

A Critical Analysis of the Concept of Nature and *Natural Balance* in Secondary Biology
Education: a Textbook Analysis.

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Abstract

Your worldview influences how you view nature and how you approach conservation of natural systems. At the moment pupils from secondary education carry multiple misconceptions in regard to the concept of *natural balance*, possibly because of the image that is portrayed of nature by biology textbooks. This qualitative research describes what image of nature and natural balance three Dutch biology textbooks and two teacher guidebooks portray. The scientific consensus is that there is no such thing as natural balance. The outcome of the textbook analysis shows that textbooks present a mechanical image of nature regarding the worldviews and natural balance is still present in the form of *stable equilibria*. We advise teachers not to use textbooks as their sole source to prepare their lessons to prevent these kinds of misconceptions.

Keywords: secondary biology education, natural balance, population dynamics, anthropocentric thinking

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A Critical View upon the Concept of Nature and *Natural Balance* in Secondary Biology Education: a Textbook Analysis.

1. Introduction

1.1 Defining nature

Defining the concept of nature is hard. You might consider a sanctuary nature. Or you might consider a park nature, or even your own backyard. In all of these definitions you can include or exclude humans. And then there is the concept of time as well: the park could *become* nature after 200 years. Even though defining nature is hard, it is important to do so because the term is used on a daily basis. Especially within biology education in which the term nature is used even more frequently.

The Oxford English Dictionary defines nature as follows:

“The phenomena of the physical world collectively, including plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creations.”

This definition is how it is applied in most secondary educational texts and therefore also the definition we will apply in this article.

A second issue of defining arises when you look at what you consider *healthy nature*. You might consider an ecosystem healthy when it is in balance and not undergoing change. Or, you could consider a collapsing or ‘changing’ ecosystem healthy as well. When we think about healthy nature, automatically a lot of assumptions arise: harmony, balance, stability. Most of these assumptions are clearly relevant in the context of an environment suitable for our survival. When speaking in a more general context, we cannot help but wonder if these are adequate assumptions (Botkin, 2012, p. 328).

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The way you are taught to view the world influences how you view nature. If you are taught that there is a role and place for everything, this would create a different view of nature than if you are taught that nature is ruthless and constantly changing. The latter seems to be true when we look at population dynamics. There has not been one example of a population that has been stable for a period of over 50 years (Botkin, 1990, pp. 25-43).

This brings us to the concept of *natural balance*. Natural balance (NB) is a balance that arises naturally, without the influence of humans. The belief in such a balance fits the idea that nature is healthy if it is stable. A good example is the Oostvaardersplassen in the Netherlands. The Oostvaardersplassen is a sanctuary in the middle of the Netherlands. For the past few decades the general belief has been that an equilibrium would arise between the species of large herbivores that have been introduced by humans (see Box 1 in the theoretical background section).

1.2 The societal problem

You have two motives for believing in NB: (1) the teleological motive; your religious and spiritual history make us see the balance and (2) the evolutionary motive; your need for structure and stability in order to survive. You cannot survive without a stable environment and/or, it has certain evolutionary advantages to try to keep your surroundings as stable as possible and to recognise it when it is not stable. Therefore you consider it self-evident to assume the reality of the concept of NB.

One of the main tasks of biology education is to present a scientifically adequate, realistic image of nature and this cannot be done by teaching concepts that are merely projected upon nature by ourselves and that lack scientific support. By teaching misconceptions you could confuse pupils or even prevent pupils from learning new information which is academically correct (Butler, 2015). The contemporary scientific

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consensus is that there is no such thing as natural balance (Botkin, 1990, p. 15; Kricher, 2009, pp. 16, 83).

To teach the concept of NB to the new generation is problematic. It is contradictory to the current paradigm, the theory of evolution, in which change and adaptation are the main concepts. By implying there is such a thing as NB, to which a population would *naturally* return if undisturbed, you are implying it will not change. While change is the foundation of the theory of evolution. The theory of evolution states that there is selection on an individual level, not on the level of a group or even a whole population or whole ecosystem. The latter would imply there is a super-natural power regulating the population and that there is some sort of design or a preferable state for this population to occur in.

Sometimes group selection is confused with kin-selection. Kin-selection is not the same as group-selection. The theory of kin-selection states that selection is still on an individual level even when the characteristics that are selected upon do favour the group. Richard Dawkins (1979) wrote an article about the 12 misunderstandings of kin-selection, of which group selection is also mentioned as one of the misunderstandings. In the introduction of the book *Adaptation and natural selection: A critique of some current evolutionary thought* the existence of group selection is also mentioned as a misconception which has never been scientifically proven (Williams, 2018, p. vii).

1.3 Research aims

This research aims to give a complete overview of all the views of nature that are presented within Dutch biology education. One additional aim of this research is to point at possible inconsistencies, both explicitly and implicitly present in the curriculum. To do this first of all we will treat a brief history of ecological beliefs of the previous century. Followed by an explanation of the three worldviews that have been described by Botkin: the mechanical, the

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divine and the organic. Botkin states in his books that the worldviews from which you reason also carries certain projections (Botkin, *Discordant Harmonies*, 1990; 2012).

This research does not aim to give the perfect recipe of how to present nature. Because textbooks are a good representation of what is eventually taught in class (Caravita, 2008; Chiappetta, 2007, p. 1863) and play a crucial role in ensuring that the goals of the curriculum are met (Ramnarain, 2016), we have chosen to analyse the text and images in effort to meet the aims of this research.

We expect that the topic of NB is still present in biology textbooks in the form of *stable equilibria* and *self-regulation*. The relation between these terms can be explained as follows. There is a correlation between stable equilibria, self-regulation and NB. Self-regulation on the level of the ecosystem implies forces that would regulate the ecosystem itself. This is the mechanism behind the equilibria. Without self-regulation these equilibria would never be able to arise, as there would simply not be enough time for them to arise. The concept of NB is the paradigm in which self-regulation will cause populations to be in equilibrium with one another (if left undisturbed for a substantial amount of time).

The two main questions addressed in this article are:

Do Dutch biology textbooks portray nature as in a state of natural balance characterized by stable equilibria, self-regulation and disturbance?

What is the dominant worldview from which the textbook is approaching the concept of nature and what are the consequences of this approach for how nature is portrayed?

In the theoretical background the worldviews and their influence on education and the concept of NB has been explained. The origin of the concept of natural balance and a brief history of ecology and ecology in education will also be treated. To be able to answer the research questions mainly the textbook analysis will suffice. In addition, we have held interviews with the lead editor of each of the textbooks. The aim of the interview was to get

more insight in the development of the textbooks and the personal views of the editors regarding natural balance.

2. Theoretical background

2.1 Origin of the concept of natural balance

Within secondary biology education the concept of NB has been taught for most of the twentieth century, following the rise of ecological thinking since the beginning of the twentieth century. The most known are probably Alfred Lotka (1925) and Vito Volterra (1928) whom devised several models in the twentieth century. These models are predator-prey models describing population dynamics in an ecosystem. Most graphs show a wave-like, more or less stable, interaction between predator-prey relationships (Figure 1). These were soon accepted within the scientific community as to be true to nature. Thus it was suggested that predators and prey are in a state of dynamic, but relatively stable equilibrium. In other words: predators and prey *regulate* each other in an ecosystem.

