Ecological engineering: from concepts to applications

About the conceptual foundations of ecological engineering: stability, individuality and values

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Abstract

This paper surveys philosophical issues raised by ecological engineering – both theoretical and practical. First, it singles out the role of stability of ecosystems and communities involved in defining ecological engineering program, and wonders about the individuation of stable entities that this presupposes. It distinguishes then a strong and a weak concept of individuality, the former being defined by natural selection, the latter by probabilistic connections between sub-entities. It argues that if ecosystems don’t have strong individuality, they still possess a weak individuality, ecological theories providing the values of the variables in the formula for individuality. Second, practical issues are derived from the ambiguous status of ecological engineering as mixing values from nature and from human agency, and this space of values is related to the pluralism of individuality concepts in ecology.

Keywords: environmental ethics; individuality; natural selection; ontological communities; stability; values

1. Introduction

Ecological engineering is a recent practice that can be said to have the following aims:
- Design and construction of ecosystems
- Use of natural systems for pollution abatement
- Restoration of ecosystems
- Use of ecosystems on sound ecological bases [1].

It thereby involves several disciplines, from soil ecology to environmental ethics, through theoretical ecology or geology. For this reason, its conceptual foundations are not clear yet, and it raises important philosophical challenges. To the extent that ecological engineering uses and produces a specific knowledge about ecologies, and in the same time introduce ecological change in order to fulfil some aims, from the viewpoint of the philosopher it raises both theoretical and ethical questions. In this paper I will survey some of those issues and suggest several viewpoints likely to address them. The first part will deal with theoretical issues about individuality and stability of

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ecosystems, the second part will sketch several ethical issues that are stemming from the theoretical positions sketched in the first section.

2. Theoretical issues

2.1. Stability

Ecological engineering at first stake deals with complex systems. Such systems are characterized by: non-linear interactions, multiple elements, emergent properties, unpredictability, etc. To this extent, intervening on them requires finding the relevant variables: whereas most of the variables will have causal effects on the ecosystem as a whole, non linear effects may imply that many variables don’t have on the whole an important impact, and some of the variables are the most relevant ones, onto which the ecological engineer should act. Finding these variables is a challenge for the theoretician as well as for the engineer.

Moreover, ecological intervention requires that targeted ecosystems have some properties of robustness and stability, in at least two senses: the range of outputs will not vary too much with variations on the input; there is some ability to return to a reference state once disturbed, etc. Without those conditions, ecological engineering cannot pretend to have sustainable goals likely to be reversible, as it is often required.

For those reasons stability – under all its modes: resilience, robustness, persistence, etc. - is a key concept for philosophical consideration of ecological engineering. Stability of course is an important term in a longstanding debate within community ecology: many theoreticians discussed the correlation between diversity and stability [2,3]. After a first period where it was accepted, whereas not proved, that diversity enhances stability, May [4] has shown that it should not be expected in general. This led to a diversification of works exploring the various meanings of diversity [5-7], etc., and how each of them (ecosystem richness, functional diversity, number of species, etc.) could promote some sort of stability. Under a large range of conditions, some statistical effects similar to portfolio effects in finance have been expected to yield community stability effects [8]. Stability appears therefore as a family of concepts: not the constancy of a property, but the maintenance of it across some variations, and is defined viz. this specific variation – hence it is not only the stability of populations in species (as it used to be before May), but the conservation of a property like biomass [7], the persistence (namely, no species gets extinct [9]), the robustness, the resilience [10]), or even the sustainability (all those concepts being related to various ways of modelling).

Considering ecosystems and communities, those concepts lead to major questions:

- **Conceptual**: What is supposed to be stable? To which entity are ascribed properties of stability? And moreover, since something has to be one system to be stable in any sense: in which sense is an ecosystem – and before that, a community - an individual entity?
- **Methodological**: how to define it such entity and draw boundaries?

I will address the conceptual questions here, and my suggestions yield answers to the methodological issues. First, *prima facie* an individual in general is a bundle of lower-level entities, and it is build in a way that many mechanisms affect and enhance its coherence. Fish, tables, cars, nations, cells, are examples of individuals. There is a huge literature on what an individual is in metaphysics (e.g. [11-14] about biological individuals), but, starting with this intuitive characterization, I will attempt to define a theoretical framework to think of individual ecosystems and communities.

