PNAS
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Supplementary Information for

Damming decisions: a multi-scale approach to balance trade-offs among dam infrastructure, river restoration, and cost

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Other supplementary materials for this manuscript include the following:

Dataset S1

www.pnas.org/cgi/doi/10.1073/pnas.1807437115

Supplementary Information Text

1. Decision criteria: additional equations. We model quantities for ten criteria that respond to dam removal and are seen as important providers of public benefit (7–10). We do not account for potential feedbacks between criteria, but instead model changes in capacity based on whether each dam is kept or removed. Units for model variables are provided in SI, or are left blank for unitless variables (refer to SI Appendix: Table S2 for data sources). Though other important criteria such as sedimentation, contaminated sediment removal, and invasive species (27) are not included in our model, they could be incorporated in future studies using our MOGA framework.

Hydropower capacity (P): We incorporate the widely available Federal Energy Regulatory Commission (45) hydropower capacity data to define the authorized capacity for hydropower generation and focus our efforts on licensed and exempt hydropower projects that obstruct river flow. Hydropower capacity is calculated as the cumulative sum of capacity

$$P = \sum_{i \in n_d} P_i \tag{1}$$

Where n_d is the set of all dams, with index i and P is the total hydropower capacity (megawatts) summed over each dam i.

Storage (S): Water storage capacities for reservoir dams are measured as the volume (m^3) constrained from reservoir depth and dam hydraulic height data or distance from the dam base to the height of water. Bathymetric data for NE reservoirs are inconsistent, so we use the cone volume method (46) to calculate storage capacity

$$S = \sum_{i \in n_d} (V_{ti} - V_{bi}) \tag{2}$$

where V_{ti} and V_{bi} are reservoir volumes (m^3) from maximum depth to the hydraulic height of the dam and the base of the dam, respectively, for each dam i in set n_d. These volumes are calculated with the following equations

$$V_t = \pi \sqrt{\frac{A}{\pi}} \frac{d}{3} \tag{3}$$

$$V_b = \pi \frac{\sqrt{\frac{A}{\pi}}}{d} \frac{(d - d_{dam})^2}{3} \tag{4}$$

where A is reservoir surface area (m^2) with the dam present, d is the maximum depth of the reservoir (m), and d_{dam} is the hydraulic height of the dam (m). Where hydraulic height is unavailable, total height from base to top of dam is used.

Sea-run fish biomass capacity (F): Sea-run fish biomass capacity (kg), henceforth referred to as biomass, is calculated as a function of available habitat extent (Figure 1b)

(20, 47–50), quality (51) (44), and accessibility (32) for four primary species (SI Appendix Table S1), which we combine as a measure of biomass for a simpler analysis

$$F = \sum_{k \in n_s} \left\{ c_k \sum_{i \in n_d} \left[h_{ik} \prod_{j \in n_{di}} (p_{jk}) \right] \right\} \quad (5)$$

where F is annual sea-run fish biomass capacity (kt a^{-1}); n_s is the set of all fish species, indexed by k; n_d is the set of all dams, indexed by i; n_{di} is the set of all dams downstream from and including i, indexed by j; h_{ik} is the accessible functional habitat above dam i for species k; p_{jk} is the product of upstream and downstream survival through downriver dam j for species k; and c_k is annual biomass carrying capacity (kt m^{-2} a^{-1}) for species k. Functional habitat h_{ik} represents the known spatial distribution, based on physical surveys and historic accounts (20, 47–50), and estimated quality of habitat (51), based on model data and habitat suitability indices (52–57). Habitat suitability models for each sea-run species are used to calculate h_{is}, as well as annual estimates for temperature and flow velocity (SI Appendix Table S2).

$$h_{ik} = \sum_{r \in g} [a_r t_{rk} v_{rk} \vartheta_{rk} * 0.8] \quad (6)$$

where g is the set of river reaches immediately above dam i up to the next set of dams or river terminus, r is an index for an unobstructed river reach above dam i, a_r is the seasonal mean wetted area within reach r (m^2), t_{rk} is the mean annual temperature quality factor in reach r for species k, v_{rk} is the mean annual velocity quality factor in reach r for species k, ϑ_{rk} is a binary value identifying if the river reach r is accessible to species k, and 0.8 is included to assume that 20% of available surface area exists along the river banks and is unsuitable for habitat use due to river height fluctuations (53). Alewife are the only species considered here that can spawn in lakes (58). Calculating h_{ik} requires lake depth data to estimate the cumulative littoral zone available to alewife following our method to calculate storage volume (S). River and stream reaches that experience seasonal drying or that are located within tidal zones are excluded from analysis to reflect species' intolerance of these conditions for spawning and rearing (44).

