S3 Table. Comments value functions. For each value function that was elicited from the river experts, we give the attribute name and abbreviation (used in the later analyses), and details concerning the attribute or shape of the value function. Also see S2 Table.

| Attribute | Abbreviation | Comments |
| :---: | :---: | :---: |
| Sediment transport | sedtrans | Sediment transport is easier to measure in meandering than in braided rivers. It is measured with topographical surveys of the river profile, and is an important monitoring measure in practice. It is usually measured all five years. The volume balance is calculated from the river profile and distributed in the measurement period (i.e. five yrs.). The measures are not exact; one can easily have deviations up to $\pm 100 \%$. A problem is the definition of the natural state (reference). Values depend on the river; our expert was only familiar with the river Sihl and gave a value function for this river (origin near Einsiedeln and flows into lake Zürich). |
| Diversity of patches of river bed (coarse substrate) | patchdiv-L | Phys was not able to give the shape of the value function; he would probably use Sigma ( $=$ root of (D16/D84), where D16 $=16 \%$ of granules are smaller than xy cm diameter, and $\mathrm{D} 84=84 \%$ of granules are smaller than xz cm diameter). One has a composition of the substrate from 0 to 20 cm diameter and determines the relative weight of each component. This number gets larger, the wider the substrate distribution. It is therefore a function of the slope: a steep river has a much higher number than a level river. In a worst-possible case, sigma would be 1 , a good natural case, sigma $=6$. <br> Another very good attribute, according to Phys, is to use LAWA classes. For this, one first needs to know the river type and whether it has fine or coarse substrate (coarse substrate for the Wigger). One assigns the river to one of seven classes (class 1: very large diversity of substrate, class 2: large, class 4: moderate, class 5: low, class 7: no diversity of substrate). These classes were treated as discrete and translated to values according to Langhans et al. (2013). Details see separate section in Supplementary Data. |
| Total sinuosity (braided rivers) | sinuos | One has to distinguish between braided and meandering rivers. The attribute is: "sum of the length of all river arms of river section (following all braids)/ (straight) length of the river section". The value function must be steep for the lower values, because an improvement when the river is in a bad state is very valuable, while the gain of additional braids, once there are some braids, is not so large. <br> For meandering rivers one has the same shape of the curve, but the range is from 1 (= minimum) to 1.8 ( $=$ maximum) for a Wigger-type river. |
| Relation between depth and velocity distribution | depthveloc | One measures the depth and the velocity at several (e.g. 100) cross-sections of the river. For each cross section, the Froude number is calculated: $\mathrm{Fr}=\mathrm{v} / \operatorname{sqrt}(\mathrm{g} \times \mathrm{h})$, where $\mathrm{v}=$ velocity, $\mathrm{g}=$ acceleration, $\mathrm{h}=$ water depth. The diversity of the Froude numbers is then measured with a diversity index such as the Shannon Weaver index and compared to a reference river. The higher the diversity, the better the value; BioPhys gave relative values and postulated that this is a linear relationship for the Shannon Weaver index $H^{\prime}$, where $S$ is the total number of species and $p_{i}$ is the frequency of the it ${ }^{h}$ species (the probability that any given individual belongs to the species, hence $p$ ). $H^{\prime}=-\sum_{i=1}^{S}\left(p_{i} \ln p_{i}\right)$ |
| Amplitude of artificial flow variation | flowampl-F | The minimal natural discharge of the Wigger is around $4,0001 / \mathrm{s}\left(4 \mathrm{~m}^{3} / \mathrm{s}\right)$. The maximum value possible (in a Wigger-type river) is around five to seven times the natural discharge, i.e. ca. 20,000 to $28,0001 / \mathrm{s}$. Anything larger than five times the natural discharge is not acceptable. There is a linear relationship in between. In larger rivers, the values can be quite different, and in extreme cases, it can be 20 to 30 times the natural discharge. |
| Amplitude of artificial | flowampl-BP | If there is a hydropower plant in the river, it creates daily amplitude of the discharge. The most common indicator in Switzerland is the ratio between the high and low discharge during one day, where factor eight is an extreme worst case, and one the natural best case. In the EU this |