At first stake, an ecosystem or a community behaves in the same way: there are lots of interacting species within ecosystems and communities, which are low level entities; it includes many mechanisms, comprising ecosystems biotic / abiotic interactions, which enhance its coherence. But those interactions are also between species and elements outside (e.g. water, nitrates, etc.).

Yet precisely because of this huge number of interactions, constantly changing, and because of the lack of salient boundaries, it is harder to consider communities or ecosystems as individuals, than organisms or artifacts.\footnote{Even if the individuality of organisms is a hotly debated topic, given some borderline cases like Portuguese men of war or slime molds. However, no matter what organisms are and how they are defined, it seems that they will clearly be individuals; but not all individuals are organisms. See [14] on « exotic » organisms (e.g. non metazoans, constituted by chimerism, etc.) and the problem of individuality.}

Concerning communities precisely, it is controversial whether they are ontological individuals in the same sense as a...
tree being an individual, or if they are only sets of species unified by our interest. This is an old controversy: almost in the 20s, Clements [15] argued that communities were so much individualized that they behave like organisms and are kinds of “Superorganisms”. Then Gleason [16] replied that in fact the grouping of species is somehow arbitrary, only individual organisms of different species are real; boundaries between communities are arbitrary and blurred, unlike boundaries between organisms. Then Whittaker’s studies about the variations of species populations along some gradients (temperature, moisture, etc.) backed up this claim by showing that it was hard to find overlapping constant clusters of individual species across those gradients. The ontological status of communities is therefore a longstanding debate in community ecology – and also because it raises the issue of the objectivity of the boundaries between communities, which impinges on the issue of determining the relevant sets of species to be considered when studied assemblage or successions: whether one accepts or denies ontological communities will change one’s approach to those problems. Recently Sterelny [17] talked of “indexical communities”, the index being e.g. the polar bear (and the “indexical community” being all the species interacting with the polar bear). Sterelny argued that we cannot take for granted the existence of ontological communities (rather than indexical), but that it is an open empirical question – even if Bryant [18] argued that indexical communities are still likely to be concerned by diversity enhancing stability mechanisms. Simultaneously, Ricklefs [19] argued against the “local, interacting assemblage of species”, as having prevented progress of the understanding of the dynamics of species at regional scale. To this extent, the ontological individuality of ecosystems, such as Forbes’ [20] initial views on lake as a microcosm, is even more problematic than the community’s.

2.2. The strong concept of individuality

In biology, the problem of individuality is raised by many weird kinds of individuals, like algae colonies, dandelions etc. One way to have a reliable concept of biological individuality is to rely on a theory, and the most integrated and sufficiently general theory is evolutionary theory (the theory must have the largest scope in order to cover all cases of biological individuality). Hull [21] argued in this sense that the only consistent concept of individuality providing a criterion to distinguish between individuals and pseudo-individuals (i.e. arbitrary aggregates of parts), is given by natural selection. To be an individual is to be a unit of selection. That is why organisms, genes and may be some groups or kin groups are individuals (some bees, for example). There are opponents (e.g. [22,23]), who contest that evolutionary theory is the only well integrated biological theory, and would define a concept of biological individuality along the lines of another theory, e.g. immunology or developmental theory. However, in our ecological case, those theories are hard to consider.

If we agree with Hull’s position, then we have to say that communities and ecosystems are individuals if there is selection upon them. Many biological individuals – including organisms - are collections of low-level individuals, which evolved into a genuine individual, likely to undergo selection in its turn: eukaryotes, multicellular individuals… According to the “evolutionary transitions” program devoted to study such process: the individuals in biological hierarchies (genes, cells, organisms, demes) appear through multilevel selection processes [24]. Selection acts in the same time on individuals and on collections of individuals [25,26], and new individuals emerge when high-level selection supersedes low-level selection.

Many biologists (e.g. [27,28]) consider that multi-level selection is equivalent to kin selection. Some (e.g. [26]) argue multi-level selection is the main process, and kin selection only a version of it. Others (e.g. [28]) argue convincingly that all supposed multi-level selection processes in fact rely on mechanisms like limited dispersion and are therefore kin selection. Yet, in this case, multi-level selection could be a way to rephrase kin selection in a way appropriate to the problems of evolutionary transitions. This program makes sense of nested individuals and of the emergence of the biological hierarchy: genes, cells, multicellular organisms. It is not clear whether communities or ecosystems, though, could be included in such hierarchy. Plausibly, at least, not all the ecosystems we consider can be understood in those terms.

