FUNCTIONALISM IN ECOLOGY AND ENVIRONMENTAL ECONOMICS: EPISTEMOLOGICAL AFFINITIES AND TEMPTATIONS

Keywords: economic rationality, functionalism, ecological functioning, ecosystem management

> Earlier, fetishes had been subject to the law of equivalence. Now equivalence itself becomes a fetish.
> --- M. Horkheimer & T. W. Adorno, *Dialectic of Enlightenment*

Functionalism is a natural bridge between ecology and economics. Faced with a systemic issue like the biodiversity crisis, functionalism is particularly useful for economic reasoning, as it allows to break down a complex reality by estimating the contribution of the parts to the general performance of the whole. In this manner, items that are crucial to the functioning of the ecosystem can be preserved in priority. However, while functionalist language is relatively common in environmental sciences, its use is very debated in the philosophy of sciences and ecology. In the philosophy of science, functionalism raises question because it implicitly introduces finalism into scientific reflection. In ecology, it interrogates because it implies a certain degree of organicism, which contemporary ecologists are relatively reticent about.

This article reviews the epistemological debates about functionalism in ecology. It attempts to identify its current area of scientific validity and highlights some important implications for economics. It emphasizes, in particular, that functionalism depends on the system examined and remains inapplicable wherever singularity prevails. Finally, we highlight the risk for economists of conceptualizing the environment through purely abstract functionalism, which could lead to assume functional equivalences without empirical verification.

Introduction. Functionalism in environmental sciences, a common but flimsy approach

Functionalism, i.e. the use of the concept of function to describe the relationships between a system's parts and whole, is very common in the environmental sciences. It has the great advantage of enabling to characterize items (in this case, living items like organisms, species, etc.) with regard to their performance, i.e. with regard to their contribution to the 'functioning' of the system to which they belong (ecosystems, for instance). This usage can be explicit (e. g. concepts of ecological functions, ecological functioning, functional biodiversity, etc.) or implicit (e. g. 'role' of biodiversity, ecosystem 'services', etc.). In environmental economics as well, functionalism plays an important role. In particular, it underpins one of the discipline's fundamental analytical frameworks: the ecosystem services (formerly known as ecosystem *functions*, see De Groot (1987) and De Groot et al. (2002)). Referring to 'ecosystem functioning' is also very common (e. g. D'amato and Korhonen 2021; Eppinga et al. 2023).

The validity of this approach, however, is rarely questioned with regard to the philosophy of science. Function as a conceptual tool is often taken for granted by environmental scientists (see Nunes-Neto, do Carmo, and El-Hani 2016). Howbeit, the concept of function in ecology has been the subject of considerable debate over the last fifty years, concerning the extent of its scientific validity (McLaughlin 2003; Jax 2005; Gayon and De Ricqlès 2010; Jax 2016; Nunes-Neto et al. 2016a; Dussault and Bouchard 2017; Dussault 2019). The concept has been questioned both in the philosophy of science and scientific ecology. In the philosophy of science, it is queried because it is very close to finalistic reasoning, which is contrary to modern science's principles. In scientific ecology, the concept is debated because organicism, from which it derives, is debated. Functionalism had formerly a structural role in post-war ecology, which was dominated by Eugene P. and Howard T. Odum's strong systemism. Its use was considerably reduced from the 1970s onwards, however, with the radical questioning of the systemic principles of the so-called 'Odumian' ecology (Worster 1990; Hagen 1992; Golley 1993; Haber 2011; Wiegleb 2011). The 'post-Odumian' ecology, as Worster called it (1994), that came to the fore at the end of the 20th century was a reductionist, evolutionary ecology focusing on population dynamics, with little acceptance of the idea of ecological functioning. Organicist and functionalist 'system ecology' gave progressively way to individualistic and evolutionary 'community ecology', letting little room for functionalist analysis.

Still, functionalist language made a discreet reappearance in ecology in the 1990s, with the creation of a new research program, the Biodiversity and Ecosystem Functioning (BEF) program (Hooper and Vitousek 1997; Tilman et al. 1997; Hector et al. 1999; Loreau et al. 2001). To some extent, it aimed at rehabilitating functionalist ecology and integrate it with 'modern' evolutionary ecology. This resurgence was somewhat paradoxical, however, as BEF does not necessarily refer to some defined ecological 'functioning'. Besides, the success of the program is still a matter of debate (e. g. Devictor 2018). On the whole, the validity of functionalism remains debated, and its use – when it subsists – must be cautious.