However, the model turns out not to represent predator-prey relations accurately in reality: it is a model, nothing more, and it is rarely, if ever, found to be correct in nature (Hamilton, 2005; Botkin, 2012, pp. 56-60). In Figure 2 the interaction between a predator and prey is shown, which have been monitored for over 50 years. These numbers show little to no resemblance with the Lotka-Volterra model that is shown in Figure 1. Budianky (1995), a former editor of the journal *Nature* and a Harvard degree in applied mathematics stated about two decades ago: “the simplistic mathematical models of predator and prey interactions still presented in practically every elementary or population biology textbook have less to do with biological reality than with the charm of simple, apparently mathematical relationships”.

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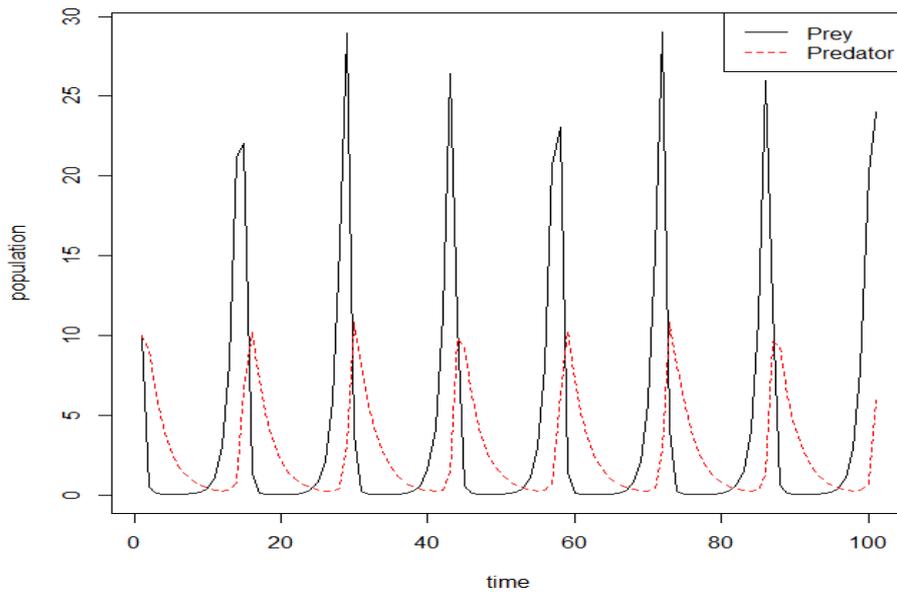


Figure 1. A theoretical Lotka-Volterra predator-prey model.

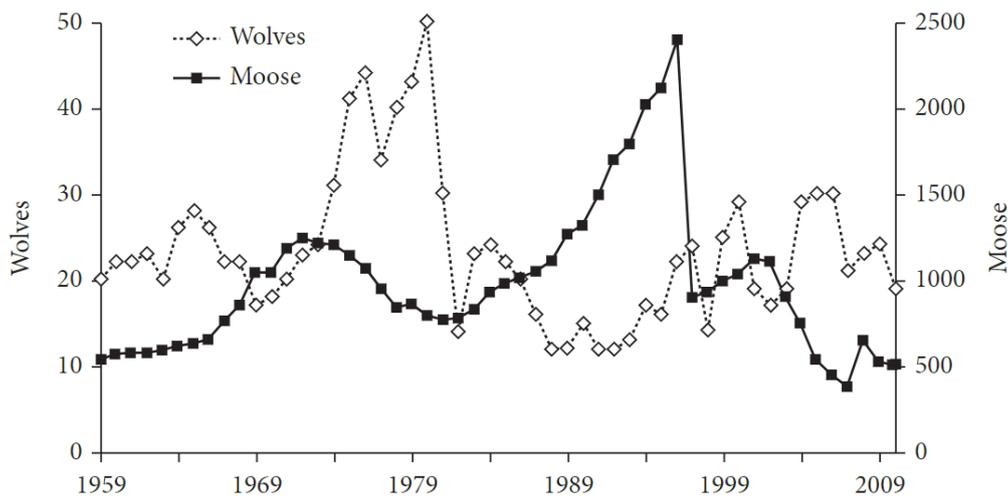


Figure 2. An example of one of the world's longest monitored predator-prey populations in Isle Royale in North-America from 1959 to 2010. The numbers of moose and wolf go further back than 1959 but, from this year the estimations have been calculated by the same method and are considered to be more accurate. Figure originates from the book *The Moon in the Nautilus Shell: Discordant Harmonies Reconsidered* by Botkin (2012, p. 59).

Some other assumptions arose in the mid-twentieth century in relation to stability.

Many naturalists and ecologists believed that *nature is unhealthy if unstable* (Gough, 1993, p. 611). Leopold (1970, pp. 197-200) who had a great influence on his peers within the ecological community, is an example. In his essay *A Sand County Almanac* he describes the American landscape and the degeneration of the environment because of the Dust Bowl in the

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1930s. Severe drought caused sandstorms and major loss of agriculture on the North-American and Canadian prairies.

Biology education has been in line with the beliefs of ecologists, who have been convinced that a NB would arise within most ecosystems if left undisturbed (Sprugel, 1991) - no matter if we take a population of large mammals with or without the top-down control of a predator, for example. In the presence of a predator the presumption was that the Lotka-Volterra model would arise (Berryman, 1992). In absence of a predator the carrying-capacity of the area would bring forth a stable number of individuals (Botkin, 1990, p. 21).

Similar predictions have been made for a sanctuary in the middle of the Netherlands, the Oostvaardersplassen (OVP). In this rewilding experiment the expectation has been that natural equilibrium would arise between the species of large herbivores introduced. The OVP is used as an example of contemporary nature conservation within this research (see Box 1). In the past five years there has been a lot of discussion if NB will ever arise within this area.

Box 1

Brief description of the sanctuary the OVP.

The OVP is an area of about 5,5 thousand hectares in the middle of the Netherlands. This area is the home of many birds and rodents, as well as some populations of large herbivores more recently introduced. We chose this sanctuary as a case-study because public opinions are divided and policy is highly debated at the moment. The initial idea was to leave this area to the 'natural' condition and that humans should intervene as little as possible, after which, a NB would arise between the species of large herbivores. The wetlands have been populated with Konik-horses, Heck-cattle and Red deer in the early nineteen-nineties. The goal of this experiment was to recreate a piece of wilderness in the Netherlands. This meant a part of the population would die each winter but the populations would stabilize as the exact carrying-capacity of the area would be met. The latest update upon the actual policy applied is that human intervention will be necessary and a substantial part of the populations will be transferred elsewhere (NRC, 29-11-2018; NRC, 10-12-2018).