| Attribute | Abbreviation | Comments |
| :---: | :---: | :---: |
| flow variation |  | indicator is called the maintenance flow regime (and not the natural flow regime) with the idea to restrict the range of small hydro-electrical plants. Amplitude of artificial flow variation $=\left(\right.$ high flow during the day in $\left.\mathrm{m}^{3} / \mathrm{s}\right) /\left(\right.$ low flow during the day in $\left.\mathrm{m}^{3} / \mathrm{s}\right)$. |
| Rate of decrease of artificial flow variation | flowrate | This is an indicator of daily storage of water due to a hydropower plant and hydropeaking. It measures whether the water level falls very steeply. The increase is not important, but for the decrease, speed can be a problem. The values given are for the river Saane, which is about the worst artificial flow variation one can have in Switzerland. The minimum (worst-possible case) is around $40 \mathrm{~cm} / \mathrm{h}$ to $200 \mathrm{~cm} / \mathrm{h}$, the best case around $10 \mathrm{~cm} / \mathrm{h}$. |
| Maximal discharge | dischav | For each of the four seasons the discharge is measured; the maximal value from the four seasons is taken and compared with a reference river: $\%$ deviation of discharge from reference river $=100-(($ max. discharge of river) x $100 /$ (natural discharge of reference river)). $100 \%$ deviation means that there is no flow, $0 \%$ that the river is in its natural state. One could also calculate $\%$ deviation of discharge separately for each season and then average over all 4 seasons. |
| $5^{\text {th }}$ percentile of discharge distribution | dischdist | The $5^{\text {th }}$ percentile of discharge distribution is the discharge which is exceeded in $95 \%$ of the days. It is an indicator for seasonal storage; i.e. if there are dams in the river which are operated on a yearly regime, where water is kept back in the summer. It is compared to a reference river: \% deviation of $5^{\text {th }}$ percentile of discharge distribution from reference river $=100-\left(\left(5^{\text {th }}\right.\right.$ percentile of discharge distribution of river) $\times 100 /$ (natural $5^{\text {th }}$ percentile of discharge distribution of reference river)). $0 \%$ means that the $5^{\text {th }}$ percentile discharge distribution is the same as in the (natural) reference river. |
| Discharge of annual flood | flooddisch | The annual flood is the highest flood which occurs on average once a year (higher floods are possible, but less frequent). One compares the discharge value of the annual flood with a reference river: $\%$ deviation of discharge of annual flood from reference river $=100-(($ discharge of annual flood of river) $x$ 100/ (natural annual flood discharge of reference river)). $100 \%$ deviation means that there is no annual flood, $0 \%$ that the river is in its natural state. For a general case, a linear relationship is a good approximation, but for more-detailed cases, one would have to introduce two to three thresholds that specify the start of different process and model the relationship between geomorphological and ecological processes. |
| Frequency of bed-moving flood | floodbed-BP | Compare the average size of the substrate with the size of the substrate of the reference system: \% deviation of frequency of bed-moving flood from reference river $=100-(($ frequency of bed-moving flood $) \times 100 /($ natural frequency of bed-moving flood of reference river) $) .0 \%$ deviation means that the substrate size of the river is the same as in the (natural) reference river. |
| Frequency of bed-moving flood | floodbed-P | The minimum is $\mathrm{HQ}_{20}=$ statistically a river-bed forming discharge (i.e. large flood) every 20 years. There is an optimum at around one flood every three to five years. |
| Frequency of floodplain flooding | floodplain-BP | Compare the frequency of floodplain floodings with those in a reference system: \% deviation of frequency of floodplain flooding from reference river $=100-(($ frequency of floodplain flooding) $\times 100 /$ (natural frequency of floodplain flooding of reference river) $) .0 \%$ deviation means that the floodplain flooding of the river is the same as for the (natural) reference river. |
| Frequency of floodplain flooding | floodplain-L | According to LAWA (2004), the frequency of floodplain inundations that are at least two times as large as the river width are assessed in seven classes (class 1: natural = flooding every one - two years, class 3 : impaired $=$ every three - five yrs., class 7 : strongly reduced = floodings fewer than every five yrs.). These classes were transformed into a continuous value function according to Langhans et al. (2013). Further details see separate section in Supporting Information. |


