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Cosme, Nuno Miguel Dias; Bjørn, Anders; Rosenbaum, Ralph K.

Publication date:
2014

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Citation (APA):

Cosme, N. M. D., Bjørn, A., & Rosenbaum, R. K. (2014). *Pursuing an ecological component for the Effect Factor in LCIA methods*. Poster session presented at SETAC Europe 24th Annual Meeting, Basel, Switzerland.

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Pursuing an ecological component for the Effect Factor in LCIA methods

Nuno Cosme¹ (nmdc@dtu.dk), Anders Bjørn¹, Ralph K. Rosenbaum²

TU259



¹ Division for Quantitative Sustainability Assessment, Department of Management Engineering, Technical University of Denmark
² Irstea, National Research Institute of Science and Technology for Environment and Agriculture, Montpellier, France

1 INTRODUCTION

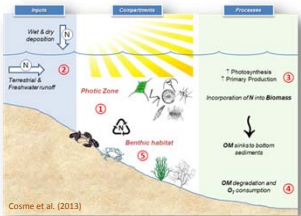
- Ecosystem-related indicators benchmark impacts as **Potentially Affected Fraction of species (PAF)** -> the fraction of species in a generic community expected to be potentially affected above its no-effect level or other predefined effect level
- PAF approaches are based on **Species Sensitivity Distribution (SSD)** -> cumulative statistical distribution useful to extrapolate responses/sensitivity of individual species to community's responses/sensitivity
- LCIA models the **marginal change** in PAF and therefore does not account for the current state of the ecosystem
- PAF can be further modelled to **Potentially Disappeared Fraction of species (PDF)** by converting it into damage ($\text{Conv}_{\text{PAF} \rightarrow \text{PDF}}$)
- Can it also account for the state of the environment** ?

$$Q_{\text{emitted}} [\text{kg}] \times CF [\text{PAF} \cdot \text{m}^3 / \text{kg}] = \text{Impact} [\text{PAF} \cdot \text{m}^3 \cdot \text{d}] \times \frac{\text{Conv}_{\text{PAF} \rightarrow \text{PDF}} [\text{PDF} / \text{PAF}]}{h_w [m]} = \text{Damage} [\text{PDF} \cdot \text{m}^2 \cdot \text{d}]$$

(loss of biodiversity)

How can this coefficient be estimated?

3 INDICATOR FOR MARINE EUTROPHICATION



The processes

- Excessive increase of primary production in response to inputs of nutrients and organic matter accumulation [2]
- Results in excessive oxygen depletion and impacts on biota, ecosystem and (socio)economy

The modelling

CF estimation in Marine Eutrophication [3]:

$$CF [\text{PAF} \cdot \text{m}^3 \cdot \text{yr} \cdot \text{kgN}^{-1}] = FF [\text{yr}] \times XF [\text{kgO}_2 / \text{kgN}] \times EF [\text{PAF} \cdot \text{m}^3 \cdot \text{kgO}_2^{-1}]$$

Indicator -> Midpoint impact score (IS_{mp}):

$$IS_{mp} [\text{PAF} \cdot \text{m}^3 \cdot \text{yr}] = Q [\text{kgN}] * CF [\text{PAF} \cdot \text{m}^3 \cdot \text{yr} \cdot \text{kgN}^{-1}]$$

Indicator -> Damage Score (DS):

$$DS [\text{PDF} \cdot \text{m}^2 \cdot \text{yr} \cdot \text{kgN}^{-1}] = \text{Conv}_{\text{PAF} \rightarrow \text{PDF}} [\text{PDF} \cdot \text{PAF}^{-1}] * IS_{mp} [\text{PAF} \cdot \text{m}^3 \cdot \text{yr}] / h_b [m]$$

(h_b = height of the bottom layer in the marine compartment where hypoxia develops)

In practice, the conversion factor (Conv_{PAF→PDF}) delivers the fraction of affected species that do not recover after the pressure is reduced.

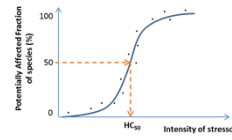
5 CONCLUSION

3 approaches for an ecological component to damage estimation were presented. Important for environmental relevance and spatial differentiation of the models.

After this exploratory research, new questions arise regarding:

- The impact of invasive species?
- The weight of keystone species?
- Do different species move in after the disappearance of the 'endemic' ones? How does that affect diversity?
- Should the ecosystem's adaptive capacity be included too?
- Should functional diversity (based on biological/ecological traits) be included to improve the conversion factor?

2 From SSD to Effect Factor

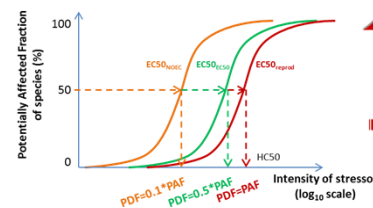


Effect Factor (FF) is calculated with HC50 obtained from SSD methodology:

$$EF = \frac{0.5}{HC_{50}} [\text{PAF} \cdot \text{m}^3 \cdot \text{d}]$$

PAF -> PDF conversion factors

ecotox indicators	Conv _{PAF→PDF}	factor	source
HC50 based on chr EC50	PDF = 0.5*PAF	2	IMPACT 2002+ (Jolliet et al. 2003)
HC50 based on NOEC effect on reproduction, long term	PDF = 0.1*PAF	10	Eco-indicator 99 (Goedkoop and Spriensma 2000)
	PDF = PAF	1	Snell and Serra (2000)
HC50 based on LOEL	PDF = ? * PAF	?	discussed here for marine eutrophication



What do they mean? Such factors are equal to change the HC50 by 1 or 0.3 log units

Ecosystems state is not included. How much have 'past impacts' affected the ecosystem?