However, if there is something like multilevel selection, since community selection is a possible case of group selection, it will be a conceptual possibility, and communities could be individuals as units of selection. Several biologists (e.g. [29]) claimed that there are empirical cases of community selection. Even more controversial, some people [30,31] claim that ecosystems can be selected (this is the most controversial topic because ecosystems include abiotic entities, which by definition do not respond to selection). The studies seem to show that ecosystem selection is a possibility; however no one exactly knows the scope of such phenomenon in nature (where it’s likely that it’s always superseded by individual and kin selection). However the very existence of ecosystem selection
would obviously be crucial for ecosystem engineering, where some of the experiments may be interpreted along those lines.

This view of individuality is somehow a strong view: for the moment, we don’t know whether most, or even some, of the known communities and ecosystems should count as an individual. So, besides this strong concept of ecosystem individuation, based on evolutionary theory, a concept under which some ecosystems may fall, but may be very few, I propose below a weaker concept under which many ecosystems should fall, and which provides criteria to decide what is in and out the individual ecosystem.

2.3. Another concept of individuality

I rely on the idea of “quasi-independence” proposed by Herbert Simon [33]. Basically, in a set of many elements there are many interactions between these elements, so each subset depends upon all the others, but you can specify a quasi-independent system in the following way. Pick up a set of some elements, define it “system S”; this is an individual system if, the interactions between elements within S are stronger than those with the external elements. This concept has been defined in order to make sense of modularity of parts of a system, which is important in computer science and cognitive science: modules are subsystems of entities that are almost independent parts of a system, which is prima facie a bundle of entities interacting all with all the others. In ecology, if you consider an arbitrary fragment of nature, everything is likely to interact with everything; however, we often think that not any arbitrary set of things is an ecosystem; even less, a community. This is why we distinguish communities and we are now able on this basis to consider “metacommunities” [34]. Communities and ecosystems are therefore systems that are individualized in a salient way among a large set of interacting entities; in this sense the idea of quasi independence originally defining modules may be imported for our purposes.

Here, I take quasi-independence as defining individuals systems. This allows us drawing the boundaries of a system by relying on the knowledge of the interactions between elements. In the case of ecology, our knowledge would therefore typically provide individuation criteria for a set of species and abiotic units. In the following, I try to develop this intuition about quasi-independence as the weak concept of individuality proper to ecosystems and communities.

There are two ways to design such concept, and the criteria of individuality associated with it:

- **Static view** – based on the number of links; define some equivalence classes and their overlaps;
- **Probabilistic view** – picks out random entity and considers chances of being connected to the others.

### 2.3.1. Static view

The static concept is the following:

Let’s consider a set X; I is a subset, belonging to the set of parts of X written: P (X)

I’ is the complementary subset of I

i and j are elements in I; k is in I’

\( n_i \) = frequency of interactions between i and j

\( n'_i \) = frequency of interactions between i and k.

Then amongst the possible systems I the individuals are the Is such that

\[
\text{Individuals} = \{ I \in P(X) / \forall i, n_i >> n'_i \}
\]

There is one obvious problem: X is supposed to be discrete, whereas reality is often continuous. However for many of our scientific purposes and especially ecology, we can consider discrete sets – for example, we count species, individuals, units of soil, etc.

Another problem here is that the by-products of the system will be counted as the individual – for example, secretions of an organism – may have more frequent interactions with the organism, than with some other stuff, but actually they are not part of it.

The real problem is that estimating the frequency of interaction is not enough. Obviously, some interactions are not so frequent but very strong: if a fox eats a rabbit, it is a less frequent interaction than the rabbit’s feces altering

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5 Odenbaugh ([32], 630) also distinguished weaker and stronger sense of individual communities, but he views the strongest sense in organismic terms like Clements.
the soils, but it might be as much relevant for the ecosystem. So the frequency should be weighted by the strength of the interaction, and we need some other measure. The real variable (instead of \( n_i \)) involved in the comparative estimation (1) would be a mix of \( n_i \) and the strength \( g \) of the interaction. Estimating strength of interactions is attempted in Ulanowicz [35], which also provides clues to define individuals.

### 2.3.2. Probabilistic view

There is another way of determining the weak concept of individual that may avoid some of the shortcomings of the static view – namely, a probabilistic view. The basic intuition is that, if you are part of an individual, chances that an entity that is strongly related with you is also part of this individual are higher, than chances that it is something external. This is intuitively valid for organisms, and then may be valid for communities. It means that, if you consider a set of individual organisms, if \( A \) is an organism, \( S \) is a community means that chances of \( A \) to be in some ecological interaction (i.e. predation, mutualism etc.) with an individual of a species within \( S \) are higher than the chances that it would be in interaction with an individual of a species outside \( S \).