| Attribute | Abbreviation | Comments |
| :---: | :---: | :---: |
| Height of artificial barriers (barriers for mix of fish species) | barrheight | This value function describes barriers for all fish species, including small fish. Fish are the most important taxa for which barriers should be assessed; other species can often pass them, e.g. insects can fly. The barriers can be any artificial obstacles (weirs, but also missing or inadequate fish ladders if there are power stations). The value function is linear, because the Fish-expert does not have any good argument for another shape. |
| No power stations | nopowerstat | For this value function the Fish-expert assumed that the power stations have fish passes (this is the case for newer power stations). So fishes can pass the obstacle upstream. However, when they wander down the river, they often get killed, e.g. in turbines. The mortality can be anywhere between $10-90 \%$. As example, assuming a mortality rate of $10 \%$, with three power stations, the rate would be $10 \% \times 3=30 \%$. The value function certainly has an exponential decrease, but the exact numbers are very dependent on the length of the fish, the power station, the size of the turbine etc. So the given value function is just a best guess. Note, the Wigger has a small power station without a fish pass. |
| Fraction of natural river banks | ripbank |  |
| Relative shoreline length only straight and braided river | shorelength | This attribute is required for braided and straight rivers, but not for meandering rivers. The shape of the curve must be asymptotic, but the maximum can depend on the measurement method. The minimum (worst value) is two because there are two banks. |
| Total width between levees and river | leveeswidth | If there are levees, the functioning of the river system can be impaired compared to the river being able to flow freely over the total width of the "natural" floodplain. The relationship must be an asymptotic curve so that an improvement when the river is in a bad state is of higher value than improvements if the river is already in a good state. BioPhys was only able to give relative values between 0 and 1 . |
| Incision | incision | The depth of incision is measured from the old stream bed, which can be seen on the margins of the river, to the bottom of today's riverbed. If there is a strong incision, the water during a flood cannot leave the channel. The curve is not linear. If incision starts, this is an indication that something is going really wrong. Once incision has started, it can go on "forever". So the value decreases strongly at the beginning. In Switzerland, in a normal river, the worst case is ca. four to five meters. |
| Substrate clogging | substrclog-L | According to Schälchli (2002), the colmation is assessed in five classes (no colmation: substrate very loose and coarsely granular / weak colmation: substrate loose and broadly tiered / medium colmation: substrate slightly cemented / strong colmation: substrate is clearly cemented / total colmation: substrate is strongly cemented). These classes were transformed into discrete values according to Langhans et al. (2013). For details see separate section in Supplementary Data. |
| Substrate armoring (äussere Kolmation) | substrarm | To describe substrate armoring one uses a relationship such as sigma = square-root of the relationship D16/ D84 (of the cover layer). The shape of the curve has to be sigmoid; the Phys-expert gave relative values of sigma. D16 means that $16 \%$ of the granulas are smaller than xy cm in diameter, and D84 that $84 \%$ are smaller than xz diameter. Near the maximum, the curve has to be very flat. The worst-possible case is $1=$ everything consists of the same material. |


| Attribute | Abbreviation | Comments |
| :--- | :--- | :--- |
| Vertical |  |  |
| hydrological |  |  |
| exchange | hydrex | This is a direct measure; there are various ways to measure it: tracers, piezo-meter, mapping of the hydraulic head, or sampling the radon <br> concentration in the sub-surface compartment. The easiest way is to sample radon, but a lab is required that can do these analyses (available at <br> Eawag). BioPhys suggests to compare the exchange in the river with a reference river that is still "natural" and that is similar with respect to <br> geomorphology and substrate. The worst case (minimum) cannot be zero, because there are always some hydrological exchange processes <br> going on. The shape of the curve has to be asymptotic with a steep increase in the beginning, because some exchange, if the river is in a poor <br> state, is very important. |