Discussions on the status of functionalism in ecology are not an abstract debate that more applied sciences could dispense with. These discussions are crucial as they reflect the evolution of ecological sciences and determine the way in which ecological reality can be interpreted. This is particularly important for environmental economics, we believe, as functionalism remains the major possible bridge between economics and ecology, as we will attempt to demonstrate. As a consequence, knowing its precise area of validity allows to know for the economist the exact possibilities of cross-disciplinary connections. The risk here, in particular, would be to rely on a biased vision of ecological reality that would be assumed to be more 'functional' (i. e. predictable and controllable) than it is.

The next sections are composed as follows. Section 2 highlights the affinities between economic rationality and functionalism. It shows that it is this rational 'channel' that will be logically privileged by economists when examining ecological reality, justifying prior verification of its scientific validity. Section 3 looks in more detail at the ebbs and flows of functionalism in ecology, which is at the heart of the still-ongoing battle between organicism and individualism. We will see that functionalist language has today a somewhat paradoxical status, belonging to an apparently outdated ecology but persisting in implicit forms. In section 4, we explore more the various contemporary theories in the philosophy of ecology that attempt to redefine an acceptable, scientifically valid use of this language. We will see that ecology is currently hesitating between a reduced, even minimal meaning of the function, and a more assumed but still marginal use. After this detour, section 5 returns to economics, pointing out the crucial condition for a valid use of functionalism: always relating any functionalist framework to an observed, well-defined structure. In relation to this prerequisite, section 6 discusses the problem of singularity or peculiarity in ecology. Section 7 concludes.

Section 2. Economic rationality and functionalism: epistemological affinities

Economic rationality consists, fundamentally, in rationally arranging means (or resources) for a given end[1]. It corresponds, in Aristotelian terminology, to instrumental rationality or *poeisis*. From an economic perspective, the given end is *necessity*; it is necessity (or needs) that justifies the exercise of economic rationality, which arranges resources and results in production. The ecological crisis, however, poses formidable questions to the exercise of such a rationality. Indeed, with the ecological crisis, the economic agent finds himself immersed in a much broader and more complex environment than he imagined. This environment is made up of multiple interdependencies and turns out to be at least partly indeterminate (Mayr 1961). In this environment, his action is diffused and eventually propagates into a multitude of unforeseen consequences. At a pinch, no action may be considered as inoffensive: each of them directly or indirectly affects planet Earth's biophysical cycles. The risk, then, is to block any process of rational action. Because of what we could call the globalization of consequences, it becomes nearly impossible to identify beneficial actions, as repercussions multiply infinitely. In each case, associated benefits may appear to be too weak in the face of the multiple ecological aftereffects. Such a situation fosters a culture of catastrophism: if the consequences of our actions propagate *ad infinitum*, no end is ultimately legitimate, and the possibility of action is annihilated.

To remedy such a difficulty, economic rationality is forced to abandon individual utility in favor of a more holistic approach (Gowdy and Carbonell 1999; Gowdy 2011; Schmitt Olabisi 2023). It means extending the scope of analysis beyond the direct environment of the agent, to include ecological interdependencies. In doing so, theorists build a rational map of the entire socio-ecological system, in order to prevent after-effects from escaping their attention. For this purpose, the concept of function is paramount: functionalism is based on the idea that the contribution of every social and ecological item to the general system's functioning can be evaluated. By incorporating this concept, theorists can begin to outline a complete socio-ecological metabolism (Pauliuk and Hertwich 2015). One can see that functionalism is in fact a natural extension of instrumental rationality. While instrumental rationality links an agent to some corresponding good (i. e. an end to some corresponding means), functionalism links a multiplicity of agents (ends) and goods (means) all together. One could say that functionalism is the appropriate language or grammar for describing situations of multiple interdependencies. So, it is no coincidence that functionalism played a significant role in early environmental studies (Westman 1977; Ehrlich and Mooney 1983; De Groot 1987) and has gained increasing popularity, especially since the *Ecosystem Millennium Assessment* (MEA 2005).