The definition would be the following:

Consider \( S \) a set of entities; \( i \) a given entity in \( S \)

\( x_{i,j} \) is a link between \( i \) and \( j \) (any kind of interaction)

\( H, n \) are constant values defined in advance (\( n \) between 0 and 1; the variable \( h \) is the value of the strength of interaction, \( H \) is a significance threshold)

\[
P(x_{i,j}, h)\quad \text{probability that links } x_{i,j} \text{ has strength } h
\]

We define the set of \( i \)-centred strong interactions: \( H_i = \{x_{i,j}/ P(x_{i,j}, H)>N\} \)

We define the set of \( i \)-strongly-interacting entities: \( J_i = \{j/ x_{i,j} \in H_i\} \)

If \( S \) is an individual system then for all \( i \) in \( S \), \( J_i \) is included in \( S \).

One problem with this definition is that \( n \) is an arbitrary fixed value, but it is plausible that some value between 0.7 and 0.9, or in general the value of significance in some statistics, will yield a result close to our usual ascriptions of individuality. The other problem is the arbitrary value of the strength of interactions; however it is reasonable to choose a quite high value for \( h \). Several parameters have to be implemented in the computation of \( h \): if we consider that all the entities are in a network of entities, or can be represented in a graph (each interaction being a link), then the main parameters would be: the number of various pathways between entities (the more pathways, the stronger the interactions), the number of steps between \( i \) and \( j \), the number of supplementary necessary conditions needed (if the interaction is conditional upon some other interactions, for example when a predator switches prey in case of scarcity of the main prey…). Once the set of entities is represented, there should be ways, along those lines to define the strength of interactions and compute it for each of them. Yet it’s not obvious that there is a general method for computing this strength for all cases of putative individuals. Restricting the problem to community and ecosystems ecology, however, the framework here roughly sketched seems plausible.

Now, the fact that we take \( n \) as a constant, plausibly reflecting high chances of strong interaction, can be alleviated by another option: considering the average value of \( P(x_{i,j}, h) \). Then clearly, the sets \( J_i \) so defined will be sets where the probability of interactions between entities is clearly higher than average, and therefore could be considered as individuals.

Hull [21] argued for his evolutionary view on the basis that a theory should provide individualizing criteria for entities, and that our best theory likely to provide individuating criteria is evolutionary theory. Recently, authors argued that on the side of physiological science (\textit{sensu} Mayr’s division between physiology and evolution as functional vs. evolutionary biology) some theories were likely to provide evolutionary criteria to define organisms as individuals, and may be other individuals: development, immunology. In my view, what is proposed here is a very general sketch for finding criteria for individualizing entities. \textit{What theories provide will be exactly the content of the variable } \( h \): how it can be defined, and then measured, namely how the components of the strength variable can be determined, and composed. For organisms, physiology, developmental theory or immunology plays this role; for ecosystems, some ecological theory of interactions will do an analogous job. The formal sketch here has to be variously instantiated by the theories proper to the ontological kind the purported individual belongs to (namely, instantiating \( h \)). The interest of such view of weak independence is that proper instantiations of the scheme allows individualization criteria for ecological systems as well. It does not settle the question of whether communities are “local ecological communities” (\textit{sensu} Stereleny [17]), or ecosystems “individuals”, but it provides a concept enabling researchers to empirically ask the question.
In all cases, decreasing h will have the consequence that we can define nested entities. Recently, several papers [36-38] argued that “organism” means rather a quantitative property (i.e. you are more or less an organism) rather than a binary property (i.e. organisms are entities that fulfil some criteria such as functional integration, coherence, being units of selection, etc.; and other entities are not organisms). Those views could be integrated in my general framework about individuals, because the scale of individuals defined by graded value of h would correspond to a scale of organismality. “Super-organisms”, like colonies of insects, Portuguese men of war, slime molds, possibly termite mounds [39] will clearly be cases where h is taken as lower than its value for metazoan organisms. Possibly, communities and, above all, ecosystems, will have the same status. A continuous view of organismality may be plausible, based on the arguments of [37] and [38], but in the end it includes systems made of clonal entities plus mutualistic species – something like a termite mound, yet it will hardly account for ecological communities as individuals, and even less for ecosystems. The present view generalizes individuality criteria to those ecological cases.