| Attribute | Abbreviation | Comments |
| :---: | :---: | :---: |
| Gradient / slope of cooling | coolslope | As for the gradient (slope) of heating. The values are similar: the worst case is $2^{\circ} \mathrm{C}$ difference to reference river under normal conditions, i.e. excluding rain events. The temperature should be measured in different spots (i.e. also over space, not only time). |
| Total suspended solids | sussolidtot-L | The value function for total suspended solids was derived from the literature: Strager et al. (2000), USEPA (2003), and own assumptions. See separate section. |
| Mean suspended solids concentratio n at low discharge | sussolidlow | Suspended solids concentration is measured at low discharge because of hydropower. The suspended solids are measured with a cone-like device, into which 3-4 liters of water are filled. The weight of the sediment is measured. BioPhys cannot give numbers for this attribute. |
| Deposition of solids in floodplain | sussoliddep |  |
| Water quality | watqual | Since we had explicitly excluded the entire branch "good water quality", but included this objective in our analyses, we assumed linearity for the value function of the corresponding "attribute" (see text). |
| Mean ecosystem respiration, R (spring) | respirspr (respirsu, respirfa) | Respiration is measured as $\mathrm{g}_{2} /\left(\mathrm{m}^{2} \mathrm{~d}\right)$. The value function is a Gaussian curve, but with different values for spring, summer, and fall. It is measured together with respiration (same comment for summer and fall). |
| Mean <br> primary <br> production, P <br> (spring) | prodspr (prodsu, prodfa) | Production is measured as $\mathrm{g}_{2} /\left(\mathrm{m}^{2} \mathrm{~d}\right)$, the minimum is 0 and the maximum for a river-type river $10 \mathrm{~g} \mathrm{O}_{2} /\left(\mathrm{m}^{2} \mathrm{~d}\right)$; both are indicative of a bad state of the river. It is an optimum curve, with different values for spring (before leaf emergence) than for summer and fall. Production can change a lot, even every 100 m in the river. It cannot be used alone, but must be combined with respiration to evaluate how the ecosystem is changing. Usually one uses the ratio of production and respiration. The values depend on the problem in the river. As example, if you have the problem of organic pollution and install a wastewater treatment plant, you will see a decrease - but not necessarily if the river is suffering from additional impacts. If the river is shaded by trees along the shore, and maybe islands and has a longer channel length, production could be lower in a Wigger-type river than it is today. If the production/ respiration values are known before the restoration, the values after restoration can be compared to measure the success of the measure (same comment for summer and fall). |
| Density of thermal refugia | refug-BP | To define the thermal refugia, the system is mapped with a thermal camera (infrared camera). Refugia is a place with a significant drop in the temperature, e.g. $2-3^{\circ} \mathrm{C}$ lower than the maximal temperature. If the river is really homogenous, the river is in the worst-possible state $(=0 \%$ thermal refugia). The maximal density of thermal refugia in a natural system would be 30 to $35 \%$; and up to $40 \%$ in extremely good conditions. The curve is asymptotic. |


| Attribute | Abbreviation | Comments |
| :--- | :--- | :--- |
| Density of <br> thermal <br> refugia | refug-BB | Thermal refugia are important, as example for fish, additionally to the structural diversity which also offers refugia. BioB gave a value function, <br> but felt unsure about it and suggested that we use the one from BioPhys for our further analyses. |
| Proportion <br> shoreline <br> length <br> channel | shorelength-BP |  |


| Attribute | Abbreviation | Comments |
| :---: | :---: | :---: |
| Refugia: structural diversity | structdiv | Shading and refugia are important aspects of structural diversity, additionally to thermal refugia. This is not covered by the hydromorphological attributes such as the relationship between depth and velocity distribution. $100 \%$ structural diversity is achieved if each point in a river section is different from all other points within one $\mathrm{m}^{2}$. Structural elements would mainly be deadwood. In the best case, around $15 \%$ of the area would be covered by deadwood. If there is more deadwood, the situation deteriorates, so the value function is an optimum curve. The worst-possible case of $100 \%$ deadwood coverage is a theoretical value, which could occasionally occur after storm events. Optimal values are achieved for up to $70 \%$ of the area being covered with deadwood. |
| Dispersal: drift / benthos ratio | driftbenthos | There are quite good data for this in the literature. The relationship is certainly not linear, and there is an optimum at ca. $1-3 \%$ benthos being in drift. Around the optimum, the curve should be fairly flat. If there are around $4-5 \%$ of benthos in drift, the river is already in a fairly bad state, the worst-possible state is if $10 \%$ of benthos (or more) are in drift. For the increasing branch of the curve, if no benthos are in drift, the value is around 0.65 . |
| Substrate armoring (colmation) for vertical refugia | colm | The worst-possible case is that the entire interstitial space is clogged with fine sediments (value $=0$ ). Although the simplest relationship would be linear, BioC thinks that it is better to place the mid-point at around $60 \%$. If there is already a good ecological level, it is ecologically more valuable to improve this to a really good state. In contrast, if the river is in a bad state, the overall value of improving the river to a medium state is not so important. However, this is also a philosophical question: does one want to improve a heavily modified (urban) river? For BioC it is more important to improve a river towards a near-natural state. The shape is sigmoid, with the steepest slope around the middle. On a logarithmic scale it would be a linear relationship. |
| Proportion of softwood vegetation/ length | softw-BP | It is important to consider the dimensions of the system. A small creek will not have more than $5-10 \mathrm{~m}^{2}$ of softwood per meter of river length, but a large river might have hundreds. Therefore, BioPhys proposes to use the ratio between area of softwood vegetation and area of wetted channel (per meter of river length). It is difficult to define the natural river for a Wigger-type river in Switzerland, because one does not have a natural state anymore. In the interview it was defined that "best-possible state" equals what can actually be achieved in Switzerland today with best-possible restoration measures. |
| Area of softwood vegetation/ length | softw-BB | The calculation for the maximum value is based on 40 m from the river edge into the land-area (at a right angle to the river) and ca. 1 km length along the river: $40 \mathrm{~m} \times 1,000 \mathrm{~m}=40,000 \mathrm{~m}^{2} / \mathrm{km}=40 \mathrm{~m}^{2} / \mathrm{m}$. |
| Proportion of hardwood vegetation/ length | hardw | Same comment as for softwood vegetation above. |
| Proportion of pioneer vegetation/ length | pionveg | Same comment as for softwood vegetation above; the numbers are the same as for softwood vegetation. |


