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Master thesis

Development and characteristics of applied ecology

Master in Applied Ecology

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Abstract

The science of applied ecology is lacking a general theory and a commonly acknowledged definition. Additionally, information about the development of applied ecology over the past years, the relation to other disciplines and the importance of applied ecology in different continents are scarce. This is problematic because applied ecology is confronted with growing problems and the society demands more and more that it fulfils its promise of solving practical problems related to the environment. In the past applied ecology regularly failed to keep this promise and is faced with the future challenge of eliminating this problem. Based on communication theory I assume that for a fruitful discussion about the future of applied ecology, the development and the understanding of ecology have to be clarified first to avoid to talk at cross.

Therefore, I conducted different qualitative and quantitative content analyses based on material from books and papers dealing with the subject of applied ecology or related disciplines to find out how applied ecology developed over time and what is understood under the term applied ecology.

I found out that applied ecology is a young and interdisciplinary oriented science. Its origin lays in the science of ecology and since the 1960s applied ecology developed from a discipline focussed on productivity and utilisation over conservation related topics to a stronger focus on social aspects today. Especially during the last 20 years the science field grew in North America and Europe.

Applied ecology wants to find solutions for real-world problems that can be of long- or short term dimension. It is concerned with ecological, economical and social problems that are connected to each other. The overall goal is to achieve harmony between humans and the environment. To do so, it wants to increase the understanding of the subject and then find solutions based in the information gained. For the implementation of the solution management plays an important role. However, people engaged in applied ecology seem to disagree about how strong the relation of applied ecology to management is and what exactly applied ecology should do to implement proposed solutions. My study shows that there is a c ommon pattern underlying applied ecology, but it also shows where ambiguities are that should be discussed and clarified in the future. It can be also used to give discussions about the challenges of applied ecology a common knowledge foundation.

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1. Introduction

Ecology is a young science, named and defined first in the year 1866 by Ernst Haeckel, a German zoologist (Egerton 2013). Egerton (2013) reprinted his definition of ecology which states that "by ecology, we mean the whole science of the relations of the organism to the environment including, in the broad sense, all the "conditions of existence. These are partly organic, partly inorganic in nature" (Haeckel 1866, p. 286–289, reprinted in Acot 1998, p. 703–706 and Egerton 2013, p. 226).
This definition and following others were too vague for Krebs (2009) who in the year 1972 defines ecology as "the scientific study of interactions that determine the distribution and abundance of organisms" (Krebs 2009, p. 5). But the core of ecology being interested in organism interactions or relationships between organisms seems to be a common part of definition approaches (Krebs 2009).

The question of how useful this new science is for the society was still existent in the end of the 20th century (Kingsland 2005) and this question is also brought up by Caldwell expressing a "widespread scepticism concerning the practical value of ecological concepts" (Caldwell 1966, p. 524). That ecology is missing a general theory (Slobodkin 1988; Beeby 1993) does not seem helpful in illustrating why its concepts can be useful to society.

Regardless, a new research field called applied ecology developed that aims to use this ecological knowledge in a practical way "to solve both daily and long-term problems" (Douglas 1974, p. 14). This science field was not just lacking a general theory (Slobodkin 1988; Beeby 1993), it is described as an intractable science because "it is called on to solve all types of real and conceivable problems about the interaction of organisms and their environment" (Slobodkin 1988, p. 338). This resulted – despite the described scepticism of society regarding the usefulness of ecological concepts – in applied ecology being held responsible more and more for finding solutions for environmental problems (Thomas & Blanford 1999) even though there might be no solution – at least not a quick one, satisfying all social needs – available (Slobodkin 1988).

But next to the contradiction of doubting the usefulness of ecological concepts for practical problems and the growing wish for applied ecology to use those concepts to solve practical problems there is another contradictory aspect in play, namely applied ecology being viewed

from some people – especially researchers – as less important than pure ecology (Thomas & Blanford 1999; Memmott *et al.* 2010). This is related to the publishing industry because pure ecology science, as the non-applied part of ecology, has generally a higher chance of being published in journals with the highest impact factors, whereas publishing is not even necessarily the main goal of applied ecological research (Thomas & Blanford 1999; Memmott *et al.* 2010).

So applied ecology can be characterised as a young scientific discipline without a general underlying theory that is trying to solve practical problems with concepts which usefulness is doubted, but that is still expected to solve exactly these problems.

And the problems in question have never been bigger (Thomas & Blanford 1999). Applied ecology is confronted with a big range of problems, going from species extinction over global climate change to pollution (Ambasht & Ambasht 2002), over problems resulting from human population increase to the problem of resource depletion (Hinckley 1976). And it is faced with the problem that it cannot meet its own demands: Applied ecology seems to fail at least partly in providing solutions that are actually implemented in practice (Milner-Gulland *et al.* 2012).
Comparing different sources, the opinion on how huge the dimension of this problem is seems to differ, but to ensure implementation seems to be a generally acknowledged challenge (Freckleton *et al.* 2005; Memmott *et al.* 2010; Hulme 2011; Milner-Gulland et al. 2012).