In this sense many biological systems of interacting entities are likely to be considered as individuals, without any evolutionary perspective, so that ecosystems can be seen as individuals - but the variable h can define a threshold under which some sets of entities, or aggregates, are not individuals, even in the weakest sense.

Now, this is a kind of instantaneous definition of individuals. In biological individuals, as we know, everything is in constant flow: parts of organisms change, cells die, species in communities get extinct, etc. So a practical criterion should be able to extend this time-slice view of individuals into a definition of temporal coherence of individual. I assume that some criteria for an entity x to belong to the same individual S as an entity to which a previous entity y related to x belonged to, would be able to do the job and provide a definition for persisting individuals as systems of changing entities. A solution for identifying individuals through time in the context of ecology is defended in [41]. Therefore one can distinguish two concepts of individuality, likely to be applied to communities and ecosystem:

- **Strong concept.** Individuals are defined as units of selection. In this case the individuality of communities and ecosystems relies on the fact that there is, in nature, salient cases of community selection or, moreover, ecosystems selection (all cases known are for the moment artificial).

- **Weak concept.** Individuals are defined by the criterion of quasi-independence. The schema of possible definitions is given above, and criteria for individuality are determined by specifying, through a relevant theory, the values of strength of interaction threshold, and choosing a proper method (often, a way of composing various parameters) for defining interaction strength in a network.

### 2.4. Instantiating the weak concept in ecology

Concerning community ecology, a major question is: what would be the relevant interactions responsible for the individuality of ecological individuals? Ecologists used to distinguish three main interactions: predation, competition, mutualism; Jones and colleagues [42-44] added a fourth one, “ecosystem engineering”, namely the activity through which individuals of a given species, by interacting with their surroundings – other organisms, or abiotic environment –, change their environment for themselves and for other species related to it. The four interactions do not have the same dynamical patterns. For instance, conditions of stability for mutualism seem harder to find; time lag effects are more frequent. And ecosystem engineering, besides entailing crucial time lag effects [45] involves many species, whereas all the other interactions are rather dyadic or at most triadic. This property makes it a very plausible candidate for being the main interaction involved in the quasi-independence (as individuality) of a community; in effect, when counting the interactions which are more frequent inside than outside the community, it will be counted more often than others. In other words, since those interactions link many species rather than two, if you pick up randomly one interaction, it has many chances to be of the ecosystem engineering kind.

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6 See [13] for issues of persistence, and [12,40].

7 Above the weaker sense of sets of individuals being there in the same time, Odenbaugh [32] distinguishes communities *senso* Hutchinson, which are interacting communities, and “clementsian” communities, “tightly integrated groups of species” (632). Given that organisms are units of selection, this distinction seemed to concur with mine, but I tried to unpack what means the Hutchinson sense: “a group of species that at least weakly interact with one another and not others at a time and through time.” I elaborated for this purpose a very general concept of weak individuality.
Moreover, concerning ecosystems, and since ecosystem engineering involves the abiotic element – and is the only one to do so –, all interactions in an ecosystem \( S \) which involve abiotic environment will be of this nature. This entails that if you pick up randomly one interaction in an ecosystem, there are much chances that it will be an ecosystem engineering interaction since chances are high that it is with the abiotic environment. Therefore, in the weak definitions of communities or ecosystems as individuals given here, if some community is an “ontological community” (\textit{sensu} Sterelny [17]) or if some ecosystem is an individual – it is very probable that ecosystem engineering will play an important role in the structure of interactions responsible for its being an individual.

The consequence of my definitions for the ecological engineering as a practice is that a specific place in its theory should be given to systems which have a specific causal-interactive structure, satisfying one of those two (static / probabilistic) requirements, because either can be considered as individuals, and because they are likely to display some properties of stability, supported by mechanisms which have to be unravelled, if one wants to define an agenda of stability-preserving, reversible, engineering interventions. When investigating the conditions of the stability of an ecosystem in all senses, given that this stability is an important property of the ecosystem as an \textit{individual}, ecosystem engineering will thereby play a key role in the mechanisms supporting such stability.