Drinking water capacity (D): We measure drinking water use as the sum of population served by all dammed drinking water reservoirs that are not removed in a scenario

$$D = \sum_{i \in n_d} D_i \quad (7)$$

where D_i is the number of people served by drinking water stored by dam i in set n_d. These population data are provided by state agencies functioning in the area covered by this analysis. In cases where multiple reservoirs drain or are pumped to a single terminal reservoir before distribution as drinking water, we assume that the source of drinking water will be compromised if any reservoir dams within this network are removed. To calculate our metric for drinking water, we measure the cumulative contributions from all individual drinking water reservoir dams and the contributions from reservoir networks only if all dams in the network remain. In other words, we assume that removal of any dam in the reservoir network will completely break the supply chain of that network, but not impact separate reservoirs.

Properties impacted by dam removal (I): The number of properties impacted by dam removal is estimated based upon the number of properties that could potentially experience a significant change in viewshed, shoreline conditions, property value, or community identity by the removal of a dam

$$I = \sum_{i \in n_d} I_i \tag{8}$$

Where I_i is the number of properties within 200 meters of dam i and its reservoir, if present. Though the influence of dam removals on property values is not clear (59, 60), we assume that a larger number of impacted properties will probabilistically lead to the involvement of a greater number of property owners who resist dam removal (8–10). We calculate an increase in impacted properties when dams with adjacent properties are removed.

Lake boating recreation (R_L): We quantify lake boating recreation capacity as the sum of lake and reservoir surface area (m^2), assuming that the value of lake recreation scales with the availability of dammed reservoirs (61). Removing dams will decrease lake recreation capacity by an amount equal to the surface area loss. We combine the positive influence of dams on lake recreation with the presence of natural lakes in NE, and in cases where lakes existed prior to dam construction using the equation

$$R_L = \sum_{w \in n_L} A_w + \sum_{i \in n_d} A_i \tag{9}$$

where n_L is the number of natural lakes and waterbodies assuming no dams are present, with index w; A_w is the surface area (m^2) of lake or reservoir w; and A_i is the surface area increase (m^2) at reservoirs attributed to increased water elevation from each dam i.

River boating recreation (R_R): River boating benefits from enhanced river connectivity and sufficient seasonal flow conditions for downstream travel. Water depth and flow velocity are also critical factors for recreational suitability (30). River boating recreation benefits from dam removal by increasing the number of potential boating routes and total trip length without requiring portages (62). However, reservoir dams can modulate flows for recreational purposes, and as a result can improve recreational quality downstream and increase the amount of time in which river discharge is suitable for recreation. These benefits of reservoir dams can often exceed the benefits of their removal for connectivity reasons. Using this logic we define river boating recreational capacity using the equation

$$R_R = \max_{i \in n_d} \left\{ \sum_{i \in n_d} \sum_{k \in n_b} \left[r_{ik} \left(\sigma_{ik} + \sum_{u \in n_{di}} \gamma_{iku} \right) \right] \right\} \tag{10}$$

Where n_b is the set of all boat types, with index k; n_{di} is the set of all dams upstream and including dam i, with index u; r_{ik} is the functional river recreation unit (m^2) for boat type k above dam i; σ_{ik} represents the mean fraction of time when recreational reaches above dam i naturally meet minimum discharge requirements for boat k; and γ_{iku} represents the fractional capacity of upstream reservoir dams to provide recreational flows that increase the number of times when discharge requirements are met. We recognize that relating R_R to the maximum river section between dams, headwaters, or coastlines, rather than sampling multiple sections across the study site, may be overly simplistic and may not adequately represent river recreational value in NE. We limit the river recreation season for our model when NE rivers are largely ice free, from April to November, and assume that all reservoir dams can only provide 20% of their storage capacity to recreational releases. Minimum discharge requirements are critical to prevent bottom dragging and collision, and depend on location and boat type (30). We use discharge thresholds of 300 and 2000 cfs, respectively, for canoe/kayak and whitewater rafts in New England (30, 63), and combine the recreational value of both in our assessment. Functional river recreation units are measured using the equation

$$r_{ik} = \sum_{r \in g} [a_{rk} * v_{rk} * d_{rk} * 0.8] \tag{11}$$

where a_{rk} is surface area at reach r accessible to boat k, v_{rk} is the velocity suitability factor, d_{rk} is the depth suitability factor, and 0.8 is included to assume that 20% of available surface area exists along the river banks where depth is too shallow for boating.

Dam breach safety (B): For each scenario we calculate a dam breach safety score, based on the cumulative hazard level of dams, where data are available (SI Appendix, Table S1)

$$B = \sum_{i \in n_d} \theta_i, \qquad \theta_i = \begin{cases} 0 \; if \; dam \; i \; is \; "low \; hazard" \\ 1 \; if \; dam \; i \; is \; "medium \; hazard" \\ 2 \; if \; dam \; i \; is \; "high \; hazard" \end{cases} \tag{12}$$

where θ_i is hazard level for dam i. High hazard dams pose risk to life downstream if they fail or are inappropriately managed (64). We assume that removal of medium to high hazard dams also removes the potential for loss of life due to mismanagement or dam breach.