| Attribute | Abbreviation | Comments |
| :---: | :---: | :---: |
| Proportion of gravel bars/ length | gravel-BP | Same comment as for softwood vegetation above. |
| Area of gravel bars/ length | gravel-BB | Because BioB does not know the numbers, the value function was elicited as \%; it was agreed to use the value function of BioPhys in the case that one value function should be chosen for further analyses. |
| Natural benthic organisms | benthos | To assess the diversity of benthos, the proportion of the different feeding groups can be assessed individually, or an index can be used. Our expert for benthos, BioA, prefers to use the individual feeding groups. He demonstrated why he prefers individual feeding groups using the F13-index from Yoshimura et al. (2006). In this index, the relative proportion of scrapers plus filterers is divided by the relative proportion of shredders plus gatherer-collectors. In an optimal, near-natural river, the index is calculated as: ( $30 \%$ shredders $+20 \%$ filterers $) /(20 \%$ shredders $+20 \%$ collectors-gatherers $)=1.25$. In one type of worst-case river, the index is: $(5 \%$ scrapers $+10 \%$ filterers $) /(40 \%$ shredders $+30 \%$ gatherercollectors $)=0.214$. Another bad example with no riparian vegetation or woods, and lots of fine sediments is: $(5 \%$ scrapers $+10 \%$ filterers $) /$ $(0 \%$ shredders $+70 \%$ gatherer-collectors $)=0.214$. As the calculations demonstrate, to get a low value of the F13-index, different causes are possible, which are masked by the index. Therefore, BioA prefers an individual assessment of the different feeding groups (which is required anyway to be able to calculate the index). This increases transparency and helps to evaluate the causes of a problem. |
| Relative proportion of scrapers | scrap | Usually one uses abundance (individuals/ $\mathrm{m}^{2}$ ), but it can be substituted by classes (see: http://fliessgewaesserbewertung.de/download/handbuch/). It is an optimum curve (optimum with around $30 \%$ scrapers of total benthos), with a "kink" in the descending branch at around $50 \%$ of scrapers, which equals a rather bad state of the river. For very small rivers (smaller than the Wigger), the optimum is around $10 \%$, and for very large rivers around $2-3 \%$ scrapers. |
| Relative proportion of shredders | shred | See comment to scrapers; optimum at around $20 \%$ shredders. Shredders are deadwood, leaf etc. devourers. In water bodies of $4^{\text {th }}$ order, lots of leaves enter the water bodies. If there are less than $20 \%$ shredders (of all benthos), this is not very good, it is an indication that the riparian vegetation and woods are missing. If there are more, this is indicative of shading due to riparian vegetation and woods. It is also an indicator of straightening of the river and lots of leaves entering the system. The maximal value can never be $100 \%$ because half of the benthos will be the next-following member in the succession chain, which are filterers and collectors-gatherers. If the maximum of around $40 \%$ shredders is reached, the river is not really in a bad state, so it receives a value of 0.5 . |
| Relative proportion of predators | pred | See comment to scrapers. Predators are an interesting case. The other benthos change along the length of the river, but predators always have a maximum of ca. $10-15 \%$; more is not possible. The reason is that from one trophic level to the next there is a reduction of $90 \%$. If there are less than $10-15 \%$ predators, this means that there are fewer long-lived organisms, which is indicative of instable conditions. This can be caused by the load of fine sediments, by pollution, or by hydropeaking due to power stations. Theoretically, there can be zero predators, for instance if the oxygen conditions are really bad. |