2.2 Views of nature

Daniel Botkin has written a book *Discordant Harmonies* in 1990 on the problematic aspects of the idea of harmony in nature and, about two decades later, a reaction at the reviews of his own work (2012). In both books he arrives at the conclusion that our worldview highly influences the way we view nature. A worldview can be defined as follows: a theoretical framework that you use to make sense of the (natural) world around you.

Botkin describes three different worldviews: the mechanical, the divine and the organic worldview (1990, pp. 13-14). Each of these worldviews has been the dominant view for a certain period within the Western World in the past 2000 years. The views will be used as a tool to analyse and classify the texts and images and are therefore described briefly in the following paragraphs. Table 1 describes how each of the views relates towards nature conservation and how each view relates to NB.

- The mechanical view; nature is viewed as a machine. However complex, if studied adequately, nature can be fully understood and 'fixed' when necessary. Within this view certain assumptions are made, for example every population of species within an ecosystem has an exact carrying capacity that can be calculated (Botkin, 1990, pp. 19-23). A Newtonian worldview, which views the universe as a clockwork, has been the foundation for this view. Botkin (1990, p. 104) argues: "Descartes and Newton built the foundation from which the organic idea was supplanted by the machine-age [mechanical] idea".
- The divine view; nature is viewed as perfect. The divine view is deeply rooted within certain religious beliefs. Nature, if undisturbed by humans, is in harmony; each species has its own place and role within the ecosystem. The teleological assumptions are clearly present within the divine view, as well as the distinction between nature and man. Teleological can be explained as follows: to be convinced that every organism

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and ecosystem has a goal (*telos* is Greek for goal) and is created according to a design. To give an example, the goal of predators is to regulate prey populations (Botkin, 2012, pp. 100-106). A teleological assumption would be that there is a form of top-down control or god-like power, which keeps these populations from extinction to be able to pursue their pre-designed goals.

- The organic view; nature is viewed as a living system. This view is more dynamic compared to the other two views: nature is viewed as ever-changing. Sometimes the whole of the earth is referred to as living, as one superorganism. A living organism passes through certain stages: birth, youth, maturation etcetera (Botkin, 2012, p. 124). Within this analogy each ecosystem can be considered an organ of the superorganism. Consequently, if too many cells die the whole organ dies. If this would concern a vital organ, this would cause collapse of the whole organism. Just like an organism has homeostasis, a superorganism/earth would also have feedback mechanisms which regulate certain processes. However, Botkin notes that the element of chance is present more clearly within this view than in the other two views; the superorganism could die prematurely just like any other organism (Botkin, 2012, p. 124). Death itself is not considered unnatural from an organic point of view, but a part of nature.

Policy-makers of nature conservation have different worldviews of nature and these views influence what choices they make (Holling, 1973). The first two views, the mechanical and the divine worldview, would be considered *anthropocentric* and the last view, the organic worldview *ecocentric*. Anthropocentric can be defined as: reasoning from a human-centered point of view and regarding humans as being supreme in relation to other organisms.

Ecocentric can be defined as: reasoning from a nature-centered point of view in which all

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organisms are of equal value. These two terms are often applied in an environmental philosophy context, for example in the work of Arne Naess (1973).

We give an example of an approach to nature conservation policy for each of the views in Table 1. In addition we also mention how each view relates to NB. In each of the views we start from the assumption that the ecosystem is producing less and less biomass.

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Table 1

Examples of Nature Conservation Policy and relation to NB from a Mechanical, Divine and Organic View. In each of the views it is assumed that the ecosystem is producing less and less biomass.

View	Nature conservation approach
Mechanical	<p>From a mechanical point of view, you would try to fix the ecosystem by analysing the ecosystem and developing a variety of models. A possible conclusion could be the introduction of a predator into the ecosystem that controls the herbivore population, the latter again controlling the primary production, hence the biomass production will increase. Another approach could be to genetically engineer one of the primary producing species to be more resistant against abiotic stress (Botkin, 1990, p. 131). The motive of this approach is that the biomass production and thereby the availability of natural resources will increase.</p> <p>This view developed from an anthropocentric point of view in which NB does not exist. Balance can arise but this balance is always human induced and does not occur <i>naturally</i>.</p>
Divine	<p>From a divine perspective it is most likely that you reach the conclusion that humans disturbed the ecosystem. By exploiting too many of the natural resources and removing them from the cycle, for example. Therefore a logical approach would be to stop humans from exploiting the system and let the ecosystem return to its natural harmonious state. The motive for this approach could be either anthropocentric, wanting to increase natural resource availability or giving the system time to recover and try a different, less intervening form of exploitation.</p> <p>This view developed from an anthropocentric point of view and in which NB does exist.</p> <p>Nature is in harmony and will return to its original state of balance if left undisturbed.</p>
Organic	<p>An organic view would apply different policy. From an organic point of view, you could also come to the conclusion the ecosystem is out of balance. However, this state of imbalance, if this would refer to decrease in natural resources, would not be labelled as 'bad' immediately. The causes would be researched and the ecosystem studied. Maybe the imbalance is due to a shift in species composition. An approach could be to do nothing, as long as not all the nutrients are exploited from the system. Change would be monitored, with a focus on system formation.</p> <p>This view developed from an ecocentric point of view in which NB does not exist. Because nature is ever-changing there is no returning to a certain <i>balanced</i> state.</p>

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We would like to stress that none of these views is intrinsically of higher quality than any of the other views. These views are merely used instrumentally within this research as a framework to be able to categorize texts and interviews. As for policy, there is not one view that is the most adequate strategy for conservation of a certain natural system. As nature itself is endlessly changing, so should policy (Berendse, 2016, p. 34; Botkin, 2012, p. 221).

3. Methods

3.1 Data collection

In total five books have been selected for analysis: three textbooks and two teacher guidebooks. This selection has been made to get a complete picture of all the books that are available for biology teachers in secondary education. The three textbooks that have been selected are: *Nectar*, *BiologievoorJou* and *10voorBiologie*. The two teacher guidebooks that are available for biology teachers in the Netherlands are: *Campbell Biology* and *Ecology: Learning and Educating*. These have also been selected because, besides previous textbook editions, the current textbooks are based upon the teacher guidebooks. Thus with this selection, we aim to be able to indicate possible discrepancies between the textbooks and the teacher guidebooks.

From the series of biology textbooks, the pre-university level (VWO in Dutch) and the fourth year of secondary school were selected. Within this year the pupils (16/17 years of age) are introduced to the discipline of ecology and sustainability as two separate chapters.

The most recent version of each of the textbooks has been selected. The chapters Ecology and the Environmental section have been selected plus the species evolution part from the Evolution chapter. The same selection of chapters applies for the teacher guides. The Evolution chapter is relevant to include to examine how the textbooks treat the evolution of groups and populations. The exact sections of each book that have been analysed can be found in appendix A.

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The total number of pages that have been analysed consisted of 362 images and 382 pages of which 102 pages were webpages. We have referred to all pages as textbooks, also *10voorBiologie* which is an online method. The images have been analysed with the same grid that has been used for the texts.