From an epistemological point of view, however, such a perspective is not trivial. Functionalism has some prerequisites. In particular, it requires a logical system of *functional equivalences* (see Dussault 2019), i. e. equivalences in the effects produced by the components of the system (e. g. species A and species A' produce the same effect inside the system, and thereby belong to the same functional group). It also requires an objective function (or meaning) for the system as a whole: the system must be a 'functioning' system (e. g. species A and species B, through their specific strategies, contribute together to the system's performance). Before laying claim to some integrated economic-ecological

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[1] This definition is consistent with the definition of 'economics' by B. M. Haddad (Haddad and Solomon 2023, 161). We leave aside here the pragmatist definition of economic rationality as 'bounded rationality', which does not directly address the essence of economics.

knowledge, it is therefore necessary to verify whether these prerequisites are valid for ecological entities.

The question of equivalence, in particular, is delicate, because – as we will see below – it is singularity more than equivalence that predominates in the 'ecological theater', to use G. E. Hutchinson's expression. One cannot simply assume the existence of functional equivalences between items in ecological systems, as when observing some mechanical system, like a watch or an engine. In the living world, equivalences must be eventually *conquered* by instrumental rationality (and ecological engineering on a concrete level), not simply assumed. Or to put it another way, ecological singularities are not easily reduced into ecological equivalences. Here, the challenge is then to curb human mind's inclination to promptly ascribe abstract equivalences when facing any new system, because it could be that, in the ecological theater, it is not the expected play that is being performed. In that respect, the question arises as to whether our tendency to assume equivalences in environmental sciences would not constitute a form of what Horkheimer and Adorno (2002, 12) referred to 'equivalence fetishism'. The two critical theorists had underlined a great risk ensuing the deployment of economic reasoning in late modernity: the risk that, as economic reasoning saturates cultural imagination, we end up believing that equivalence is the rule, when it is the exception. The risk, then, is of not being aware of the specificity of the ecological problem, and of underestimating what is at stake with it.

Section 3. Ups and downs of functionalism in ecology

Functionalism is not evenly distributed in ecological thought. Ecology is a plural science that brings together very different – not to say sometimes antagonistic – theoretical perspectives (Wiegleb 2011; van der Valk 2011). One of the discipline's main theoretical divisions that determines the adoption (or not) of a functionalist approach is the distinction between what Hutchinson (1978) called the 'mereological approach' (from ancient Greek '*meros'*, partial) and the 'hological approach' (from '*holos'*, entire). The mereological approach is entity-oriented, focusing on populations dynamics; the hological approach is process-oriented, focusing on matter and energy flows. While the mereological approach has populations (of one species) and communities (of several species) as its main object of study, the hological approach is primarily concerned with biochemical aspects, where populations appear only as indirect 'performers'. Callicott et al. (1999) used the terms 'compositionalist' and functionalist'. More simply, the first approach may be called 'demographic' and the second 'physiological' (Hagen 1989). The first approach is mainly the field of population and community ecologists, while the second is the field of system or ecosystem ecologists[2].

This division does not simply distinguish between different epistemic orientations. It also reflects an essential debate about the fundamental unit of ecology (Jax, Jones, and Pickett 1998; Jax 2006). In particular, the question is whether order can be inferred at the level of super-individual complexes (Friederichs 1958). The demographic approach tends to posit that it is the level of the population (eventually aggregated into communities) that remains the fundamental unit of measurement in ecology, and the basis, consequently, of theoretical elaborations. The physiological approach, on the other hand, postulates that we can define supra-individual regularities, which constraint populations in one way or another. The demographic/physiological division is thus also related to the debate between holism and reductionism, or organicism and individualism. In contrast to the bottom-up (or reductionist) perspective of the demographic approach (Golley 1993, 22–23), the physiological approach has a top-down (or holist) perspective, which postulates that constraints apply at the ecosystem scale that determine population dynamics. The ecosystem may even be seen as a 'super-organism' (i. e. an organism of a higher order) in which species play a role comparable to that of organs, in the sense postulated by one of the fathers of ecology, Frederic E. Clements (1916). In that

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[2] Taylor (2011, 88) deduces a series of contrasting features from this theoretical division: "the two schools", he says, "mapped broadly onto a series of conceptual-methodological contrasts: function and process vs. structure and demography; properties of wholes vs. explaining parts and building up from there; field measurements vs. mathematical modelling."

case, “the whole comes before the parts, which fulfil their tasks in a functionalist, teleological way” (Schwarz 2011, 133). Naturally, it is within the physiological approach that functionalism finds its justification, since it is there that supra-individual coherence is assumed, requiring roles to be assigned among the system’s compartments.