Nitrogen removal capacity (N): Reservoir dams have the potential to increase the nitrogen removal capacity in a watershed by their tendency to locally increase the residence time of flowing water (31). Nitrogen removal may be a significant metric for protecting estuaries from elevated nutrient loads that accelerate coastal eutrophication and degrade habitat (31, 65–67). We estimate the potential nitrogen removal capacity of reservoir dams first by estimating the percentage of nitrogen removal μ for every waterbody, dammed or undammed, within the watershed (modified from Kellogg et al. 2010, Gold et al. 2016)

$$\mu = 79.24 - 33.26 * \log_{10}\left(\frac{Q_n W}{A}\right) \tag{13}$$

where A is surface area of the waterbody (m^2), W is watershed area, and Q_n is the estimated discharge normalized by watershed area, given a value of 0.6223 m s^{-1} (68). SPARROW model data for New England (69) are used to estimate annual nitrogen loading to each waterbody, and these data are then used to estimate cumulative nitrogen removal f_N by all waterbodies w for the entire watershed

$$N = \sum_{w \in n_L} \frac{(\mu_w + \mu_w^{dam})\alpha_w}{100} \tag{14}$$

where α_w is the annual nitrogen loading (kg a^{-1}) for each naturally occurring waterbody w, μ_w is the percentage of nitrogen removal at each waterbody, and μ_w^{dam} is the increase in percentage of nitrogen removal for each dammed waterbody attributed to increased surface area from damming. Values of N will decrease if reservoir dams are removed because waterbody surface area will decrease as the dam is removed, but there may still be a contribution to nitrogen removal if some waterbody area remains after removal. Change in surface area is calculated based on Equation 9. We assume that removal of run-of-river dams, or those dams with no reservoir, will not decrease N.

Cost (C): Dam removal costs were predicted using parameters from Blachly and Uchida (35). The study modeled cost of dam removal across the U.S. as a function of dam height and length using a linear regression model

$$C_i = \beta_1 height_i + \beta_2 length_i + \varepsilon_i \quad \forall i \in n_d \tag{15}$$

where C_i is the estimated removal cost for each dam i in set n_d, β_1 and β_2 are model coefficients scaling removal cost to dam height and length, respectively, $height_i$ is dam height (ft), $length_i$ is dam length (ft), and ε_i is an idiosyncratic error term. Estimates of β_1 and β_2 are 30,557 (s.e.=17,162) and 1,375 (s.e.=953), respectively. Cost of removal includes a simplifying assumption of no uncharacterized environmental risks (e.g. contaminated sediment removal/remediation, invasive species control, site specific riparian restoration) that may represent significant local and regional concern. We predict potential removal cost for all dams using these parameter estimates and sum only the dams that are removed in each scenario

$$C = \sum_{y \in n_{di}} C_y \tag{16}$$

where n_{di} is the set of removed dams, with index y and C_y is the removal cost for each removed dam. To predict removal cost in cases where dam height and length data are unavailable for non-reservoir dams, approximately one third of all dams in the database, we assume that dam width and height match the dimensions of the channel in which they are located, estimated with equations (70)

$$length_i \approx 3.28 * k_w \sqrt{Q_w} \tag{17}$$

$$height_i \approx \frac{length_i}{a_{dl}} \tag{18}$$

where k_w is the width-drainage area coefficient, given a value of 10 $s^{0.5}$ $m^{-0.5}$, Q_w is mean annual discharge at the dam location (L^3T^{-1}), and a_{dl} is the width to depth ratio set to 20.

