Class | Trait Category | Code | Life-history strategy |
| maximum life span (years) | <8  8-15  >15 | ls1  ls2  ls3 | O  P/O/E  P/E |
| maximum body length (cm) | <20  20-39  >39 | bl1  bl2  bl3 | O  E  P |
| female maturity (years) | <2  2-3  3-4  4-5  >5 | ma1  ma2  ma3  ma4  ma5 | O  E  E  E  P |
| spawning time | 1 per year  > 1 per year | st1  st2 | P/E  O |
| fecundity (no. oocytes) | < 55,000  55,000 - 60,000  > 60,000 | fe1  fe2  fe3 | O/E  P/O/E  P |
| egg diameter (mm) | < 1.3  1.3 - 2  > 2 | ed1  ed2  ed3 | P/O  P/O/E  E |
| parental care | no parental care  protection with nest or hiding eggs  no protection with nest or hiding eggs | nop  pnh  nnh | P/O  E  E |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Rheophily habitat | Feeding habitat | Reproduction habitat | Spawning habitat | Reproductive behaviour | Temperature tolerance | Oxygen tolerance | Incubation period | Relative fecundity | Larval length | Larval stage duration | Shape factor | Swimming factor |
| Atlantic salmon | rheophilic | water column | lithophilic | rheoparous | single | stenotherm | intolerant | ip3 | fr1 | ll3 | ld3 | sh2 | sw2 |
| Brook lamprey | rheophilic A | benthic | lithophilic | rheoparous | single | stenotherm | intolerant | ip1 | fr3 | ll1 | ld1 | sh4 | sw3 |
| Brown trout | rheophilic A | water column | lithophilic | rheoparous | single | stenotherm | intolerant | ip3 | fr2 | ll3 | ld2 | sh3 | sw2 |
| Bullhead | rheophilic A | benthic | speleophillic | rheoparous | single | stenotherm | intolerant | ip3 | fr1 | ll3 | ld2 | sh3 | sw2 |
| Common dace | rheophilic A | water column | phylithophilic | rheoparous | single | eurytherm | intermediate | ip3 | fr2 | ll3 | ld1 | sh2 | sw2 |
| European chub | eurytopic | water column | lithophilic | rheoparous | fractionnal | eurytherm | intermediate | ip1 | fr1 | ll3 | ld2 | sh2 | sw2 |
| European grayling | rheophilic A | water column | lithophilic | rheoparous | single | stenotherm | intolerant | ip3 | fr1 | ll3 | ld1 | sh2 | sw2 |
| European perch | eurytopic | water column | phylithophilic | euryoparous | single | eurytherm | intermediate | ip2 | fr2 | ll2 | ld1 | sh1 | sw2 |
| Gudgeon | rheophilic A | benthic | psamnmophilic | rheoparous | fractionnal | eurytherm | intolerant | ip3 | fr3 | ll2 | ld2 | sh3 | sw1 |
| Minnow | eurytopic | water column | lithophilic | euryoparous | fractionnal | stenotherm | intolerant | ip2 | fr3 | ll1 | ld1 | sh3 | sw1 |
| Ninespine stickleback | eurytopic | water column | phytophilic | limnoparous | fractionnal | eurytherm | intermediate | ip3 | fr1 | ll1 | ld1 | sh3 | sw1 |
| Stone loach | rheophilic A | benthic | psamnmophilic | euryoparous | fractionnal | eurytherm | intermediate | ip3 | fr3 | ll1 | ld1 | sh4 | sw3 |
| Three-spined stickleback | limnophilic | water column | phytophilic | limnoparous | protracted | eurytherm | intermediate | ip1 | fr3 | ll1 | ld1 | sh3 | sw1 |

Table A.3: Supplementary ecological traits

Table A.4: Coding matrix of the supplementary traits

|  |  |  |  |
| --- | --- | --- | --- |
| Trait Class | Trait Category | Code | Life-history strategy |
| Incubation period (days) | < = 7  7 – 14  > 14 | ip1  ip2  ip3 | O  P  E |
| Relative fecundity (no. oocytes/g) | <=57  57-200  >200 | fr1  fr2  fr3 | E  P  O |
| Larval length (cm) | <=4,2  4,2-6,3  >6,3 | ll1  ll2  ll3 | O  P  E |
| Larval stage duration (days) | <12  12-25  >25 | ld1  ld2  ld3 | O  P  E |
| Shape factor | <=4,35  4,35-4,78  4,78-5,6  >=5,6 | sh1  sh2  sh3  sh4 | ?  ?  ?  ? |
| Swimming factor | <=0,38  0,38-0,43  >0,43 | sw1  sw2  sw3 | ?  ?  ? |