3.2 The textbook analysis

In order to analyse the texts and images we have developed a grid. The stages in development consisted of a pilot and coding of a sample of text by a second coder. Inconsistencies between the coders have been discussed after which some adjustments were made, for example removing entire categories. The total selection of texts has been analysed by the same researcher. The grid is based upon a design from Caravita (2008, p. 111).

The grid comprises three categories: *equilibria*, *disturbance* and *worldview*. The aim of the grid is to measure to which extent the textbook leans towards one of the worldviews. The other two categories are quantitative: the frequency of equilibria and disturbances are measured.

Within the first category, equilibria, the exact word count or a direct derivative of the word equilibrium, for example *equilibrium-point*, have been counted. Besides the word count has been monitored if the text mentioned a *stable* or a *dynamic* equilibrium. A stable equilibrium indicates that there is one equilibrium point, a dynamic equilibrium indicates that there are two or more point and the equilibrium could move from one point toward another. By measuring this additional information we hope to get a better indication of how equilibria are used within the texts.

The second category, disturbance, needs some elaboration. By stating that something can be disturbed it is implied that there is a *steady state*, only something that is stable can be disturbed. We also assume that it is implied that this steady state is preferred above other

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states of, for example, imbalance. This category only gets a positive scoring if the disturbance is mentioned in relation to a population or the entire ecosystem. We have also monitored if the reference was regarded as due to human influence. By doing this the level of anthropocentric or ecocentric thinking can be measured. If the majority of all disturbances are caused by humans, we can conclude that the textbook is reasoning from an anthropocentric point of view and vice versa.

The third category, worldview, has been explained in the theoretical background. We have given some examples of how each of the three worldviews could occur in the texts:

(1) examples of mechanical references: a change in the DNA of an organism, introduction of a natural enemy, calculations of maximum sustainable yield, calculations of carrying capacity or other calculations with exact numbers;

(2) examples of divine references: separate humans and nature, place boundaries, give nature a holy status in order to protect it;

(3) examples of organic references: consciously let an ecosystem change, refer to dynamics aspects of nature, accept imbalance as part of nature, refer to extreme death events.

Do note that a section of text may get multiple scorings in the worldview category. Unlike the other two categories, the worldview category is not mutually exclusive. We chose this method since we want to capture to which extent the textbooks lean towards one of the worldviews. If we made the category mutually exclusive we would lose some of the nuance in the texts.

3.3 Examples of scoring

We have depicted an example of scoring with an actual example from one of the textbooks for each of the categories on the next two pages. All the examples originate from the same

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textbook, *10voorBiologie*, and are presented in italic. The original example which are in Dutch can be found in Appendix B.

The equilibrium category

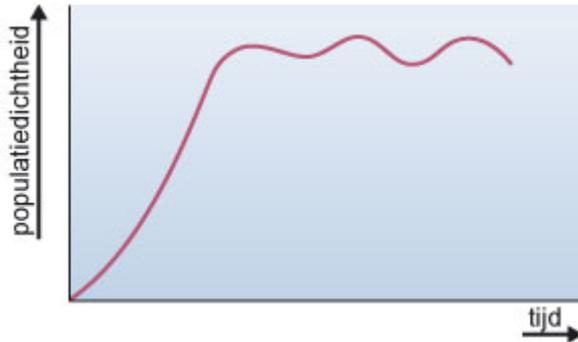


Figure 3. S-curve

After exponential growth an equilibrium arises (10voorBiologie, p. 23.4.3).

This section, figure 3 plus the description, has been scored as a *stable equilibrium*. Even though you see a fluctuating line in the end of the graph, the figure indicates that there is one state of population density which is fluctuating annually. This is confirmed by the text underneath the figure. The axes show *population density* on the y-axis and *time* on the x-axis.

The disturbance category

If an invasive species reproduces exponentially, this has consequences for the ecosystem in which this takes place (10voorBiologie, p. 23.4.4).

The example above has been scored as a *non-human disturbance*. While the word *consequence* is neutral if applied in an academic text, we are convinced that in this context it is implying *negative consequences*, that is why we have chosen to attribute scoring in the *disturbance* category. We chose to score a non-human scoring, since the textbooks linguistically make a distinction between man and nature, and we assume this is the case when using the term 'species' as well. To be more specific, we assume that the term *species*

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are all the organisms apart from humans, which are referred to as 'humans'. In addition, humans are rarely referred to as invasive species.

The worldview category

An example: let's say a plant makes 5 grams of glucose in one day. The plant burns 3 grams a day, what remains is $5 - 3 = 2$ grams a day to invest in growth. These 2 grams are 'available' for the ecosystem, for example to be eaten. That is why we can call this productivity of the ecosystem: this is the net primary production per unit-area per year (10voorBiologie, p. 23.7.2).

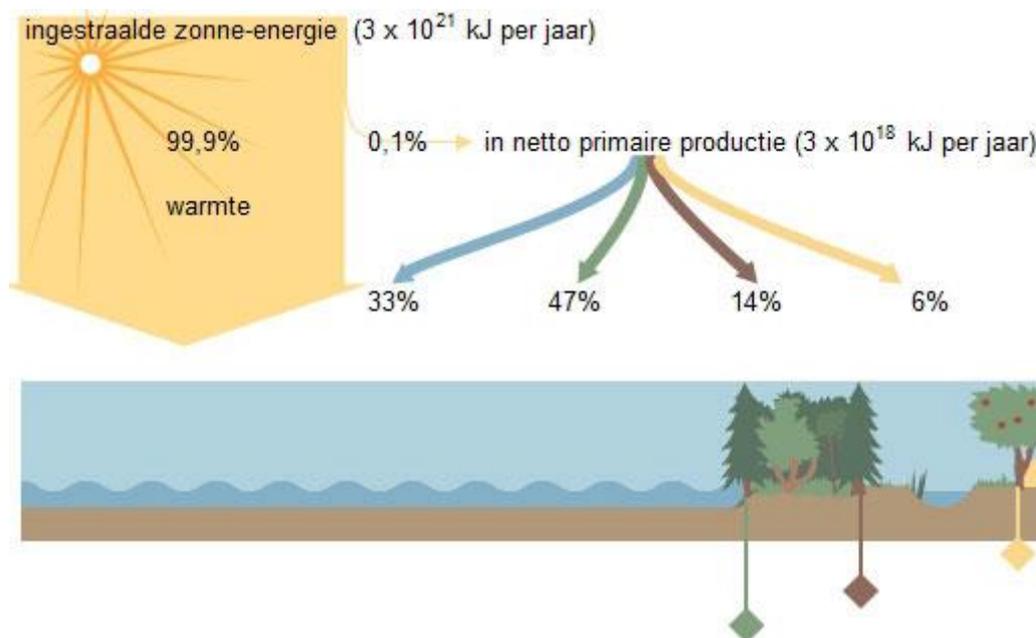


Figure 4. Net primary production.

The text above figure 4 has been scored as a *mechanical reference*. The assumption that we can study nature and come to exact numbers, is clearly present. The latter is one of the key elements of the mechanical worldview.