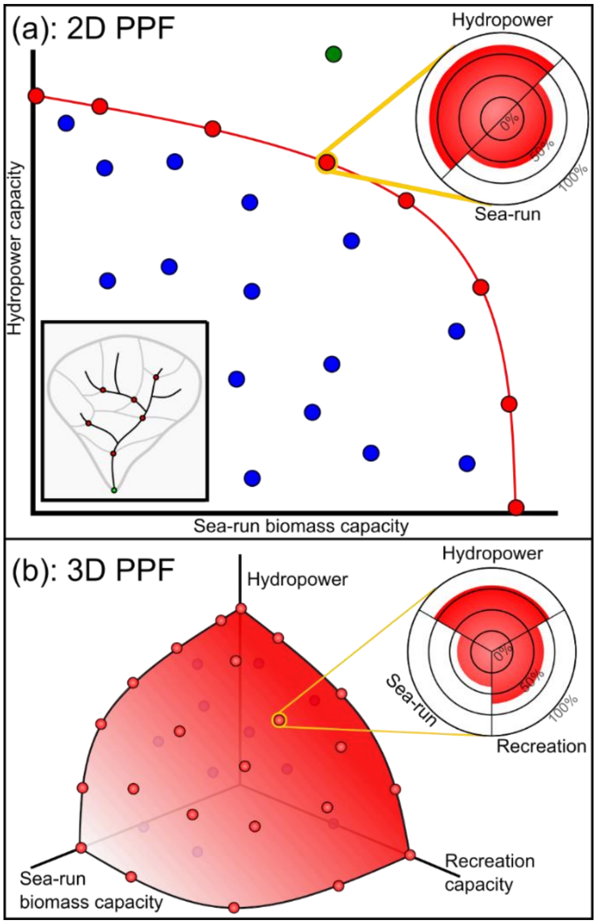

Fig. S1. (a) Cartoon PPF representing the potential trade-offs between hydropower capacity and biomass for multiple efficient scenarios of strategic dam removal in an imaginary watershed (inset grey). The PPF is drawn to intersect efficient scenarios (red). Inefficient scenarios (blue) are less productive and lie underneath the PPF. There are six dams in the watershed with a total of 1,957 different scenarios of dam removal (not all are shown), but only eight are efficient. Hypothetical scenarios that lie above the PPF (green) are currently infeasible, but may be possible if there are infrastructural, technological, or managerial advancements to improve production. The rose plot displays the normalized capacity of hydropower and biomass of a scenario selected by the weighted product model. Weights for this selection are 0.7 and 0.3 for hydropower and biomass, respectively. (b) Three dimensional PPF displaying hydropower, biomass, and recreation for efficient scenarios. Inefficient scenarios again lie below the frontier. The rose plot displays normalized capacity of the three services for a scenario selected by the following weights: 0.6, 0.25, and 0.15 for hydropower, recreation, and sea-run biomass, respectively. Though we are unable to effectively visualize the distribution of efficient scenarios as a PPF with more than three criteria, we can use the same sampling technique to generate rose plots for individual scenarios.