*Table A.5: Selected HI by LASSO regression according to the three time frames (2,5 and 10 years). Variables are ranked according to their relative importance (unitless, from 0 to 100).*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Indexes | Importance | Period | Indexes | Importance | Period | Indexes | Importance | Period |
| ml22 | 100.00 | 2 years | fl1 | 100.00 | 5 years | dl1 | 100.00 | 10 years |
| ta2 | 63.36 | ma24 | 87.57 | fh6 | 62.97 |
| ra5 | 58.23 | ml22 | 81.46 | dh19 | 57.47 |
| dh16 | 56.30 | dl2 | 79.69 | ma10 | 55.88 |
| dh18 | 54.54 | ra8 | 79.11 | ml22 | 55.02 |
| ma25 | 53.37 | fh5 | 78.50 | dh18 | 53.43 |
| mh16 | 50.26 | dl16 | 77.57 | ma38 | 46.78 |
| dh17 | 47.80 | ra5 | 71.80 | ma43 | 39.44 |
| dh15 | 44.90 | fh6 | 71.39 | fl2 | 39.39 |
| ra8 | 44.70 | ma35 | 69.03 | dl17 | 33.21 |
| mh17 | 40.34 | dh21 | 58.63 | ta1 | 32.06 |
| fh2 | 39.72 | ma29 | 48.80 | mh18 | 31.78 |
| ta1 | 38.31 | ma45 | 43.50 | ma45 | 30.28 |
| dh9 | 38.18 | ma9 | 39.13 | mh8 | 30.17 |
| ma29 | 35.91 | mh22 | 37.57 | dl7 | 29.97 |
| dh10 | 35.49 | ma37 | 37.36 | th2 | 25.94 |
| ma31 | 35.47 | dh7 | 36.83 | dh1 | 24.41 |
| ml18 | 32.19 | mh24 | 35.10 | ma4 | 23.29 |
| dl15 | 30.57 | dh18 | 30.75 | ma9 | 22.31 |
| ma35 | 24.91 | ma38 | 29.93 | ma11 | 21.49 |

Figure A.1: R-square values calculated from species’ GLM according to the three different time frames (1,5 and 10-years). Common dace for the 10-years period was not significant resulting in a null value for R-square.