Functionalism has long found a fertile ground in system ecology. Following the work of P. E. and H. T. Odum (1953), system ecology tended to detach itself from evolutionary aspects, to offer an explanation of ecosystems as stabilized, stratified and functionally differentiated structures, which were "as much (if not more) physico-chemical as biological*[3]", as Dussault (2016, 90) points out. Rooted in cybernetics and thermodynamics, the Odumian model was made of feedback loops, where individuals were ‘performers’ of the different ecological functions (such as primary production, nutrient recycling, etc.), with little attention on their phylogeny. Many of the propositions of system ecology had a strong teleological emphasis: homeostasis was seen as an objective function for ecosystems; the ‘principle of maximum power’ was conceived as an directional principle for ecosystem development (H. T. Odum and Pinkerton 1955); stability as a criterion for natural selection; ecological wholes considered as the object of this selection (instead of individual differentiated reproduction), etc. From the 1970s onwards, however, Odumian principles were subject to increasing criticism, as field observations did not seem to correspond with the proposed models. The discovery of pervasive chaotic dynamics, the absence of the expected ‘balance of nature’ and the importance of contingency contributed to the gradual rejection of Odumian systemism (Engelberg and Boyarsky 1979; Simberloff 1980; Strong et al. 1984; Worster 1990). Due to the predominance of physico-chemical parameters, it was also accused of being a physical ‘crypto-reductionism’ and a ‘hyper-simplification’ of the ecosystem (Mansson and McGlade 1993; Bergandi and Blandin 1998). Robert E. Ulanowicz (1990), one of its eminent contributors, attempted a final defense of system ecology, but by the end of the century the demographic approach had won the battle (Wiegleb 2011). Interestingly, the decline of system ecology also led to a loss of interest in environmental issues among ecologists; whereas many ecosystem ecologists were also active on the environmentalism front, according to Hagen (2008) newly dominant community ecologists tended to move away from these considerations, calling for scientific neutrality.

With the onset of the biodiversity crisis, however, the question of ecological management came back to the fore – and with it, functionalist language. A pivotal moment of this ‘functionalist turn’, as Devictor (2018, 137) names it, was the Biodiversity and Ecosystem Functioning research program, or BEF (see Hooper and Vitousek 1997; Tilman et al. 1997; Hector et al. 1999; Loreau et al. 2001). This program took precedence over the ‘diversity-stability’ debate of the 1960s-1970s[4] by attempting to assess, in the context of the biodiversity crisis, the role played by species diversity in ecological functioning. Nunes-Neto et al. (2016a) depict this program as a broadening of the biodiversity issue, no longer reduced to taxonomic aspects, but opening up to the problem of species’ differentiated performance. Biodiversity is seen as a causal agent whose contribution to the ecosystem must be evaluated. In line with the BEF, the concept of functional biodiversity emerged (Dussault 2019), giving functional ecology new impetus. For Loreau (2010), one of the BEF’s main authors, the aim is nothing less than to bring community ecology and ecosystem ecology together and achieve a ‘unified ecological theory’.

This return to the functionalist language is not without raising questions, however. For Devictor (2018), it is incoherent, since contemporary ecology is unable to describe the ‘functioning’ to which this language should refer. Less radically, Nunes-Neto et al. (2016a) notice that “in this reappearance the notion of function is detached from a strong organicist thought such as found in Clements’ ideas”. The question that remains is what this functional language is referring to exactly.

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[3] Asterisks indicate that we translate from French.

[4] The ‘diversity-stability’ debate focused on the possible positive relationship between species diversity and ecosystem stability (McCann 2000).

Section 4. Restrictive use of functionalism in the philosophy of ecology

Functionalism has been the subject of considerable epistemological debates in biology for several decades (McLaughlin 2003; Gayon 2006; Gayon and De Ricqlès 2010; Walsh 2014; Saborido 2014; Garson 2016). The main reason is that functionalist statements bypass conventional causal schemes by explaining causes with effects. Instead of sticking to strictly causal statements (like "the heart circulates the blood in the organism", or "the iceberg provides drinking water to the valley"), these statements provide 'total' explanations ("the purpose of the heart is to circulate blood in the body", or "the purpose of the glacier is to supply drinking water to the valley"). By doing so, functionalist statements reintroduce a teleological way of thinking[5]. A function is a sort of expected effect; but saying that an item "has a function" is not only supposing some effect regularity of the item, but it is also saying that the *raison d'être* of this item is to produce the effect. This is a typical finalist/teleological statement.