| Attribute | Abbreviation | Comments |
| :--- | :--- | :--- |
| Relative | collgath | See comment to scrapers; optimum at around 20\% collectors-gatherers (of all benthos), the maximum is $50 \%$ collectors-gatherers. They can |
| proportion of |  | never reach $100 \%$. They are an indicator that a lot of detritus is introduced into the system. If there is substantially less than $20 \%$ this is also a <br> collectors- <br> gatherers |
|  | bad sign and means that there is hardly any nutrition for this group, i.e. crushed or shredded material. The decreasing branch from 20 to $50 \%$ |  |
| is rather typical and indicates that there is a diffuse input of material, while the increasing branch is untypical. |  |  |

Relative filter See comment to scrapers; optimum at around $20 \%$ filterers. This corresponds to the fourth order in the "river-continuum concept". Theoretically
proportion of filterers

Relative periph-BA proportion of periphyton
Seasonally periph-B
averaged
density of
periphyton
the proportion of filterers can reach $90-100 \%$. In contrast to collectors and gatherers, the filterers are capable of feeding on diffuse input material. Nevertheless, high values of $90-100 \%$ are rather theoretical. Zero filterers are a special case if there is acidification and no fine material, and thus no nutrition. This is indicative of a diffuse load.
Theoretically, the relative proportion of periphyton concerns the production, but it is difficult to measure in practice. One would have to also measure the production of macrophytes and phytoplankton, which is difficult. The average value of periphyton is difficult to determine, and it strongly depends on the river type. However, there are a lot of good measurements available for this indicator. The shape is an optimum-curve. If there is few periphyton, this is an indicator of strong shading due to straightening of the river, or toxic substances in the water, or similar. If there is a lot of periphyton, there is no shading of the river, which indicates that there is a large distance from the river to the riparian vegetation. The optimum is around $50 \%$.
Benthos diversity depends strongly on the river type and can be different for different rivers. According to the river-continuum-concept, you would have more shredders, the higher up you are (i.e. in the wooden zones); the nearer you are to the river, the more filterers and periphyton you would have. But the Wigger is not fringed by riparian forest. BioB would need all the benthos feeding groups, but cannot give values; it is fine to use the value functions from BioA. Periphyton is measured as ash free dry biomass (AFDM)/ $\mathrm{m}^{2}$; there is an optimum at around 100 g $\mathrm{AFDM} / \mathrm{m}^{2}$ in summer; but BioB is not sure about the numbers.
Reti-index:
reti-index
(scrapers +
wood-eaters

+ shredders)/
all feeding
types
F13
Yoshimura
index:
(scrapers +
filterers)/
(shredders +

The Reti-index was developed for smaller rivers and is appropriate for rivers up to the $4^{\text {th }}$ order, i.e. such as the Wigger. It assesses the relative proportion of the most-important feeding groups for a Wigger-type river. It cannot increase to $100 \%$ because there are follow-organisms. The best-possible state is at around $40-50 \%$ of scapers, wood-eaters, and shredders. If there are fewer, there will be many filterers, and sediment loads or impacts of other substances. An improvement in the Reti-index always reflects a more-natural state of the river.

## F13-index

The F13-index from Yoshimura et al. (2006) is also well suited to assess $4^{\text {th }}$ order water bodies such as the Wigger. BioA calculated a few examples. Optimum (near-natural river): ( $30 \%$ shredders $+20 \%$ filterers $) /(20 \%$ shredders $+20 \%$ collectors-gatherers $)=1.25$. Worst-case river: $(5 \%$ scrapers $+10 \%$ filterers $) /(40 \%$ shredders $+30 \%$ gatherer-collectors $)=0.214$. Another bad example with no riparian vegetation, and lots of fine sediments: ( $5 \%$ scrapers $+10 \%$ filterers $) /(0 \%$ shredders $+70 \%$ gatherer-collectors $)=0.214$. A value of zero is hardly possible because this would mean that all feeding groups are reduced to zero. In reality, however, they would be replaced by other feeding groups. As the calculations demonstrate, to get a low value of the F13-index, different causes are possible. Therefore, BioA prefers an individual