Table A.6: HI estimates values from the significant species’ GLM according to their respective flow component (duration, magnitude, frequency, and timing) for high flow conditions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Flow Component** | **HI description** | **HI** | **Estimate** | **Species** | **Period** |
| Duration | Means of 7-day maxima of daily discharge | dh12 | 0,036 | Stone loach | 1 |
| Flood duration 1 (monthly flow equaled or exceeded 95% of the time) | dh14 | 0,886 | Brook lamprey | 5 |
| -0,987 | European chub | 5 |
| High flow pulse duration | dh15 | -0,534 | European chub | 10 |
| Variability in high flow pulse duration | dh16 | -0,015 | European grayling | 5 |
| 0,037 | European chub | 5 |
| 0,112 | Ninespine stickleback | 5 |
| High flow duration 1 (where the upper threshold is defined as 3 times median flows) | dh18 | 0,104 | European perch | 1 |
| 0,097 | Gudgeon | 1 |
| -0,250 | European grayling | 10 |
| -0,168 | Brook lamprey | 10 |
| 0,252 | Gudgeon | 10 |
| Variability in annual maxima of 1-day means of daily discharge | dh6 | 0,016 | Brown trout | 5 |
| -0,014 | European chub | 5 |
| Variability in annual maxima of 7-day means of daily discharge | dh7 | -0,023 | Gudgeon | 5 |
| Frequency | High flood pulse count 1 (where the high pulse is defined as the 75th percentile) | fh1 | -0,043 | Bullhead | 1 |
| 0,035 | Stone loach | 1 |
| Flood frequency 3 (where the median of the annual minima is used as the upper threshold) | fh10 | 0,236 | Three-spined stickleback | 5 |
| -0,531 | Atlantic salmon | 10 |
| 0,288 | Bullhead | 10 |
| Mean number of high flow events per year using an upper threshold of 1-time median flow over all years | fh5 | 0,090 | Three-spined stickleback | 5 |
| Mean number of high flow events per year using an upper threshold of 3 times median flow over all years | fh6 | -0,361 | Atlantic salmon | 1 |
| -0,062 | Brown trout | 1 |
| -0,074 | Brook lamprey | 1 |
| 0,072 | European chub | 1 |
| -0,128 | Brown trout | 5 |
| -0,219 | Atlantic salmon | 10 |
| -0,109 | Brown trout | 10 |
| Flood frequency 1 (where the 75th percentile are used as the upper threshold) | fh9 | -0,365 | Bullhead | 5 |
| -0,091 | Brook lamprey | 10 |
| -0,391 | Ninespine stickleback | 10 |
| Magnitude | High flow discharge | mh15 | 0,115 | European chub | 5 |
| 0,029 | Three-spined stickleback | 5 |
| Skewness in annual maximum flows | mh19 | 0,747 | Brook lamprey | 5 |
| -0,281 | Minnow | 5 |
| Mean of the high peak flow during the high flow event (the upper threshold is defined as 7 times median annual flow) | mh26 | -0,030 | Brown trout | 1 |
| Mean maximum September flows | mh6 | -0,302 | European grayling | 1 |
| Timing | Julian date of annual maximum | th1 | 0,001 | Brook lamprey | 10 |
| Variability in Julian date of annual maximum | th2 | 0,009 | Brook lamprey | 5 |
| 0,010 | Stone loach | 5 |
| 0,028 | Minnow | 10 |
| -0,018 | Bullhead | 10 |

Table A.7: HI estimates values from the significant species’ GLM according to their respective flow component (duration, magnitude, frequency, and timing) for low flow conditions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Flow component** | **HI description** | **HI** | **Estimate** | **Species** | **Period** |
| Duration | Annual minima of 1-day mean of daily discharge | dl1 | -0,241 | Brown trout | 1 |
| 3,005 | European perch | 1 |
| -0,144 | Brown trout | 5 |
| 2,276 | European chub | 5 |
| -0,124 | Bullhead | 5 |
| 1,345 | Gudgeon | 5 |
| -0,169 | Brown trout | 10 |
| 1,499 | Brook lamprey | 10 |
| 1,855 | European chub | 10 |
| Means of 1-day minima of daily discharge | dl11 | 7,438 | European grayling | 1 |
| -8,235 | Atlantic salmon | 1 |
| -4,805 | Gudgeon | 1 |
| Variability in annual minima of 7-day means of daily discharge | dl8 | 0,074 | Minnow | 10 |
| Variability in annual minima of 30-day means of daily discharge | dl9 | -0,074 | European grayling | 10 |
| Frequency | Low flood pulse count (number of annual occurrences during which the magnitude of flow remains below a lower threshold) | fl1 | -0,177 | Atlantic salmon | 5 |
| -0,079 | Brown trout | 5 |
| Magnitude | Baseflow index 1 | ml17 | -10,772 | European grayling | 1 |
| 4,149 | Three-spined stickleback | 1 |
| 4,817 | Gudgeon | 1 |
| Ratio of baseflow volume to total flow volume | ml20 | -2,457 | Minnow | 1 |
| 2,368 | Bullhead | 1 |
| Mean annual minimum flows divided by catchment area | ml22 | 0,320 | Brown trout | 5 |
| 0,480 | Bullhead | 5 |
| -524,349 | Brook lamprey | 10 |
| 0,350 | Bullhead | 10 |
| Mean minimum in May flows | ml5 | -3,185 | European perch | 1 |
| 1,825 | European chub | 1 |
| 0,708 | Gudgeon | 1 |
| Timing | Julian date of annual minimum | tl1 | -0,017 | Brown trout | 10 |

Table A.8: List of species' models according to the three time periods