De Ricqlès and Gayon (2010, 143) also underline a paradoxical aspect of the concept of function: it is an abstract notion, but in fact it is inseparable from a concrete structure, which gives it its full meaning. Function is not a substance but an interaction, which cannot be considered apart from the structure that produces it. De Ricqlès and Gayon evoke some "indissociable structural-functional couple*": if the function is abstract, there can only be a function in relation to a fully described system, whose function is an emergent property[6]. As highlighted by Devictor (2018, 150), if the functions are described independently of any precise ecological context, they lose their meaning and become what he calls "phantom functions*". This point seems particularly important to us to keep in mind when using the concept in economics.

In the philosophy of ecology too, functionalism has been the subject of important controversy (Jax 2005; 2016; Nunes-Neto, do Carmo, and El-Hani 2016; Dussault and Bouchard 2017; Dussault 2019), reflecting the evolutions of the discipline itself. Beyond the problem of finalism and scientificity, debates in the field focus on the compatibility of the function concept with evolutionary ecology, and the idea of natural selection in particular.

A first set of theories, called the etiological or selected effect theories, gives the function a minimalist, strictly evolutionary meaning (Wright 1973; Godfrey-Smith 1993). The function here is nothing more than a 'trait', i. e. a morphological, physiological or phenological individual property (like beak size, body mass, metabolic rate, freezing tolerance, etc.), whose presence can be explained by natural selection. The function is akin here to a 'selected effect' (Gayon 2006; Dussault 2019). It relates to a trait such that it historically conferred a selective advantage on the 'typical' individual who bears it. These theories are sometimes referred as the 'Standard Line'. If they are consistent with evolutionary biology, they have the disadvantage of offering an explanation that is strictly historical, without consideration for ongoing processes. Ernst Mayr, the renowned biologist, once said that biology was made up of two complementary parts, both necessary for a complete explanation (Mayr 1961): evolutionary biology, related to the 'ultimate causes', and functional biology, related to the 'proximate causes'. Ultimate causes refer to the long-term of natural selection, where diachronic causality applies, while proximate causes correspond to the short time of present biological patterns, where synchronic causality applies. In the etiological theories of the function, the second is clearly missing.

A second set of theories, called the systemic or causal role theories of the function, seeks to remedy this gap (Cummins 1975; Craver 2001). Unlike the first group, these theories wittingly ignore history, considering only structure as it can be described. Function, in this case, is an effect or capability inferred from more basic capabilities. Gayon (2006, 485) characterizes this conception as "overtly mechanistic and analytical*". It consists in breaking down the system into parts and identifying among these parts some phenomenal regularities. It is no longer a question here of finding

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[5] Functionalist language, says Gayon (2006, 481), "is a spectacular example of a teleological way of thinking in modern science*". The examples of the heart and the glacier are taken from Gayon and De Ricqlès (2010, 3).

[6] With regard to the philosophy of sciences, this logical combination between 'structure' and 'function' reveals couples of functional and structural disciplines, like physiology and anatomy, or, as De Ricqlès and Gayon (2011, 144) suggest, ecology and demography. The authors describe ecology as a "meta-physiology of supra-specific interactions*".

explanations for the origin of a trait, but looking for laws that can be replicated on the scale of the system. This is typically the functionalist reasoning we described in section 2. The counterpart of this approach is that, to remain compatible with orthodox biology, these theories pose themselves as perfectly neutral. The inferred functions do not relate to an objective reality, but depend entirely on the observer's eye, who decides to focus his attention on this or that aspect. This relativization to the researcher's interests is problematic, as it entails that no distinction can be made between accidental interactions and key processes (such as primary production, decomposition, etc.), or even that interactions that are harmful to the ecosystem could be qualified as 'functions' (Dussault 2019, 311).
A third group of theories, called the organizational theories, have more recently attempted to propose a more satisfactory approach (Collier 2000; Mossio, Saborido, and Moreno 2009; Nunes-Neto, Moreno, and El-Hani 2014). In these theories, functions are seen as the contribution of the parts (e. g. the species) to the maintenance of the system's organization (e. g. the community). An important step (or demarcation) is made here: these theories refer to some general performance of the ecosystem, which is said *to maintain itself*. This is a clear reappearance of the organicist perspective. The idea of self-maintenance fits into what Jax (2010, 4–5) had called the 'conceptual cluster' of ecosystem functioning, which includes ideas like ecosystem resilience, integrity, health[7], or even collapse. All these terms postulate some objective function applying at the super-individual scale. Jax supported this perspective: if ecological entities are "not just a happenstance or loose collection of relations between organisms and their environment", he says, we should be able to speak of *functioning* or *not functioning* systems (Jax 2010, 2).