Figure 4 has been scored as a mechanical reference as well. Even though the figure is repeating what is written (the concept of net-primary-production) it gets an individual scoring. We are of the opinion that an image is a strong stimulus for pupils and each textbook can choose to substantiate a piece of text with an image or not. The consequence of this approach

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is that these pages weigh double in the textbook analysis. The words in the image from left to right can be translated as: *solar radiation*, *warmth* and *in net primary production (kJ a year)*.

3.4 Interviews

The interviews that have been held were structured one-to-one interviews. All interviews have been held by the same researcher and have been held according to Densombe's *The Good Research Guide* (2014, pp. 172-195). The aim of the interviews is to get more insight in the development of the textbooks and to see if the personal views of the editor or lack of knowledge regarding NB influences the content regarding this topic. To be able to do this the interviews have been analysed using the constant comparative method (Boeije, 2002). This method implies that all the questions of the three interviews are compared to one another. Each interview is also laid beside the research question of this article.

All the interviews have been held in the native language of the participants which is Dutch. All interviewees have been asked the same questions which are listed in appendix C (including a translation in English). A summary of the interviews is treated in the results (section 4.2).

3.5 Participants

The participants of the interviews consisted of lead editors directly involved in the editing of the ecology section. We chose lead editors and not writers of the texts because lead editors make the final decisions. In addition, they have the authority to return texts that they find insufficient or too subjective. Therefore the lead editors are considered to have the most influence on the content of the chapters.

The participants were not informed beforehand on all the topics of this research. The only information they got on this was that 'the research is about the way we look at nature'.

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The reason for this discretion is that information about the aims of this research could possibly influence their answers.

4. Results

4.1.1 *The textbooks analysis*

The most relevant results of the data analysis are shown below. (The complete data-set is stored at the servers of the University of Utrecht and available on request.) We have used abbreviations of the names of the books in the tables. For the textbooks, with the exception of Nectar (which remains Nectar), these are: 10vBio = 10voorBiologie and BvJ = BiologievoorJou. For the teacher guide these are: Eco L&O = Ecologie Leren & Onderwijzen and Campbell = Campbell Biology: Global edition.

4.1.2 *Equilibria*

In Table 2a the number of the times equilibrium is mentioned is shown for each of the textbooks. In Table 2b the number of the times equilibrium is mentioned is shown for each of teacher guidebooks. The percentage of stable equilibria (SE) is shown as well. All of the textbooks and teacher guidebooks mention equilibria multiple times. In All of the textbooks more than half of the cases refer to an SE.

Table 2a
Equilibria word count for each of the textbooks

Category	Textbook		
	Nectar	BvJ	10voorBio
equilibria	9	15	17
of which stable	90	73	53
(%)			

Table 2b
Equilibria word count for each of the teacher guidebooks

Category	Teacher guidebook	
	Campbell	Eco L&O
<i>N equilibria</i>	4	9
of which stable	75	22
(%)		

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In Table 3a an exemplary quote including the term equilibrium is shown for each of the textbooks. In Table 3b an exemplary quote including the term equilibrium is shown for each of the teacher guidebooks. The textbook 10voorBiologie mentions that the SE are theoretical and that you will not find this within nature. Both teacher guidebooks indicate that the term equilibrium belongs to a previous ecological paradigm. Within the teacher guidebooks is mentioned in every instance, in which the SE is mentioned, how it is currently in debate within the ecological scientific community and no longer considered to be true to nature.

An argument in favour of teaching something that is purely theoretical, is that it is taught for instrumental purposes. Even though the SE does not exist, the SE is used as a tool to be able to understand certain ecological phenomena. If it is applied in such a manner this should be clearly stated, as is done in 10vBio (see Table 4a.). Do note the term equilibrium is used several times in paragraphs of 10vBio, leading up to this statement.

We would like to add that it is hard to directly compare the textbooks to each other since the number of pages and images vary per textbook. However, it is each textbook's own choice to make the chapters that were selected for analysis as extensive as they would see fit. In general, the more important a textbook values a certain topic, the more pages are assigned to it.

Self-regulation is rarely mentioned by all books. To demonstrate how the textbooks and teacher guidebooks apply the term equilibria we made a table with an exemplary quote from each book (see Table 4a & Table 4b).

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Table 3a

Example of how the textbooks use the term equilibria.

Textbook	page	Quote from the textbook
Nectar	265	Predators are not always <u>the</u> solution for regulating equilibria .
BvJ	100	The result of this is that the density of the population oscillates around an equilibrium-point . The population is now situated in a biological equilibrium . So there is self-regulation within the ecosystem.
10vBio	23.8.4	However, a perfect biological equilibrium does not exist.

Table 3b

Example of how the teacher guidebooks use the term equilibria.

Teacher method	page	Quote from the teacher guidebook
Campbell	1294	Decades ago, most ecologists favoured the traditional view that biological communities are at equilibrium , a more or less stable balance, unless seriously disturbed by human activities.
Eco L&O	69	There are also terms that are not used within ecology anymore, while amateurs and therefor also pupils think they are a part of the core of ecology, for example ' natural equilibrium '.

4.1.3 The textbooks analysis – disturbance

Table 4a shows how frequent disturbance references have been made for each of the textbooks. Table 4b shows how frequent disturbance references have been made for each of the teacher guidebooks. The percentage of disturbances due to human influence is shown as well. Disturbances have been mentioned more frequently and multiple times by each book. In all of the books at least two fifths of the disturbances have been assigned to human causes.

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The difference in quantity between Table 2a and Table 2b and the difference in quantity between Table 4a and Table 4b can be explained as follows: disturbance is a more broadly applicable term than equilibria. In addition, not the word count but disturbance *references* were monitored. To elaborate, this means that not only the literal word ‘disturbance’ has been counted but also other texts or sentences that describe forms of disturbance.

Table 4a
Number of disturbance references for each of the textbooks

Category	Textbook		
	Nectar	BvJ	10voorBio
disturbance	18	29	42
of which human (%)	56	48	94

Table 4b
Number of disturbance references for each of the teacher guidebooks

Category	Teacher guidebook	
	Campbell	Eco L&O
disturbance	46	8
of which human (%)	43	88

We are of opinion that a possible consequence of these percentages of human disturbance, is that pupils get the impression that the stability of nature is dependent on humans. In reality, it is the other way around. The human race is extremely dependent on nature; without plants we die. The opposite is not true. Not only do plants provide us with oxygen, they provide us with food and shelter.¹ We have labelled this misconception *reversed dependency* and have elaborated on this phenomenon in the discussion.

¹ Some theories state we are not able to develop psychologically healthy without sufficient nature, in the form of plants and trees in our environment (Krcmarová, 2009).

4.1.4 Worldviews

Table 5a shows what the percentage of mechanical references taken from the total number of worldview references for each of the textbooks is. Table 5b shows what the percentage of mechanical references is taken from the total number of worldview references for each of the teacher guidebooks.