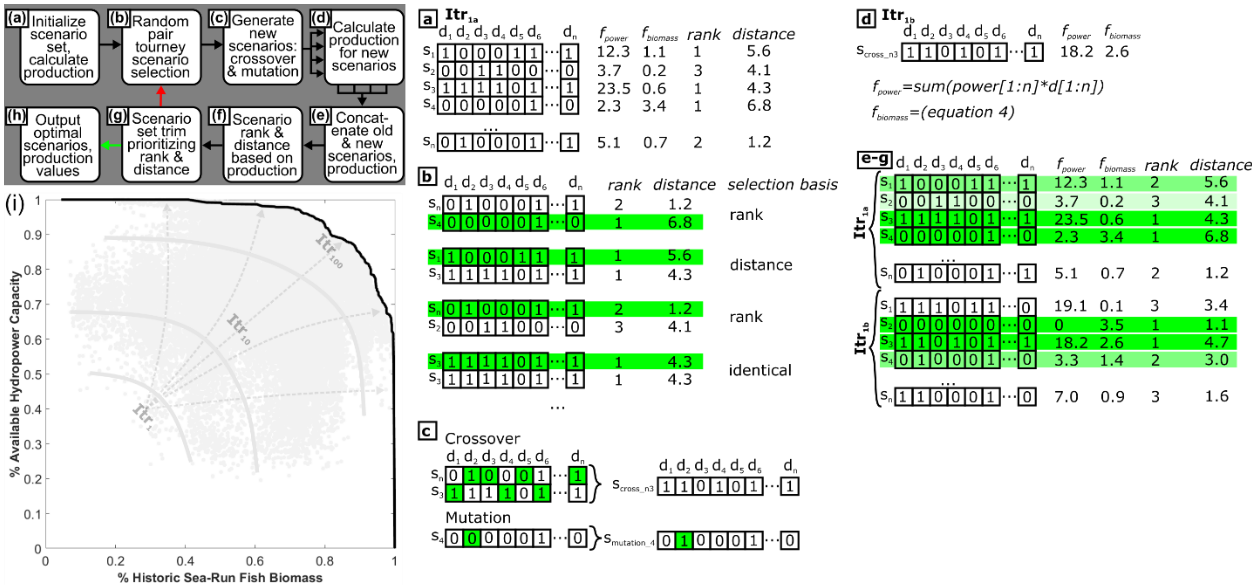

Fig S2. Flow chart describing stages within the MOGA. The MOGA begins by (a) initializing the set of scenarios [S] with random binary sequences representing dams [d] that are kept [1] or removed [0], then calculating quantities for each criteria [*f*], rank, and distance for each scenario. Next, (b) scenarios are randomly paired in tournaments (tourney) and the ones with higher rank are selected to produce the next generation of scenarios. In the case of a tie, the scenario with greater distance is selected. It is possible for a scenario to be paired with itself because the assignment is random. (c) The selected scenarios are then used to generate new scenarios using crossover and mutation algorithms. The crossover algorithm generates 80% of all new scenarios, while mutation generates 20%. For crossover, two of the previous selected scenarios are once again paired randomly. Each cell on the array of the new scenario is populated by a value that is picked randomly from either of the previously selected scenarios. For mutation, each previously selected scenario produces a new scenario by randomly changing the binary value in 1% of all cells in the original scenario. Next, (d) service capacities are calculated for each of the new scenarios and (e) they are subsequently concatenated with the previous scenarios and (f) ranked together. It is possible to calculate service capacities with parallel computing methods, symbolized by the multiple arrows in (d). (g) Scenarios from this long list are then selected based on their rank and distance. In this way it is possible to retain elite scenarios across multiple generations, but also allow for the generation of new scenarios that may increase the range of the PPF. If scenario selection produces no changes to the PPF, then (h) the MOGA reports the efficient scenarios that define the PPF and their service capacities. If the selection process produced an improvement in the PPF, the cycle continues and iterates until there is no further improvement in the PPF. (i) PPF (black line) representing efficient scenarios for hydropower and sea-run biomass capacity for New England. Grey point clouds: inefficient scenarios produced by the MOGA over multiple iterations ($Itr_{1\text{-}100}$), dashed grey lines denote general repositioning pattern of new scenarios generated through many iterations. The MOGA tends to produce new scenarios that shift progressively toward higher capacities for services based on the scenario selection process. Solid grey curves represent the general pattern of preliminary PPFs generated at earlier iterations, reflecting the need for many iterations to identify globally efficient scenarios.

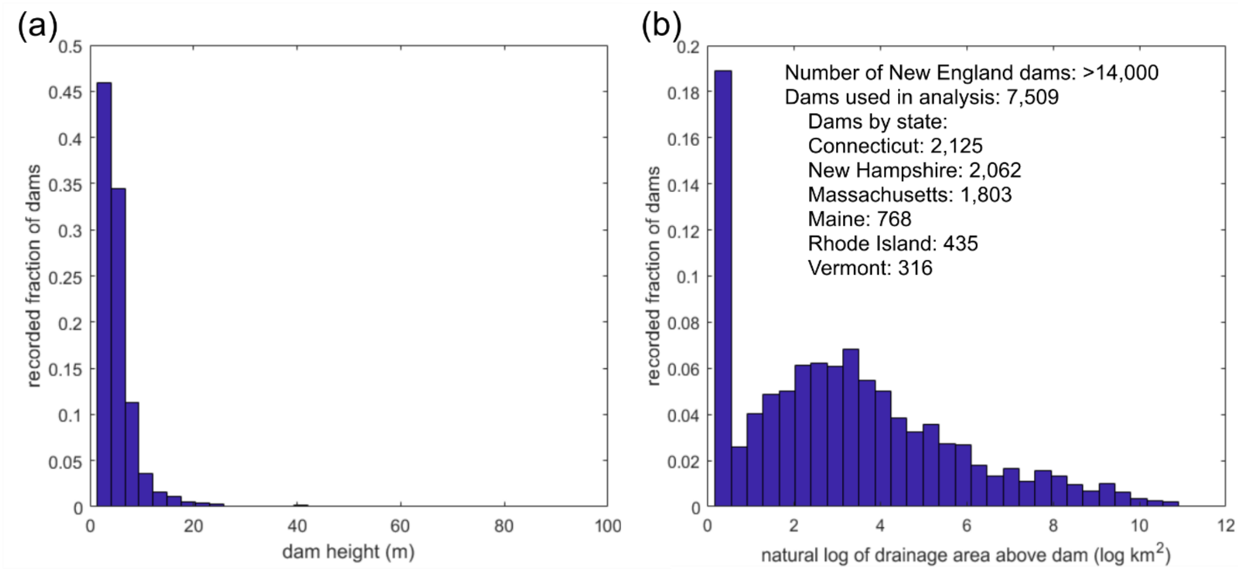

Fig. S3. (a) Frequency of dam heights in New England. A significant portion of dams used in our analysis are less than 2 meters tall. (b) Frequency of log(drainage area) above dams in New England. Almost 20% of all dams in our assessment have drainage area near our bottom threshold of 1 km^2. The majority of New England dams are located in the states of Connecticut, New Hampshire, and Massachusetts.