Among the ecosystem’s interaction structure, ecosystem engineering, playing a pivotal role, will have to be dealt with at first stake. Because it concerns the reasons of the individuality of an ecosystem, this pivotal role is such that one can use it to draw the boundaries of the ecosystem – since what is and what is not part of an individual defines the boundaries of it. As Levins and Lewontin ([46], 54) wrote: “The question of the boundaries of communities is really secondary to the issues of interaction among species”\(^5\). In this sense, investigating the interactive structure of ecosystems as individuals, and specifying the main ecosystem-engineering interactions within it, allows one to specify the targets of ecological engineering. On this basis, one should wonder whether the status of the ecosystem as individual – whether it is an individual or not, or, along the lines of the previous paragraph, to which degree it is an individual – entails specific different kinds of ecological engineering, different rules for them, different values they should aim to. Considering the salience of ecosystem engineering in the individuality of ecosystems, the nature of ecological engineering as we aim to practice it can be retrospectively understood as an extension of the ecosystem engineering proper to ordinary organisms\(^6\). To this extent, “ecological engineering” as an intervention therefore is another ecosystem engineering activity (by humans) that, as “ecological”, should enhance the kinds of boundaries and cohesion defined by the reference or expected ecosystemic state – the considerations about individuality-enhancing mechanisms being therefore crucial to define the meaning of “reference state”, and should play a role in defining the “expected state”.

3. Ethical issues

From the viewpoint of practical philosophy, “ecological engineering” is obviously an oxymoron. It is a longstanding structure of our conceptual scheme that we oppose nature and technique – an antinomy first rigorously formulated by Aristotle’s Physics, for whom “natural” characterizes the things having their own principle of growth, and “technical” are the things requiring an external principle of growth (e.g. engineers). The name “ecological engineering” therefore combines nature (because of “ecological”) and technique (because of “engineering”). According to this robust mental structure, it has therefore an ambiguous status. From the viewpoint of ethical philosophy, given that nature and technique are two ontologically different domains supporting different kinds of values, it should easily yield heterogeneous values. On this basis, conceptions of ecological engineering as a practice incorporate many conflicting values.

The conflict of values proper to ecological engineering is reflected within three oppositions between alternative views of how this practice should be conducted.

A. \textit{Who should benefit?} Should ecological engineering subscribe to a kind of utilitarianism\(^7\); according to which the society as a whole benefits from it? Is it rather beneficial for some classes of the society – if conflicts within a society are irreducible? Or for some species in the ecosystem? And which ones in priority?

\(^5\) Cadenasso et al. [47] suggest a framework to draw boundaries between patches based on interactions, and then objective.

\(^6\) The use of “ecosystem engineering” in restoration practices is defended in Byers et al. [48].

\(^7\) Namely, the theory that defines a social good as what maximizes the quantity of good for as many people as possible.
B. “Balance of nature” or “flux of nature”? Ecological engineering often aims to restore a state of nature, and to preserve it. Or it aims at designing an ecosystem in such a way that it becomes a reliable provider of some public good. This requires that the engineered ecosystem turns out to be somehow stable; this stability is often conceived as equilibrium - a balance between species, output and input, etc. – regarding which the previous human interventions, undirected by ecological engineers, are seen as a disturbance of a natural balance. However, recent ecological views are emphasizing that many modes of stability are hardly likely to be reached by natural ecosystems, and that a minimalist view of stability such as persistence is the most likely stability property of ecosystems [9], hence that ecosystems are in fact in perpetual flux. Along those lines, practical goals that include or require balance and a strong concept of stability may seem ill-conceived. Hence we have two conflicting views of ecological engineering, which plausibly support major differences in its practice.

C. “Care” or “cure”? The idea of restoring organisms can be understood in terms parallel to medicine: when an organism is diseased, physicians have to restore its health, i.e. cure it, so that it recovers as much as possible its previous state – the same goes for ecosystem and ecological engineers. But bioethics and social ethics recently introduced other views of the medical relationship and the public health concern: the aim would to be to care for, organisms or people – rather than to cure them. Care is the expression of a concern that does not by principle aims at eradicating illness, but rather at changing general conditions in which illness may appear, or altering the context in which disease is experienced so that its harm is alleviated. A parallel alternative could be conceived for ecological engineering: the abovementioned aim 3 of “Restoration of ecosystems” would pertain to a “curing” view of the practice, whereas aim 4, “Use of ecosystems on sound ecological bases”, would pertain to a “caring” conception. Yet, even if this alternative between conceptions at first stake holds between various aims of ecological engineering, it could also describe an alternative between general conceptions of the whole field, each aim being likely to be conceived of under one or the other option.