Table 5a

The percentage of mechanical references for each of the textbooks

Textbook	Mechanical references (%)
BvJ	79
Nectar	93
10voorBio	89

Table 5b

The percentage of mechanical references for each of the teacher guidebooks

Teacher guidebooks	Mechanical references (%)
Campbell	100
Eco L&O	98

4.2 The interviews

In this following paragraph we will present a summary of the three interviews with the participants, the lead editors of the textbooks. The majority of questions had similar responses (a list of all the questions is available in appendix C). The questions that were related to worldview of the textbook had more diverse responses. First, we will present the questions which had similar responses and second, the questions with inconsistencies between the answers.

All editors had a hard time defining nature and/or related terminology. A hard time can be defined as taking more than 30 seconds to begin formulating an answer. In reply to the question *if their textbook makes a bifurcation between man and nature?* all of the participants replied affirmatively. When asked *why?* all the participants gave answers with similar key-aspects: due to practicality, to create overview for the pupils.

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Two out of the three participants replied they believed in the concept of NB. When the participants were asked more precisely about equilibria and the nature of regulation they replied these were maintained by humans. This does not fit in the *natural* balance paradigm as we have defined it within this article. A possible explanation is that the concept of NB was not explained clearly enough. Another explanation could be that the participants had inconsistencies in their personal theoretical framework. When the participants were asked *if they believed NB will occur between the large mammals of the OVP?* the reply was unanimously negative. The latter would substantiate the inconsistent framework explanation.

To get insight in the personal worldview of the lead editors, several questions have been asked that could have either have had a mechanical, a divine or an organic response. The editors gave a variety of positive answers at least once for all of the three worldviews. In reply to the question *if we are able to solve every ecological crisis heading our way?* two out of three participants answered negatively. We regard this as an *organic* response and a negative response in regard to the mechanical worldview.

We consider an answer which involves the maintaining of equilibria, like in the previous paragraph mentioning NB, a mechanical answer in relation to worldviews. One participant has replied positively to a divine worldview as well, in a question regarding nature conservation approaches.

5. Discussion

5.1 Answering the research question

To repeat the research questions that have been formulated:

Do Dutch biology textbooks portray nature as in a state of natural balance characterized by stable equilibria, self-regulation and disturbance?

What is the dominant worldview from which the textbook is approaching the concept of nature and what are the consequences of this approach for how nature is portrayed?

We have given answers to the research question of this article in three parts:

- stable equilibria and the concept of natural balance are still present within the textbooks
- the mechanic worldview is dominant in all books
- the concept of nature is defined as uninfluenced by humans, excluding the species of humans from the concept of nature as well. We call this a dualistic conception of nature.

In the following paragraphs we will discuss each of the findings of this research in the order in which they have just been presented. We have attempted to explain each of the findings in three aspects: the reason of existence, the potential risks involved and a possible solution and/or alternative. After the worldview section we also discuss the results of the *disturbance* results and *reversed dependency*. In regard to the third finding, even though we stated the definition of nature dualistically in the introduction of this article ourselves, we would like to pay attention to several risks that involve applying this dualistic definition. We end this article with an advice for the lead editors and for biology teachers. We consider the lead editors to be inadequately informed about the latest scientific consensus regarding equilibria and natural balance.

5.2 Equilibria

Stable equilibria are still taught up until this day within Dutch secondary biology education. Even though these equilibria never seem to occur within nature itself. The question remains, why teach something that does not exist in reality? Two possible answers could be: (1) as a tool, used purely instrumentally and (2) as a perished paradigm. The first reason could be insightful for pupils, picturing a system in balance makes it easier to realise what would bring the system out of balance. In this case it has to be absolutely clear that we are speaking of a theoretical situation, which only one textbook *10voorBiologie*, did.

The second reason could be insightful for pupils as well, as many educators have shown the value of analysing perished paradigms. By retaking thinking steps of researchers in the past pupils could get a better insight in the process of science. In addition, by being conscious that there have been many wrong or naive paradigms in the past, pupils can become aware that truth is a social construct. At this moment both teacher guidebooks but none of the textbooks are applying it in this manner (see Table 3a & 3b).

We can speculate about the discrepancy in appliance of the term equilibria in the textbooks and in the teacher guidebooks. We came to think of two explanation for this phenomenon. The first explanation is that the teacher guidebooks, as expected, are clearly better up to date to the latest scientific consensus. The second conclusion is that there is some nuance lost in the translation from teacher guidebooks to textbooks. Some of the lead editors informed us that the teacher guidebooks are used as a source when designing the textbooks.

We are of opinion that to keep teaching about (stable) equilibria and about the theory of evolution is inconsistent. If you want to transfer the fact that nature is dynamic and constantly changing you cannot keep teaching ecological theories including equilibria. The same applies for self-regulation at the scale of ecosystems. *Equilibria* and *self-regulation* are

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such a contradiction to the theory of evolution that we propose to discard these terms. We solely propose to discard these two terms in relation to ecology and sustainability. We are not questioning the existence of self-regulation within organismic and cellular processes.

Removal of these two terms is only possible if the Endterms (the curriculum guidelines in the Netherlands) are revised thoroughly. In the Endterms of 2019 both equilibria and self-regulation are still mentioned frequently.

5.3 The mechanical worldview

The subject biology is presented as an exact science in secondary school. This goes hand in hand with the dominant worldview, the mechanical view found in the textbooks. As a consequence the concept of nature is also presented as exact. By doing this you might limit the pupils in approaching nature as closely as possible.

Botkin has described certain assumptions that accompany the mechanical view. The main assumption is our control over nature. A machine is predictable, timeless and we can adjust it according to our wishes (Botkin, 2012, pp. 140, 147). We have to ask ourselves if this is the right analogy in which to view nature. A lot of processes are for example irreversible or we cannot adjust them. As for predictability; we are not able to predict the weather accurately more than a week from now, the same applies for predicting the development of populations or entire ecosystems.

Botkin describes the shift from a static to a dynamic view of nature as a paradigm shift in ecology. According to Botkin the foundations of a discipline are strongly revised within a paradigm shift (2012, pp. 346, 347). This would mean the majority of ecological models will also need revision. Consequently, Botkin concludes, that relying on predicating models that still consist out of old-fashioned ecological theory and designing policy accordingly can be

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harmful for nature. We tend to agree. These models give a false sense of understanding of nature as well as control over nature.²

In addition, we consider forms of technocracy in which society believes it can resolve *every ecological crisis that is heading our way* is part of the mechanical worldview. Maybe society and biology education should dare to admit a bit more often than we are doing at this moment, that we do not understand a lot of processes taking place within nature, nor will we in the near future. As a result this will make us more cautious about the systems we are possibly destroying and bring back a sense of respect towards nature that we lost when we found our 'way out of the woods'.³

This does not mean you are not allowed to teach or do anything concerning nature conservation - to the contrary. Botkin (2012, p. xv) states: "Once we recognize the naturalness of many kinds of changes, then nature provides us with a metric to decide among them". Policy should be designed accordingly: adjustable and situation specific.

Consequently, this is something the sustainability chapters in the textbook should teach.

However, from a mechanical worldview it is often as if there is only one solution to a problem. With ecological problems and nature conservation this is rarely an adequate approach. Policy needs to be reevaluated and changed annually.