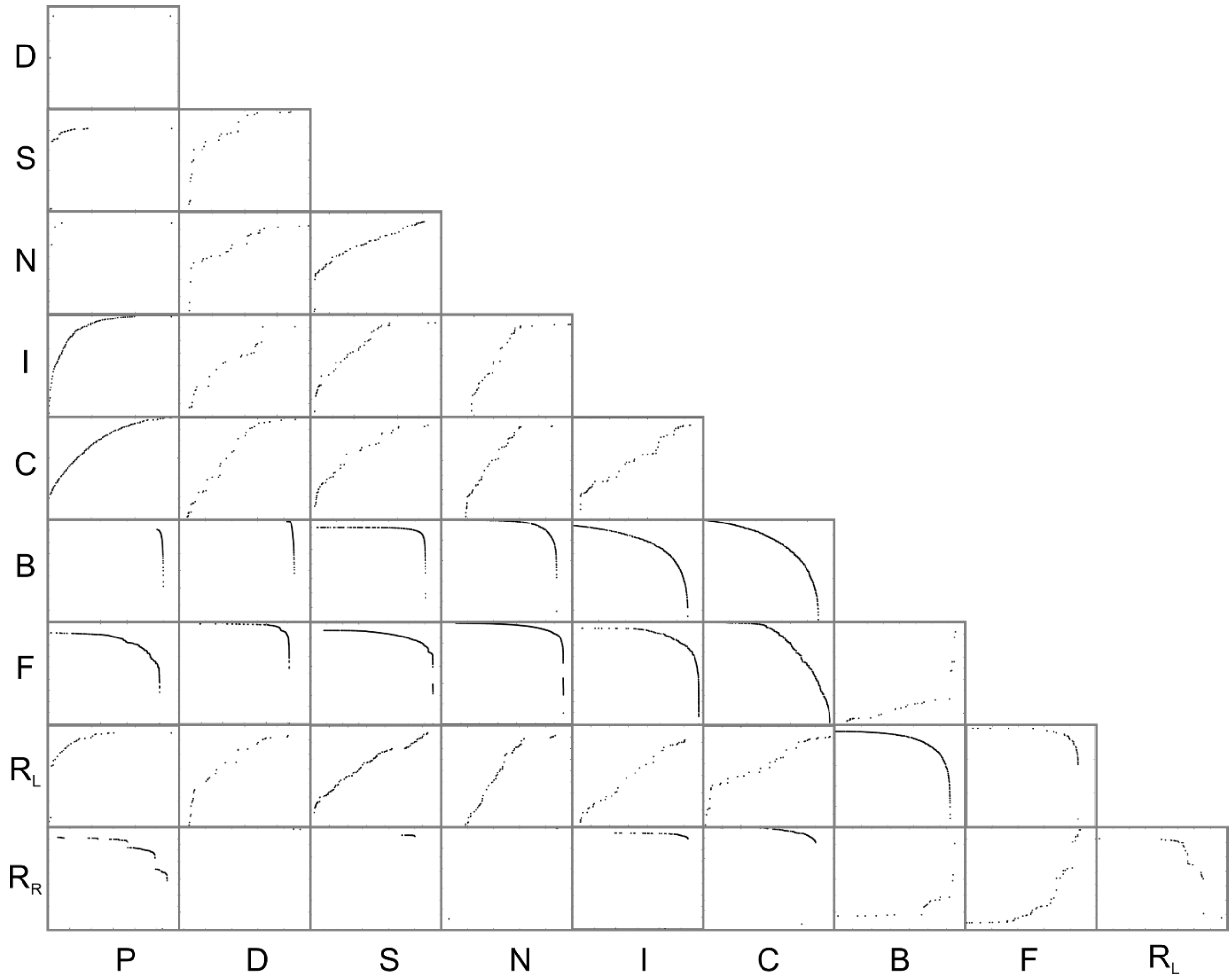

Fig. S4. PPFs for pairwise criteria: P: hydropower, D: drinking water, S: water storage, N: nitrogen removal, I: number of properties impacted by dam removal, C: dam removal cost, B: dam breach safety score, F: sea-run fish biomass, R_R: river boating recreation, R_L: lake boating recreation.

SI Appendix Table S1: Spatial data sources for services, dams, and river networks.