One half, one tenth, or all the species, will not recover from the (toxic) stress and disappear, when adopting the 'recovery time approach', which assumes [1]:

- Biodiversity linked with water quality (species disappear when stress reaches a certain level, reappear after pressure drops below that level)
- Equal time for disappearance and recolonisation and equivalent diversity before and after recolonisation

4 NEW CONVERSION APPROACHES

- PAF is built on biological/physiological endpoints – present conversion factors do not add any extra layer of information.
- Duration and intensity are reflected in the EF, but not the 'erosion' of species' tolerance from 'past impacts'.

3 possible approaches to include an ecological component:

- Trait-based approach:** Apply percentage of change (1980-2006) of ecological (trophic level, TL) or biological (maximum length) traits to an initial 0.5 conversion factor. The pressure from 'past impacts' that might have degraded the recovery capacity is reflected in the conversion factor.

LME #	LME name	trait	1980	2006	var	Conv _{PAF→PDF}	factor
3	California Current	mean TL	3.13	3.38	0.08	0.46	2.2
		mean max length (cm)	45.8	57.8	0.26	0.37	2.7
5	Gulf of Mexico	mean TL	2.41	2.50	0.04	0.48	2.1
		mean max length (cm)	31.0	33.7	0.09	0.46	2.2
12	Caribbean Sea	mean TL	3.29	3.14	-0.05	0.52	1.9
		mean max length (cm)	70.5	48.8	-0.31	0.65	1.5
22	North Sea	mean TL	3.37	3.34	-0.01	0.50	2.0
		mean max length (cm)	50.0	45.4	-0.09	0.55	1.8
23	Baltic Sea	mean TL	3.70	3.21	-0.13	0.57	1.8
		mean max length (cm)	56.1	41.2	-0.57	0.79	1.3
40	NE Australian Reef	mean TL	4.01	3.85	-0.04	0.52	1.9
		mean max length (cm)	156.2	129.0	-0.17	0.59	1.7
48	Yellow Sea	mean TL	3.51	3.44	-0.02	0.51	2.0
		mean max length (cm)	89.2	78.2	-0.12	0.56	1.8

Example limited to demersal, benthic and benthopelagic fish species resident in the Large Marine Ecosystems (LME) considered. Other taxonomic groups and traits can be included. Data from searounds.org and fishbase.org.

- V*R approach:** Integrates **Vulnerability** [4] and **Resilience** [5]. **V** (0-1) proxies for degradation of the community and propensity to be permanently affected. **R** uses population's recovery time, or doubling time (yr) - capacity to withstand fishing exploitation, proxy for propensity to shift to an undesired regime.

Climate zone	spp (n)	GM Vulnerability	GM Resilience	V*R	Conv _{PAF→PDF}	factor
Polar	3	0.66	2.92	1.92	0.52	1.9
Subpolar	11	0.48	4.40	2.09	0.48	2.1
Temperate	12	0.46	4.40	2.03	0.49	2.0
Subtropical	10	0.46	4.82	2.23	0.45	2.2
Tropical	3	0.53	11.38	6.01	0.17	6.0
Global	12	0.46	4.40	2.03	0.49	2.0

Example with data from 5 climate zones and a global default, limited to the 12 demersal, benthic and benthopelagic fish species used in the CF modelling for marine eutrophication [3] - can be expanded to all relevant fish species in LMEs or climate zones. Geometric means (GM) are used. Data from fishbase.org.

- V*U*R approach:** Integrates **Vulnerability** and species **Uniqueness**, weighted by ecosystem's **Resilience**. **V** and **R** are proxies for ecosystem quality. **U** gives higher value to rare species, using the phylogenetic diversity index (PDI) from 0.5 (low) to 2.0 (high, rare) [6].

LME #	LME name	spp (n)	GM U _{ln}	GM U _{ln} ²	GM Resil	sum(V*U ^{ln})	sum(R)	Conv _{PAF→PDF}	factor
1	East Bering Sea	38	0.52	0.65	5.15	90.65	234.40	0.39	2.6
9	Newfoundland-Labrador	38	0.56	0.60	5.56	114.07	264.21	0.43	2.3
13	Humboldt Current	18	0.47	0.70	4.19	37.75	93.62	0.40	2.5
20	Barents Sea	41	0.57	0.66	5.53	121.44	271.90	0.45	2.2
23	Baltic Sea	36	0.51	0.64	4.44	80.36	195.33	0.41	2.4
26	Mediterranean Sea	59	0.49	0.59	4.16	108.46	301.97	0.36	2.8
27	Canary Current	59	0.45	0.59	3.60	88.29	257.39	0.34	2.9
31	Somali Coastal Current	7	0.42	0.69	3.82	11.88	36.18	0.33	3.0
40	NE Australian Shelf	11	0.44	0.60	3.33	12.02	43.11	0.28	3.6
48	Yellow Sea	33	0.47	0.57	3.76	46.42	145.33	0.32	3.1

Limited to demersal, benthic and benthopelagic fish species in the LMEs considered. Expansion is difficult due to lack of information and threat level for other taxonomic groups. Geometric means (GM) are used. Data from searounds.org and fishbase.org.



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