Increased global warming is partly a *political problem* besides a scientific one. The same applies to the OVP, which is now becoming more of a political debate, or even a philosophical debate, rather than an ecological one. By already introducing these themes in upper secondary school, we can teach pupils that many global ecological problems we are

² Charles Taylor describes the dominant mechanical worldview as making a "cost-benefit analysis" of every natural system in his essay *Ethics of Authenticity*. Taylor states this is a negative enterprise and typical for the decades since the industrial revolution. He calls this "the primacy of instrumental reason" (1992, p. 5).

³ Within risk assessment approaching a situation that one does not fully understand carefully is known as the Precautionary Principle (Sunstein, 2002). Within climate politics it is a common principle to refer to.

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facing today are not purely scientific problems but also of a political nature. These aims can be met by approaching ecological problems not solely from an exact science perspective, but from a social sciences/political perspective as well.

A final comment regarding worldviews: even if we are able to influence the majority of natural processes to our bidding, looking at nature from different perspectives will be valuable. Logically, the more perspectives, the broader and more creative the range of options to choose from will be. Therefore our suggestion is a win-win solution.

Reversed dependency

As we have shown in the disturbance results, more than half of all disturbances are attributed to human action. We are of opinion these numbers of disturbances attributed to humans combined with a dominant mechanical worldview could lead to a misconception which we labelled *reversed dependency*; the idea that nature is dependent on humans. One of the consequences of *reversed dependency* is that we promote anthropocentric thinking: thinking from a perspective in which humans are superior to other beings. Literature has shown it is easy to project anthropocentric thinking on the world around us and hard to prevent this (Kopnina, 2012; Cronon, 1996; Coley, 2015). Many pupils still believe that the world is created to suit their needs or can be forced to do so. Of course this is not the case, we are merely one of thousands and thousands of species which are inhabiting this planet.

Instead of promoting reversed dependency and anthropocentric thinking we are convinced we should be doing the exact opposite: promote ecocentric thinking. There should be more reasoning from a nature-centered point of view. Especially within the subject of biology it is important that we aim at stimulating ecocentric thinking in the pupils. Since the frequency of ecological crises will, most likely, continue to grow, it is important to teach to look at nature from different perspectives. Pupils should be stimulated to think outside of the

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anthropocentric box. That is why it is important that pupils become aware of the worldview from which they are reasoning. Without being aware of your worldview you will never be able to leave your dominant worldview (and the projections that accompany it). If we are aiming at science to be performed as objectively as possible, it is important that we will be able to discuss these views in class.

A solution to prevent solely anthropocentric thinking within biology education could be focussing on process formation instead of on the seemingly, static result. We define process formation in a biology context as follows: the natural aspects that make a functioning system and the development of these aspects within nature. By approaching natural systems from a process formation perspective it hopefully becomes clear how long it took for these systems to develop, that there are many alternative systems that could have developed and that this process is still ongoing and will never stop.

Another part of a solution to promote ecocentric thinking could be to teach the pupils to think on larger timescales than their own lifespan. A basic course of the natural history of the past billion years could aid this process. Some consider natural history as the basis for ecology (McComas, 2002). By showing the plasticity of nature and the different circumstances of, for example, gas ratios in the atmosphere, pupils will hopefully learn to ‘understand’ nature’s true form and even come to respect it more.

5.4 Dualism

An unexpected finding of this research is the dualistic definition that is applied within all of the textbooks and other ecological as well. We are aware of the fact that we chose to apply the dualistic definition in this article. The reasons for this were pragmatic, all other texts hitherto did so, so to prevent linguistical confusion we chose to copy the exact definition. To repeat the definition of the Oxford English Dictionary: ‘The phenomena of the physical world

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collectively, including plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creations''. We would like to point out the dangers of applying this dualistic definition of the concept of nature.

Cronon (1996) points at the dangers of defining nature and excluding humans from the concept of nature: we create a dualism that is not there in reality and evade our moral responsibilities towards our surroundings. This is echoed by Lamb (1996), Schuyler (1999) and Singer (2009). In addition, from an educational perspective, when teaching the chapter evolution it becomes inconsistent to keep excluding man from nature.

Let us elaborate on the latter. By applying the dualistic definition, this inherently means that where nature is, humans are not. Or as Cronon (1996) states '... our very presence in nature represents its fall. The place where we are is the place where nature is not''. In the textbooks the concept of nature is never defined. By not stating the definition explicitly, it is a subtle, implicit value that is being conveyed to the pupils. In addition, excluding humans from the concept of nature in the Anthropocene seems an unwise thing to do.⁴

As for conservation of nature, the dualistic view of nature is problematic when designing or teaching nature conservation policy. The majority of policies would most likely aim to separate man and nature. (Since as Cronon (1996) argues the mere presence of man in nature would make it none existent.) Botkin has shown an example where this separation approach fails and even causes the collapse of the population that the approach was actually trying to conserve: the Elephants in Tsavo declined rapidly when a fence was put up around the entire area (2012, pp. 25-29). The same applies for the three populations of large herbivores in the OVP. Unable to move elsewhere a carnage occurred in one winter: in the

⁴ Officially this epoch is called the Heliocene, but more and more historians are pleading the Anthropocene might be a better classification (Harari, 2016, pp. 83-116; Zalasiewicz, 2015; Steffen, 2007).

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first few months of 2018 more than half of the population of Red Deer and about a third of both other herbivore populations died of starvation (NRC, 11-20-2018).

To come back to the OVP example, this sanctuary shows a lot of phenomena which we have underlined in this article, hence the symbolic role. To name a few: the OVP became more of political issue than a scientific/ecological one, separating man and nature did not bring forth a natural balance or conserve one of the species of large herbivores, and our predictions of the development of the populations in the area were inaccurate, which was not the case. The OVP is a classical modern-day example of our desire for wilderness and simultaneously our desire for control of nature. We want true nature, but not the death that univocally accompanies it, certainly not in the extreme quantities in which these are taking place in the OVP. However, as long as we are in control of the deaths, through controlled killing for example, hardly anybody complains. The yearly culling of wild pigs on the Veluwe in the Netherlands is an example of the latter, as well as, all the other sanctuaries in Europe where yearly culling is accepted as a necessary measure⁵.

6. Conclusion

Natural balance is still present in all of the biology textbooks that have been analysed in the form of stable equilibria. Only one of the textbooks mentioned that the stable equilibria will never be found in reality. Disturbance references are present in all of the books that have been analysed, of which over two fifths are attributed to have been caused by humans. Self-regulation has rarely been encountered in the textbooks. The mechanical worldview is the dominant view in all of the books that have been analysed. From the interviews with the lead editors we conclude that we do consider the participants to be insufficiently informed about the concept of natural balance.

⁵ The Białowieża Forest in Poland is the only exception sanctuary in Europe where no yearly culling is occurring.

7. Recommendations and future research

We advise the lead editors to get up to date with the latest scientific consensus. In addition we advise the lead editors to state a clear definition of the concept of nature at the introduction of each of the textbooks. This prevents certain values regarding the concept of nature being sent to the pupils implicitly.