Attributes	Reference
Dam locations	New England Dams Database. Available online: http://ddc-dams.sr.unh.edu (accessed 1 September 2016) *Dam data for all New England states* • Maine office of GIS: impoundments and dams. Available Online: http://www.maine.gov/megis/catalog/ (accessed 1 September 2016) • NH GRANIT: Dam Inventory. Available online: http://www.granit.unh.edu/data/metadata?file=damsnh/nh/damsnh.html (accessed 1 September 2016) • RIGIS: Dams. Available online: http://www.rigis.org/datasets/dams (accessed 1 September 2016) • Vermont Open Geodata Portal: Dams. Available online: http://geodata.vermont.gov/datasets/VTANR::dams (accessed 1 September 2016) • MassGIS: Dams. Available online: https://docs.digital.mass.gov/dataset/massgis-data-dams (accessed 1 September 2016) • Connecticut Department of Environmental Protection GIS Data: Connecticut Dams. Available Online: http://www.ct.gov/deep/cwp/view.asp?a=2698&q=322898&deepNav_GID=1707%20 (accessed 1 September 2016)
Maine culvert locations	• Maine Department of Transportation Public Map Viewer. Available online: https://www1.maine.gov/mdot/mapviewer/
Dam breach safety ratings	*Dam data for all New England states* • Maine office of GIS: impoundments and dams. Available Online: http://www.maine.gov/megis/catalog/ (accessed 1 September 2016) • NH GRANIT: Dam Inventory. Available online: http://www.granit.unh.edu/data/metadata?file=damsnh/nh/damsnh.html (accessed 1 September 2016) • RIGIS: Dams. Available online: http://www.rigis.org/datasets/dams (accessed 1 September 2016) • Vermont Open Geodata Portal: Dams. Available online: http://geodata.vermont.gov/datasets/VTANR::dams (accessed 1 September 2016) • MassGIS: Dams. Available online: https://docs.digital.mass.gov/dataset/massgis-data-dams (accessed 1 September 2016) • Connecticut Department of Environmental Protection GIS Data: Connecticut Dams. Available Online: http://www.ct.gov/deep/cwp/view.asp?a=2698&q=322898&deepNav_GID=1707%20 (accessed 1 September 2016)
Hydrography (used for dam indexing and	USGS (2016), NHDPlusV2. Available online: http://waterdata. usgs.gov/nwis/ (accessed on 1 August 2016)

calculating recreation capacity)	
Hydropower capacity	FERC (2016), complete list of active and exempt licenses. Available online: https://www.ferc.gov/industries/hydropower/gen-info/licensing.asp (accessed on 1 September 2016)
Property data (properties impacted by dams)	*Address locations for all New England states:* • State of Connecticut Department of Emergency Services and Public Protection, 2017 (accessed on 12 December 2016). • Maine Emergency Services Communication Bureau: Augusta, ME, USA. Available online: http://www.maine.gov/megis/catalog/ (accessed on 1 September 2016). • The Executive Office of Public Safety and Security: Boston, MA, USA. Available online: http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/master-address-data.html (accessed on 1 September 2016). • New Hampshire parcel mosaic; New Hampshire's Statewide GIS Clearinghouse: Durham, NH, USA. Available online: http://www.granit.unh.edu/data/search?dset=parcels (accessed on 1 September 2016). • Environmental Data Center, University of Rhode Island: Kingston, RI, USA. Available online: http://www.rigis.org/datasets/e-911-sites (accessed on 1 September 2016). • Vermont E911 site locations; The Enhanced 911 Board: Montpelier, VT, USA. Available online: http://geodata.vermont.gov/datasets/vt-e911-site-locations-building-address-points (accessed on 1 September 2016).
Drinking water capacity	*Drinking water population served for each New England state:* • Connecticut Department of Public Health (CTDPH), 2017. Connecticut surface drinking water sources (accessed 9 October 2017). • Maine public drinking water wells; Maine Department of Environmental Protection: Augusta, ME, USA. Available online: http://www.maine.gov/megis/catalog/ (accessed on 1 September 2016). • Massachusetts Department of Environmental Protection (MassDEP), Massachusetts surface drinking water sources (accessed 3 May 2017). • New Hampshire Department of Environmental Services (NHDES) Drinking Water and Groundwater Bureau. New Hampshire surface drinking water sources (accessed 6 March 2017). • Rhode Island Department of Health (RIDOH). Rhode Island drinking water reservoirs (accessed 5 May 2017). • Vermont public water sources; Department of Environmental Conservation, Water Resource Section: Montpelier, VT, USA. Available online: http://geodata.vermont.gov/datasets/VTANR::public-water-sources (accessed on 1 September 2016).
Sea-run fish habitat extent	McKerrow, A. 2004. *Atlantic states marine fisheries commission*. Abbott, A. 2006. *Maine Atlantic salmon habitat atlas*. Houston, B., S. Lary, K. Chadbourne, and B. Charry. 2007. *Geographic*

	distribution of diadromous fish in Maine. Martin, E. H., and C. D. Apse. 2011. *Northeast aquatic connectivity: an assessment of dams on northeastern rivers*. Abbot, A. 2016. *Alewife ponds*.
Sea-run fish habitat quality variables	Olivero, A. P., and M. G. Anderson. 2008. *Northeast Aquatic Habitat Classification*. Boston, MA. USGS. 2017. *National Hydrography Dataset (NHD) plus, version 2*.
Sea-run fish passage presence, efficiency	Martin, E. H., and C. D. Apse. 2011. *Northeast aquatic connectivity: an assessment of dams on northeastern rivers*. Noonan, M. J., J. W. A. Grant, and C. D. Jackson. 2012. A quantitative assessment of fish passage efficiency. *Fish and Fisheries* 13(4):450–464.
New dam hydropower candidate sites and capacities	Kao, S.-C., R. A. McManamay, K. M. Stewart, N. M. Samu, B. Hadjerioua, S. T. DeNeale, D. Yeasmin, M. F. K. Pasha, A. A. Oubeidillah, and B. T. Smith. 2014. *New stream-reach development : a comprehensive assessment of hydropower energy potential in the United States*. New-stream reach development data are distributed through the National Hydropower Asset Assessment Program (NHAAP) Public Portal (http://nhaap.ornl.gov/). Detailed, location-specific results are accessible through a user agreement to insure the appropriate use of data. Readers can contact NHAAP to request access through their contact website (http://nhaap.ornl.gov/contact).