I will not get into the details of those debates. I just want to display that the dualistic nature of ecological engineering gives rise to a multilayered set of values, and that any position on those three debates has to take a place into this structure. I will then argue that this multilayered structure is reflected into the multilayered view of ecological individuality that I sketched above, which is thereby especially relevant to ecological engineering.

In fact, if we consider all the values that the various aims of ecosystem engineering would like to serve, they can be ordered into a continuum ranging from the “technique” pole to the “nature” pole of the meaning of the discipline. Typically, ecological engineers deal with three ecological notions, which enable them to formulate the values they wish to satisfy:

- Ecosystem services and ecosystem goods (and, on this basis, the possibility of defining economic values for ecosystems [49])
- Ecological functions: in a community, each species, given its position in the trophic webs and in the many webs of interactions, can be considered as the transformation of an input into an output, hence having a functional role. Some values could be defined, in terms of the hierarchy of functions, their plurality, etc.
- Biodiversity: We have many indicators of biodiversity, not all of them being consistent. Not only species richness, but the phylogenetic distance between species in an ecosystem, and the ecological functions of them, can be variously considered in constructing a measure of biodiversity. Often efficient measures, such as Shannon Diversity Index, compose several predictors of biodiversity – here, species richness and species evenness. There is an ongoing public discourse about the value of biodiversity per se – yielding the fears about biodiversity loss -, so that respecting and enhancing biodiversity constitutes a value for ecological engineering to, but the question remains: under which definition of it?

Those three kinds of notions ground values that can be variously considered and served by ecological engineering projects. Interestingly, in this list they switch from a “man-centred” viewpoint, proper to technique, towards a “nature-centred” viewpoint, proper to ecology. The space of values inhabited by ecological engineering is therefore defined by a gradient linking its two poles, indicated by the two terms of its name (Fig. 1).
Kinds of values

<table>
<thead>
<tr>
<th>Natural</th>
<th>technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiversity (indicators)</td>
<td>ecosystems services</td>
</tr>
<tr>
<td>ecological functions</td>
<td>Human centered</td>
</tr>
<tr>
<td>Other species centered</td>
<td></td>
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</tbody>
</table>

Fig. 1. The gradient of values in ecological engineering

However, this gradient of values is exactly reflected by the ontological hierarchy of individuals that ecological thinking deals with, as presented in the first section. Indetical communities, the least “ontological” of all ecological individuals, are indexed on our explanatory and practical interests; on the other hand, “strong individuality”, given by units of selection, is something objective in nature, since natural selection is a process out there, whether we are interested in it or not. In the middle, the concepts of weak individuality, given by the views of quasi-independence, are less human-centred than indexical communities, but ontologically weaker – i.e. more dependent upon our theoretical interests – than units of selection (Fig. 2).

Concepts of individuals

<table>
<thead>
<tr>
<th>Ecosystem/community selection</th>
<th>Weak individuals</th>
<th>indexical communities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object centered</td>
<td>Scientist centered</td>
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</table>

Fig. 2. The gradient of concepts of individuals, according to the ambivalent structure of ecological engineering

This does not intend to solve ethical problems, but shows that the space of values, in which all ethical issues arise, is coextensive to the ontological space of individuality concepts, both of them being ordered along the same gradient, which proves constitutive of the ambiguity of the discipline. In this sense, the two kinds of philosophical issues, theoretical and ethical, raised by ecological engineering, are intertwined. It does not mean that solving theoretical issues will clarify ethical issues but, on the other hand, that when it comes to solving an ethical problem or choosing an ethical stance such as the ones sketched here, ecological engineering also involves some ontological commitments.

4. Conclusions

Ecological engineering obviously raises new ethical issues because of its interdisciplinary status, and of the intertwining of a natural-centred and a man-centred viewpoint in its very definition. Conflicts of values can arise, and section 3 sketched some of the lines along which they develop.

Yet it also raises specific conceptual problems, crucially related to the models of stability and the concepts of individuality. Far from being purely metaphysical problems, those arise in a sort of “metaphysical space” defined along the same gradient than ethical issues, and often an implicit solution for them is presupposed when constructing given projects in ecological engineering or arguing about its definition and scope. However, I argued here that making explicit these problems and the implicit commitments is of interest for a better understanding of what we are
doing in ecological engineering; it is also one of the theoretical benefits we can expect from the pursuit of such project.

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