| Attribute | Abbreviation | Comments |
| :---: | :---: | :---: |
| gatherercollectors) |  | assessment of the different feeding groups (which is required anyway to be able to calculate the index). This increases transparency and helps to evaluate the causes of a problem, while the causes are easily masked when using an index. |
| Natural diversity of macroinvertebrates | macroinvert | BioA would not use the diversity of macroinvertebrates as indicator; one would have to state exactly, which level one is assessing (specieslevel, genus-level?). Experience concerning diversity valuations is not so good; diversity can strongly fluctuate, is dependent of the season, amongst many other factors. Hence, even if diversity of macroinvertebrates is theoretically important, in practice it is not a very useful indicator. |
| Natural diversity of macroinvertebrates | macrinv-BP | BioPhys cannot give value functions for benthic organisms. One should use either the feeding groups or an index (not both). With respect to scrapers there is a certain overlap with primary production, which feeds the scrapers, but it is not the only thing that affects scrapers. BioPhys would prefer an assessment of the different feeding groups to an index. He gave a (linear) value function for the diversity of macroinvertebrates, for which he suggests using the Shannon Weaver index $H^{\prime}$, where $S$ is the total number of species and $p_{i}$ is the frequency of the $i^{\text {th }}$ species (probability that any given individual belongs to the species, hence p ). $H^{\prime}=-\sum_{i=1}^{S}\left(p_{i} \ln p_{i}\right)$ |
| Natural diversity of macroinvertebrates | macrinv-BB | The diversity of the macroinvertebrates can substitute the other benthos feeding groups and can be used as attribute instead. The value function increases: the more diversity the better. It is possible to use any diversity index. |
| Mean density of ground beetles | grbeetl | BioA assessed ground beetles in his PhD ; he found differences to other assessments, but these are mainly caused by more nutrient-rich or nutrient-poor rivers. However, this objective should not be used to assess the nutrient content of the river, but rather whether the shoreline is in a natural state. Ultimately, the more beetles, the better. There is also an extreme variance, depending on the season, the spot, etc. The relationship is not linear. It is a combination of nutrient richness, the proportion of near-natural shorelines, and aquatic-terrestrial interactions. If the latter alone were accessed, the relationship would be linear, but the nutrients cause an exponential value function. The maximum value is reached at about ten individuals per $\mathrm{m}^{2}$ and stays there for up to 50 individuals $/ \mathrm{m}^{2}$. |
| Mean density of rove beetles | rovbeetl | The density of rove beetles is highest when the flooding regime is (near-)natural. This equals around four individuals/ $\mathrm{m}^{2}$; the more, the better. Variability is very high and depends on river type. Effects of morphology and habitat quality are not so strong. Shape of the value function is very similar to that of ground beetles. |
| Natural fish diversity, lower reaches Wigger | fish_low |  |
| Total biomass of trout | totbiomasst | Salmo trutta. The value function is steeper if the river is in a bad state, because it is more important to improve the river if it is in a bad state than when it is already in a good state. The maximum in lower reaches is at around $250 \mathrm{~kg} / \mathrm{ha}$. |


| Attribute | Abbreviation | Comments |
| :---: | :---: | :---: |
| Number of young of the year trout | YOYt | The young of the year are an indicator of natural reproduction. The value function is steeper when the river is in a bad state. |
| Number of juvenile trout | juvent | The juvenile trouts are the rest of the young trouts, i.e. without young of the year. Again, the value function is steeper when the river is in a bad state. |
| Total biomass of adult trout | adbiomasst | It is easier to assess the biomass of adults (kg/ ha) than to count individuals. The value function is steeper when the river is in a bad state. |
| Total biomass of adult barbel and/ or chub | adbiomass | Barbus barbus; Leuciscus cephalus. The value function is steeper if the river is in a bad state. |
| Number of young of the year barbel | YOYb | Barbel is a migrating species. Young barbel are very small and rather difficult to catch. Therefore, abundance is a difficult measure; they do not gather in swarms. Time of assessment is important. It should be autumn, e.g. September. The populations are not that large. Value function is steeper if the river is in a bad state. |
| Number of juvenile barbel and/ or chub | juvenb | The value function is steeper if the river is in a bad state. |
| Number of adult nase | adultn | Chondrostoma nasus. For the nase, the number of adult fish are counted at the spawning ground. If there are several spawning grounds, they are summed up, but typically there is only one. Today one would find around 100 adult nase in the Wigger. The increase from 0 to 300 individuals is very steep, because it is important to Fish to have some nase if there are none at the spawning ground. Hence, the first individuals are very valuable. |
| Occurrence of young of the year nase | YOYn | The young of the year nase are a very difficult attribute, and Fish thinks that there are no experts who could give a value function. The question is how to measure them. Additionally, in the Wigger they wander into the river Aare. However, if they do occur in the Wigger, it is very special. Therefore, the Fish-expert decided that two (yes/ no) classes for occurrence would best reflect this. One could, additionally, assess the occurrence in additional classes (sporadic, numerous), but the occurrence alone suffices. |
| Total biomass of spirlin | totbiomasssp | Albumoides bipunctatus. The Wigger has a rather low density of spirlin, typically, one does not find many. The juvenile spirlin were not assessed separately in the lower reaches, it is sufficient to have the total biomass of spirlin. |
| Dominance of any fish species | domin | In the Wigger it would be barbel (Barbus barbus) or chub (Leuciscus cephalus) that could dominate, both in the lower and the mid-reaches. In the lower reaches it could theoretically also be stoan loach (Barbatula barbatula), but this species does not have any weight compared to the other two species. If it were to be included, one would have to use another measure than $\mathrm{kg} / \mathrm{ha}$. |