SI Appendix Table S2: Habitat suitability and carrying capacity parameters for three sea-run fish species

	Salmon	Shad	River herring
Temperature range [C]; suitability[a]	Cool; 100% Trans. cool; 66% Trans. warm; 33% *References:* (52, 53)	Cool = 50% Trans. cool = 100% Trans. warm = 100% *References:* (54–56)	Cool = 60% Trans. cool = 100% Trans. warm = 100% *Reference:* (57)
Flow velocity range [m s^{-1}]; suitability[a]	0; 0% 0.05-1; 20% 1-1.8; 100% 1.8-2.7; 5% >2.7; 0% *References:* (52, 53)	0 = 0% 0.083-0.33 = 50% 0.33-1 = 100% 1-1.5 = 50% >1.5 = 0% *References:* (54–56)	0-1 = 100% 1-1.5 = 50% 1.5-2 = 10% >2 = 0% *Reference:* (57)
Mean fish count per km^2	3,002 *References:* (53, 71)	24,216 *References:* (54, 56)	21,300 *Reference:* (72)
Mean weight per spawning fish [kg]	4.5 *References:* (52, 53, 71)	1.96 *Reference:* (56)	0.23 *Reference:* (72)

Notes: [a] [Temperature classes "cool, trans. cool, trans. warm" determined from mean annual air temperature data (44, 51). Percentage values represent the normalized suitability of a species under different ranges of temperature and flow velocity, where 100% is completely suitable and 0% is completely unsuitable].

SI Appendix Table S3: Hypothetical stakeholder preference weights used to generate rose plots in Figure 2.

	Status quo	River restoration	Equal preference	$NE2_C$
Hydropower (*P*)	0.1429	0	0.15	0.333
Drinking water (*D*)	0.1429	0	0.04	0
Reservoir storage (*S*)	0.1429	0	0.09	0
Nitrogen removal (*N*)	0.1429	0.05	0.01	0
Impacted properties (*I*)	0.1429	0	0.05	0
Removal cost (*C*)	0.1429	0	0.1	0.333
Dam breach safety (*B*)	0	0.1	0.22	0
Sea-run fish Biomass (*F*)	0	0.85	0.22	0.333
River boating recreation (R_R)	0	0.05	0.11	0
Lake boating recreation (R_L)	0.1429	0	0.01	0

SI Appendix Table S4: Pearson correlation coefficients for pairwise criteria: P: hydropower, D: drinking water, S: water storage, N: nitrogen removal, I: number of properties impacted by dam removal, C: dam removal cost, B: dam breach safety score, F: sea-run fish biomass, R_R: river boating recreation, R_L: lake boating recreation.

	P	**D**	**S**	**N**	**I**	**C**	**B**	**F**	**R_L**	**R_R**
P	1									
D	0.3097	1								
S	0.6292	0.8568	1							
N	0.3372	0.8621	0.9464	1						
I	0.8172	0.9672	0.9423	0.8794	1					
C	0.9485	0.9706	0.9603	0.9507	0.9907	1				
B	-0.2107	-0.1845	-0.4745	-0.6804	-0.8701	-0.9091	1			
F	-0.8267	-0.5543	-0.7068	-0.6457	-0.7064	-0.8910	0.8355	1		
R_L	0.6490	0.9452	0.9844	0.9370	0.9956	0.9624	-0.7513	-0.5672	1	
R_R	-0.7786	0.8615	0.8194	0.9952	-0.0949	-0.0949	0.6936	0.8592	-0.7108	1

SI Appendix database captions

DamIndex.zip *Text files containing dam ID numbers and nearest downstream neighbor ID numbers*

NEdamsOut6-12-18.txt *Text file containing dam data used to quantify decision criteria*

DPPF_run.m *Main script to access data and execute MOGA functions*

DPPF_prep.m *Access dam database, define the decision criteria and study area*

DPPF.m *Main script to initialize MOGA with initial data*

DPPF_fitfn.m *Calculates quantities for each criteria based on the combination of dams removed in an iteration*

DPPF_netOV.m *Calculates quantities for criteria that require network analysis: quantities are dependent on removals at other dam sites: fish biomass, river recreation*

DPPF_idx.m *Arranges index of dams and downstream neighbors for initial dam set and further sets used in the MOGA*

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