According to Dussault (2019, 300), there is today a "near consensus" for a not strictly historical interpretation of ecological functions[8]. He emphasizes, however, that this interpretation relates to a more open conception of the idea of 'functioning', which should allow contingency to interact with ecological structures[9]. In particular, it is less a question of thinking of functions as the result of a *design* (in the sense that some item is 'designed to'), but as the result of *use* (some item 'is used for') or *service* (an item 'serves as'). In other words, functions should be seen essentially as by-products of ecological interactions that are strongly context-based. As Jax (2010, 79) highlights, "the one and only role of a species does not exist. Roles are strongly context-dependent." This more open concept of 'functioning', in which the structure can evolve and where functions may not be fulfilled, results in more attention being paid to key ecological processes than on some rigid, totalizing 'functioning'.
If this interpretation of functionalism tends to gain in relevance, it should be kept in mind that it is still an area of debate. Underlying this debate is the pending question of the integration degree of ecological entities, or – to use Friederichs' expression – of 'super-individual complexes'. What seems to emerge is a sort of weak organicism, with a lesser degree of part-whole integration than the vision of Clements or Odum. The model here would rather be that of the ecologist Charles S. Elton (1933), for whom the organization of ecological communities was more comparable to that of human societies than to the organism.

Section 5. The risk of assuming functions without considering structures

We see that functionalism does have some relevance in ecology, provided its meaning is clarified. As De Ricqlès and Gayon (2011, 155) emphasized, the concept remains polysemous. To get an idea of this conceptual amplitude, Jax (2005) mapped the different meanings in use in the environmental literature. It includes:

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[7] About the idea of 'ecosystem health', see Rapport (1989), Karr (1996), Callicott (1995).

[8] Still, Dussault (2019, 312) expresses certain reservations with regard to organizational theories, which tend to explain the presence of organisms in an ecosystem by their function, an interpretation which would not leave enough room for contingency.

[9] As Taylor (2011, 91) argues, "historicity need not eliminate ideas about regularities or structuredness of ecological patterns and processes. To say that ecological structure has a history could be to say that it changes in structure and is subject to contingent, spatially located events, while at the same time the structure constrains and facilitates the living activity that constitute any ecological phenomenon in its particular place."

- function as a synonym for ‘process’ or ‘interaction’ between two entities, in a purely descriptive meaning of cause and effect;
- function as a process related to a coherent whole, which itself is assumed to ‘work’;
- function as the role attributed to certain entities within the system, which makes it possible to distinguish the function from the entities that provide it, and to define ‘functional groups’ or ‘types’ (e.g. primary producers, primary consumers, decomposers, etc.); and finally
- function in the sense of an ecosystem service, following an expressly anthropocentric conception.

What is interesting with that conceptual mapping is that, as one might see, these four meanings implicitly draw the path of what we could call a progressive rational ‘mobilization’ of ecological entities, going from the simple statement of existing causal relationships, to an examination with regard to some general functioning, then an attribution of ‘roles’ (several items being able to perform the same role), and eventually to a normative selection of convenient ecological processes. What such a progression suggests, in fact, is the possibility of an assimilation of functional statements by economic rationality, which could eventually design an overall performance scheme that integrates ecological entities with economic entities. Here again, we see that functionalism makes the link between ecology and instrumental reasoning.

This is not a problem in itself. As Gayon (2006) pointed out, the concept of function *is* a normative concept – just like the economy, as the etymology indicates. Since we are taking an economic (i.e. normative) point of view, it is entirely possible to say, based on ecologists’ statements, that it is *desirable* for ecological communities to be ‘functioning’, or resilient, or efficient, or healthy, etc. For instance, Nunes-Neto et al. (2016b) deliberately use a normative terminology when analyzing the problem of socio-ecosystems: the objective, they say, is to adjust within socio-ecosystems what they call "natural norms", i. e. the basic functions (or constraints) of ecological systems, with “social norms”, that is to say the functions (or constraints) of social regulation. One might even say that it is the function of economists, if we may put it that way, to build this reflection at the crossroads of ecology and ethics.