| Attribute | Abbreviation | Comments |
| :---: | :---: | :---: |
| Number of non-sitespecific species | nonsite | Some fish can enter the lower reaches that do not really belong there. The values and range should be the same as in the middle reaches. The maximum would be around ten non site-specific species. |
| Percent fish with anomalies or injuries | anom | One would compare the percentage of fish with anomalies or injuries to all fish. The maximum of $50 \%$ is an extreme value that is hardly reached in reality (but is possible). There is a very strong decrease in value in the beginning, i.e. if one finds the first few fish with anomalies or injuries. |
| Natural fish diversity, mid reaches Wigger | fish_mid |  |
| Total biomass of trout | totbiomasstm | Salmo trutta. Trout in mid-reaches is identical to head waters. It is still the dominant fish species. Additional indicators are barbel and a small fish species: stone loach. |
| Number of young of the year trout | YOYtm | Identical to head waters. |
| Number of juvenile trout | juventm | Identical to head waters. |
| Total biomass of adult trout | adbiomasstm | Identical to head waters. |
| Total biomass of barbel | totbiomassbm | Barbus barbus. If number of attributes is to be kept as small as possible, it suffices to assess total biomass of barbel. It is not necessary to assess biomass of adult barbel separately, since this is more or less the same. Rationale: total biomass of barbel is dominated by adult barbell and barbel are a migrating species. |
| Number of young of the year barbel | YOYbm | Barbel is a migrating species. The young barbels are very small and rather difficult to catch. Therefore, abundance is a difficult measure; they don't gather in swarms. The time of the measure is important. You would have to carry it out in autumn, for instance September. The populations are not that large. |
| Number of juvenile barbel | juvenbm | Without young of the year (YOY). |
| Biomass of stone loach | totbiomasslm | Barbatula barbatula. This is a site-specific species, but not a very sensitive indicator. However, Fish needs to know whether they occur or not. They should not be massively abundant. |

Langhans SD, Lienert J (2016) Non-valid MCDA Simplifications. Plos One Supporting Information.

| Attribute | Abbreviation | Comments |
| :---: | :---: | :---: |
| Dominance of any fish species | dominm | Compared with trout, i.e. in the middle reaches of the Wigger, the dominating species would be barbel (Barbus barbus), or chub (Leuciscus cephalus). For this attribute it does not matter whether the dominating species is site-specific or not. Important is only that trout is not dominated by another species. |
| Number of non-sitespecific species | nonsitem | To have ten non-site-specific species would be an extreme value. |
| Percent fish with anomalies or injuries | anomm |  |
| Natural fish diversity, head water Wigger | fish_head |  |
| Total biomass trout | totbiomassth | Salmo trutta. In head waters, the "total biomass of trout" is the same as "total biomass of fish". |
| Number of young of the year trout | YOYth | The young of the year are an indicator of natural reproduction. The value function is steeper when the river is in a bad state. |
| Number of juvenile trout | juventh | These are the remaining of the young trouts, i.e. without YOY. |
| Total biomass of adult trout | adbiomassth | It is easier to assess the biomass of adults ( $\mathrm{kg} / \mathrm{ha}$ ) than to count individuals. |
| Percent fish with anomalies or injuries | anomh | One would compare the percentage of fish with anomalies or injuries to all fish. |

## References

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