That said, the lead editors turn to the Endterms as a main guide when designing the textbooks. The Endterms should be researched and possibly revised. We would like to advise teachers not to rely too strongly on the textbooks. As this research has shown, there are still several inconsistencies within the ecology and sustainability chapters of the textbooks. Therefore using a textbook as a sole source to prepare a lesson is bound to lead to misunderstandings among the pupils.

As for future research, we hope to have shown a clear portrait of the inconsistencies that are present in the current curriculum. As mentioned before, we have reason to believe that the Endterms should be researched and possibly revised.

Another assumption that we came across in relation to stability was a relation between complexity and stability. Some theories state that there is a positive correlation between complexity and stability. We noticed that this theory is now being stated as a fact within the educative material that was analysed, while it is heavily debated within the scientific community. Consequences of this assumption should be researched.

Since this study was focused on secondary education it would be interesting to do exactly the same study with the focus on education within the universities. Especially the ecology and evolution courses should be researched. Because *Campbell: Global Edition* is still mandatory for all biology students, the data from this research can be used.

8. Conflict of interests

The authors see no conflict of interests

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References

- Berendse, F. (2016). *Wilde apen: Natuurbescherming in Nederland*. Zeist: KNNV Uitgeverij. doi:ISBN 978-90-5011-597-7
- Berryman, A. A. (1992). The Orgins and Evolution of Predator-Prey Theory. *Ecology*, 1530-1535.
- Boeije, H. (2002). A purposeful approach to the constant comparative method in the analysis of qualitative interviews. *Quality and quantity*.
- Boeije, H. (2002). A purposeful approach to the constant comparative method in the analysis of qualitative interviews. *Quality and quantity*, 36(4), 391-409.
- Botkin, D. B. (1990). *Discordant Harmonies*.
- Botkin, D. B. (2012). *The Moon in the Nautilus Shell: Discordant Harmonies Reconsidered*. Oxford University Press.
- Budiansky, S. (1995) Chaos in Eden, *New Scientist*, 33-35.
- Butler, J. M. (2015). An investigation into the prevalence of ecological misconceptions in upper secondary students and implications for pre-service teacher education. . *European Journal of Teacher Education*, 38(3), 300-319.
- Chiappetta, E. L. (2007). Analysis of five high school biology textbooks used in the United States for inclusion of the nature of science. *International Journal of Science Education*, 29(15), 1847-1868.
- Coley, J. D. (2015). Relations between intuitive biological thinking and biological misconceptions in biology majors and nonmajors. *Life Sciences Education*.
- Cronon, W. (1996). The trouble with wilderness: or, getting back to the wrong nature. *Envrionmental history*, 7-28.
- Dawkins, R. (1979). Twelve misunderstandings of kin selection. *Zeitschrift für Tierpsychologie*, 51(2), 184-200.
- Denscombe, M. (2014). Interviews. In Denscombe, *The good research guide: for small-scale social research projects* (pp. 172-195). UK: McGraw-Hill Education.
- Gough, N. (1993). Environmental education, narrative complexity and postmodern science/fiction. *International Journal of Science Education*, 15(5), 607-625.
- Hamilton, A. J. (2005). SLAC: A tool for addressing chaos in the ecology classroom. *International Journal of Mathematical Education in Science and Technology*, 36(5), 489-496.
- Harari, Y. N. (2016). *Homo Deus: A brief history of tomorrow*. Random House.
- Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual review of ecology and systematics*, 1-23.
- Kopnina, H. (2012). Education for sustainable development (ESD): the turn away from 'environment'in environmental education? *Environmental Education Research*.
- Krcmarová, J. (2009). Wilson concept of biophilia and the environmental movement and the USA. Klaudyán. *Internet Journal of Historic Geography and Environmental History*.

NATURAL BALANCE IN SECONDARY BIOLOGY EDUCATION

- Kricher, J. (2009). *the Balance of Nature*. Princeton University Press.
- Lamb, K. L. (1996). The problem of defining nature first: A philosophical critique of environmental ethics. *The Social Science Journal*.
- Leopold, A. (1970). A sand county almanac: With other essays on conservation from Round River. . *Outdoor Essays & Reflections*.
- Lotka, A. J. (1925). *Elements of Physical Biology*. Williams and Wilkins, Baltimore, Md.
- McComas, W. (2002). The ideal environmental science curriculum: I. history, rationales, misconceptions & standards. *The American Biology Teacher*, 665-672.
- Naess, A. (1973). The shallow and the deep, long-range ecology movement. A summary. *Inquiry*, 16(1-4), 95-100.
- NRC, 11-20-2018, Oscar Vermeer, Oostvaardersplassen Besluit Afschieten Grote Grazers Niet Geschorst
- NRC, 10-12-2018, Arjen Schreuder, Afschieten edelherten Oostvaardersplassen Begint
- Orr, D. W. (1992). *Ecological literacy: Education and the transition to a postmodern world*. Suny Press.
- Ramnarain, U. D. (2016). An analysis of South African Grade 9 natural sciences textbooks for their representation of nature of science. *International Journal of Science Education*, 38(6), 922-933.
- Read, R. &. (2017). The Precautionary Principle Under Fire. *Environment: Science and Policy for Sustainable Development*, 59(5), 4-15.
- Schuyler, A. E. (1999). Defining nature and protecting rare plants. *Ecological Restoration*.
- Singer, P. (2009). Speciesism and moral status. *Metaphilosophy*, 40(3-4), 567-581.
- Sprugel, D. G. (1991). Disturbance, equilibrium, and environmental variability: what is 'natural'vegetation in a changing environment? *Biological Conservation*.
- Steffen, W. C. (2007). The Anthropocene: are humans now overwhelming the great forces of nature. *AMBIO: A Journal of the Human Environment*, 36(8), 614-621.
- Sunstein, C. R. (2002). Beyond the precautionary principle. *University of Pennsylvania Law Review*, 151, 1003.
- Taylor, C. (1992). *The ethics of authenticity*. Harvard University Press.
- Volterra, V. (1928). Variations and fluctuations of the number of individuals in animal species living together. *ICES Journal of Marine Science*, 3(1), 3-51.
- Williams, G. C. (2018). *Adaptation and natural selection: A critique of some current evolutionary thought (Vol. 61)*. Princeton university press.
- Zalasiewicz, J. W. (2015). When did the Anthropocene begin? A mid-twentieth century boundary level is stratigraphically optimal. *Quaternary International*, 383, 196-20.

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Definition 'nature' Oxford English dictionary, <https://en.oxforddictionaries.com/definition/nature>, visited 01-11-2018

Source Figure 1:

[https://en.wikipedia.org/wiki/Lotka%E2%80%93Volterra_equations#/media/File:Lotka-Volterra_model_\(1.1,_0.4,_0.4,_0.1\).png](https://en.wikipedia.org/wiki/Lotka%E2%80%93Volterra_equations#/media/File:Lotka-Volterra_model_(1.1,_0.4,_0.4,_0.1).png)

Endterms. (2019) Eindtermen. <https://www.examenblad.nl/examen/biologie-vwo-2/2019> visited - 01/10/2018

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