Economists must, however, keep in mind that the systemic approach and its functionalist language do not show an objective ecological reality but still depend on a point of view, even if certain basic, very general processes such as nutrient recycling or primary production appear universal[10]. As Jax pointed out (2005, 644), “Ecosystems cannot be identified or found in nature. Instead, they must be delimited by an observer”. To put it another way, what we call the ecosystem is a heuristic unit, not a real entity (Jax 2006). As economists, we must keep that in view and always keep an eye on the ‘system’ we presume, checking the validity in space and time of our assumptions and categories. This has the important consequence that any ‘totalizing’ view is forbidden, especially given what we know today about the ecological theater: that non-equilibrium and heterogeneity are predominant.

The danger of the functional interpretation is essentially to remain abstract. As said above, if functions are detached from structures, i. e. from situations in a certain place and a certain time, they retain only a rhetorical, empty meaning. Functional and structural perspectives must remain closely linked, otherwise contact with reality can be lost, with the risk of falling into fetishism. This danger is not purely theoretical; there are examples in recent environmental works where abstraction seems to prevail over empiricism. A first example is the BEF itself, in which, as Devictor (2018) and Nunes-Neto et al. (2016a) perceived, a function is attributed to a purely abstract entity, something that does not exist *per se*: biodiversity. There, structure appears to be insidiously eluded: “functioning is no longer the result of a structure […] but the fact of biodiversity itself” (Devictor 2018, 136). The same problem occurs with works on biodiversity and ecosystem services (Cardinale et al. 2012): often, ecosystem services remain notoriously separated from any contextualized structure. These two cases are an illustration of ecological complexity underestimation, or to put it in another way, illustrations of excessive confidence in abstractions. Any economic perspective that would attempt to compel

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[10] Woodward (1994) uses the term “universal functions” to describe these general processes.

ecological complexity within the confines of its inherent equivalence-oriented logic risks promoting a dangerously simplified vision of ecological realities.

Section 6. The question of singularity

Georg Picht, the German philosopher, defined ecology as "the science of the singularity of situations, founded on the generality of natural laws"[11]. Singularity has an important place in ecological thought: if the search for laws constitutes (like any science) the final ambition of the discipline, ecologists are generally aware of the great complexity of their object, which encourages caution in the elaboration of definitive statements. Blandin (2009, 87), for example, is reticent about the idea of 'law'. According to him, ecology only offers falsifiable models for interpreting data. In ecology, each field of study, each experimental isolate is caught up in a complex environment, which it interacts with. The fundamentally hierarchical nature of the living world creates a multiplicity of 'openings', of connections between levels, which prohibits any definitive theoretical closure. Even in rudimentary ecosystems, the number of species and the complexity of their interactions strongly limit the possibilities of mathematical modelling. Species richness is often such that a substantial part of the taxa remains unknown. For example, a single gram of soil may contain tens of thousands of prokaryotic species. From a biogeochemical point of view, different cycles (energy, carbon, nitrogen, phosphorus, etc.) intersect and influence each other, while they evolve irreversibly at the same time (erosion of the bedrock, soil formation, atmospheric deposits, etc.). A field study, even over an extended period of time, corresponds to a more or less instantaneous image of a dynamic process made up of different rhythms, different impulses – some of which going back several centuries or millennia. Blandin (1992, 274) pointed out that "any fragment of the biosphere, as we can observe it today, is the local product of a singular history: it is definitely unique*". It is this complexity that made Ulanowicz (2004, 349) say that the world of the ecologist is "granular" rather than universal. The singularity of each situation becomes a methodological prerequisite.

We said above that functionalism makes the link between ecology and instrumental reasoning; singularity constitutes here the stumbling block, conversely. Singularity is not admissible for economic rationality, which requires clear functional statements (what is this item for?), both generalizable and persistent. The challenge, therefore, is to establish a system of equivalences (i. e. this item is equivalent to this item with regard to their performance) that could reduce complexity and bypass singularity. In the same way that the ecological crisis requires mapping all biomes without leaving a blank spot on the map, it requires identifying the role played by each item within biological cycles, without leaving uncertainty about the respective contributions of the different items.

Economically, the aim is to find practicable (functional) statements at some reasonable cost that would be both strategically sensible and sufficiently in accordance with the ecological reality. With regard to industrial history, we probably stand at the beginning of this process. Only a limited number of attempts have been sketched out, of which the most emblematic example is probably carbon accounting. Although it is a remarkable example of widely shared theoretical construction, one can wonder about the relevance of some categories that have been defined. For instance, characterizing the extremely varied ecological situations under gross headings such as 'forests' or 'grasslands' are poor approximations that can result in problematic oversimplification.

