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Connectivity at a cost

Economic dynamics of connectivity restoration

Wisdom Akpalu
United Nations University, Ghana
Jesper Stage
Luleå University of Technology, Sweden

What is connectivity restoration?

- Many natural habitats have become increasingly *fragmented*
  - Cause: various human activities
  - Result: loss of biodiversity, and welfare losses linked to this

- *Connectivity restoration* aims to reconnect remaining habitats

We look at rivers & hydro, but issue is more general

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”But gentlemen, this is not economics!”

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Keeping it simple…

Assume that a river habitat *A* has been subdivided into *N* fragments of equal size by *N*-1 identical hydropower plants

Each hydro plant produces electricity worth *h*

Assume that diversity loss has been maximal: *S* has declined to

$$S_{eqnew} = c\left(\frac{A}{N}\right)^{z} = cN^{-z}A^{z}$$

Still keeping it simple…

Assume that the value of species diversity in this river habitat is a linear function of S, $B(S) = bS$

Assume that perfect connectivity can be restored, through bypasses or other measures that entail

- a one-time investment cost I,

- and a continuous loss of hydropower value dh

per hydro plant

Is the value of the restored biodiversity worth the cost?

Two possibilities

Without connectivity restoration:

PV of remaining biodiversity + PV of hydropower

$$\int_0^\infty bcN^{-z}A^z e^{-rt}dt + (N-1)\int_0^\infty he^{-rt}dt$$

With connectivity restoration:

PV of improved biodiversity + PV of remaining hydropower – investment cost

$$\int_0^\infty bS(t)e^{-rt}dt + (N-1)\int_0^\infty (1-d)he^{-rt}dt - (N-1)I$$

Which gives us the result…

…that restoring connectivity only makes sense if

$$bcA^{z}(1-N^{-z})\left(\frac{k}{r+k}\right) > (N-1)(rI+dh)$$

…so for some parameter values, connectivity restoration is **not** socially optimal

Kinda obvious and not very exciting

Let's (try to) make this (a bit) more interesting

Impose an extra constraint

Assume that the value of the lost biodiversity is greater than the value of the hydropower produced

$$h(N-1) < bcA^{z}(1-N^{-z})$$

➔ It would have been better if the hydro plants had never been built

Is this enough to ensure that restoration measures will be socially beneficial?

Plug in this constraint, and…

…we get that restoration can **still** entail a net social loss, if

$$bcA^{z}(1-N^{-z})\left(\frac{k}{r+k}\right) < (N-1)(rI+dh) < (N-1)rI + bcA^{z}(1-N^{-z})d$$

Two reasons why we might get this outcome:

- Investment cost, *I*
- Time lag for diversity recovery, $k < \infty$, while hydro loss *dh* begins instantly

Let's get rid of *I*. Assume that building a bypass is costless, $I = 0$

Set *I* = 0, and…

…we get that restoration can **still** entail a net social loss, if

$$bcA^{z}(1-N^{-z})\left(\frac{k}{r+k}\right)<(N-1)dh<bcA^{z}(1-N^{-z})d$$

This outcome is possible if

$$\left(\frac{k}{r+k}\right)<d$$

Is $\left(\frac{k}{r+k}\right) < d$ likely to be the case?

d usually > 0.05 and often > 0.20

r typically 0.02 – 0.05

If half the species diversity recovers in twenty years, *k* ≈ 0.035

With *r* = 0.035 and *k* = 0.035, connectivity restoration can cause social loss if *d* > 0.5

With *r* = 0.05 and *k* = 0.0175, connectivity restoration can cause social loss if *d* > 0.26

So what?

Well, even with a model that exaggerates net benefits of connectivity restoration, we have found…

…that because of the lag in recovery…

…there are plausible economic parameters for which connectivity restoration may not make sense…

…even in river systems where hydropower should never have been established in the first place

Increase *k* artificially?

If we restore connectivity, and re-establish *N'* species at a cost *f* per species, the net benefit is

$$\int_0^\infty bN' e^{-kt} e^{-rt} dt - fN'$$

If we *don't* restore connectivity, but still re-establish *N'* species, the net benefit is…

$$\int_0^\infty bN' e^{-kt} e^{-rt} dt - fN'$$