Horkheimer and Adorno (2002) had shown that the stakes for instrumental reason, which was personified by Ulysses in their famous book, consisted of three things. First, to recognize the superiority of antagonistic forces (Ulysses, in front of the odyssey's various monsters, is never the strongest); second, to cede to them in proportion to their superiority; and third, to bypass them by a lateral, indirect way. Monsters may have strength, but they are without flexibility: this is Ulysses' wisdom[12]. Instrumental reason therefore faces two limits: the first is the obstacle itself, to which one

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[11] In "Ist Humanökologie möglich? (1979), quoted by Haber (2011, 225).

[12] One can wonder if some proposals of carbon engineering do not deviate from Ulysses' rule, when they attempt to adapt biological cycles to human rhythms rather than adapt human rhythms to biological cycles. One can fear that these attempts

must grant some inessential part (each monster has its own requirements, but these are always secondary to Ulysses' goal). This limit is eventually the easier one, the limit that Ulysses knows how to bypass. The second limit is more insidious, since it relates to the limits of our knowledge and understanding capacities. We have to make an effective recognition, a fair assessment of the antagonistic forces at play. This limit raises the question of the acuity of the instrumental reason itself. It may prevent Ulysses from fully seeing what kind of forces he is dealing with. Regarding the environmental issue, one could say that the limit is constituted as much by the ecological constraints to which one must agree to cede, as by the impossibility of recognizing the obstacles – due, in particular, to predominant singularity[13].

Section 7. Conclusion

In this paper, we attempted to show that functionalism is the natural way to approach the ecological problem from an economic point of view, due to the fact that it makes it possible to articulate economic and ecological items within the socio-ecosystem. However, we have emphasized that functionalism has prerequisites that contemporary scientific ecology is not necessarily able to validate. In particular, functionalism is closely related to organicism. Saying that an ecological item 'has a function' implies that the system in which this item is inserted is 'functioning'. This is a typical organicist statement, about which scientific ecology has significant reservations. If organicism is accepted, it is only in a weak form, which would give a significant place to contingency, without assuming that functions will be fulfilled nor that the ecosystem will be balanced.

Another prerequisite of a functionalist approach is that it should be possible to build a rational system of functional equivalences, grouping together items presenting similar performances. Indeed, it is only under this condition that items can be related to the overall 'functioning'. However, this logic of equivalence (which is the logic economic rationality itself) comes up against the omnipresence of singularity in ecological entities. Due in particular to the influence of history, each ecological entity appears to have a high degree of singularity, which restricts the possibilities of functional extrapolation. It follows that a functionalist perspective can only be applied if one proceeds very cautiously. Assuming abstract equivalences that would not have been empirically supported would be akin to what Horkheimer and Adorno called the 'fetishism of equivalence', which would run the risk of losing contact with the ecological reality. More generally, we remind in the paper that a crucial condition for a valid functionalist perspective is to always associate functional statements with a well described structure, from which the functional statements emerged.

Given the scale of the biodiversity crisis and the transformation of our economies that is required, we believe that it is necessary for economics to maintain a strong interdisciplinary link with ecology, so as to know exactly what their (etymologically) sister discipline has to say about the ecological reality. This is important, in particular, in order not to underestimate the complexity of the problem, and to find appropriate ways to deal with it. A few years ago, Rockström et al. (2017) had stressed that solving the ecological crisis would require "herculean" efforts; we could say similarly, given the complexity of the problem, that what we need is *cunning*, and that the appropriate model is Ulysses as much as Hercules.

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poorly recognize the ecological forces and cede too little. Certainly, ecological engineering will be able, in the coming decades, to refine its action and increase socio-ecological coherence. However, one could also see behind the mix of insufficient measures and political stalemate the effects of a weakened reason, confronted with a Cyclops that is too big for it to handle.

[13] This impossibility of recognition is revealed, in practice, by the appearance of unforeseen ecological behaviours, which are theorized by ecologists as 'surprises' (Lindenmayer et al. 2010). Ecological surprises are the clue, for the economic agent, of an inadequate representation of ecological entities, or an overly naive tactic. As long as functional equivalences prove to be too simplified, the agent is forced to narrow his field of action, to concentrate his attention on a more restricted perimeter.

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