Consequently, applied ecology is confronted with huge future challenges. These challenges were discussed in a meeting of leading experts in the field of applied ecology – amongst others E. J. Milner-Gulland and C. J. Krebs – taking place in Hedmark University College, Campus Evenstad on 14th October 2014. The panel members illustrated amongst other challenges the increasing problem of applied ecology researchers to get funding and the challenge of making sure that applied ecology has real-world impact was brought up. Increasing real-world impact and thus increasing the social benefit of applied ecological research was also mentioned as a likely important factor for possible sponsors.
The absence of an acknowledged definition of applied ecology was mentioned and one definition was proposed and commented on. Through the comments it became apparent that there does not seem to be a clear shared perception of what applied ecology actually is. This

might also be one reason for the various opinions on how the future of applied ecology should look like.

Discussing the future of applied ecology might be easier if a common understanding of the origins of applied ecology, its development and the current characteristics of the science would exist. We know from social science that even if humans agree on certain problems, if they disagree in their beliefs about their causation, conflicts occur and research is needed to provide a common knowledge basis (Holling 1997). These conflicts are likely to occur in the discussion about challenges of applied ecology because even if all researchers agree that not having real-world impact is a problem, the discussion of the reasons for it might be blurred. When it is not clear what applied ecology actually is, it might be also not clear what applied ecology is responsible for when tackling the problem, how it should do research to increase real-world impact and in how far it is involved in implementing the results found. So how the problem is perceived can differ without the researchers realising that this could occur because there is no common theory explaining what applied ecology is actually about – thus, they do not realise that they talk about different things when they say applied ecology.

We also know that "conservation and resource management problems cannot be solved without effective communication" (Jacobsen 2009, p. 2). This sentence seems true not just for external communication, but for internal communication within the field of applied ecology. For this to happen, the communicating people have to understand each other (Jacobsen 2009). So having a common understanding of the subject under discussion or at least understanding what the other person means by it is a prerequisite for communication to take place (Jacobsen 2009). Thus, making sure that everybody understands applied ecology in the same way or making clear where differences in the understanding lie, appears as important if not necessary for truly fruitful discussions leading to useful results to take place.

However, there is little literature explaining what applied ecology is and how it developed available (Douglas 1974; Egerton 1985) and the information existing appears to be distributed over the few available text books and articles.

Even though there is doubt that applied ecology will ever develop a general theory (Beeby 1993), the tractability of the science could be increased by a theoretical advance powerful enough to do so (Slobodkin 1988). And as different as the topics applied ecology is dealing

with might be, clarifying basic aspects like what these different topics actually are and if they maybe have something in common that would help to get a clear overview about the existing variety might be useful to identify common denominators of applied ecological science. Such common denominators put together might not lead to the development of a complete applied ecological theory, but it might be one way of coming closer to it. Accumulating and structuring the information about the characteristics of applied ecology already out there might be a first step to an extensive overview about what characterises applied ecology as a scientific discipline. Taking the development of applied ecology in the past into account is part of this because it shows how applied ecology changed over time which might help to understand applied ecology's current situation and its future development. Already Confucius (551 BC - 479 BC) said that who wants to define the future should study the past (Confucius, translated by Kubin 2011). Maybe we should still stick to that today.
Through searching for aspects of applied ecology researchers agree upon one might also be able to find aspects that are blurry or researchers disagree about. One might be also able to find topics or aspects of applied ecology that are blurry and undefined. If they can be considered applied ecology or how applied ecology deals with them is important for reaching the goal of environmental problem solving.

So in this thesis I want to work towards a common understanding of applied ecology by identifying general characteristics of the science and pointing out ambiguities to provide a common knowledge basis for the discussion about the challenges of applied ecology. I do this based on the belief that a common understanding of what applied ecology is and where it came from should help to develop a common understanding where applied ecology should be heading in the future.

While working on this goal I also want to look out for applied ecology's relation to other scientific disciplines because this information might be useful for explaining the development and characteristics of applied ecology. The same applies – in a more intrinsic way – for differences between applied ecology research conducted in different countries. Applied ecology research might be more important in some countries than in others or the topics of research might be different. That could be also reflected on continent level. To find information about this might help to explain the development and characteristics of applied ecology as well.

1.1 Research questions

The main goal of this thesis is to increase the understanding of two main topics:
-The understanding of the development of applied ecology and
-The understanding of the attributes characterizing the science applied ecology.
Trying to identify relations with other disciplines and differences between continents is part of both topics.

Consequential, the questions I tried to answer are the following:
1. How did applied ecology develop over time?
1.1. When did applied ecology develop?
1.2. Why did applied ecology develop?
1.3. From what did applied ecology develop?
1.4. How did the topics applied ecology is concerned with develop over time?
1.5. Is there a difference in the development of applied ecology between the continents?
1.6. How did applied ecology develop compared to related disciplines?

2. What are characteristics of applied ecology?
2.1. What are the problems applied ecology deals with?
2.2. What are the goals applied ecology is working towards to?
2.3. What tasks does applied ecology have to achieve its goals?
2.4 How is applied ecology defined?

3. How is applied ecology related to other disciplines and society?
3.1. Is applied ecology in contact with other disciplines?
3.2. Is applied ecology in contact with other groups of society (organisations, politics,…)?
3.3. What are the differences and similarities of applied ecology and related disciplines?
3.4. Is there a difference between the applied ecology research done in different continents?

2. Material and methods

2.1 Material and methods in general

2.1.1 Material

To answer these questions I decided to work with already existing text material of different forms. Because I wanted to choose material that gives me further information about different aspects of applied ecology I decided to work with books and papers that mention the issue of applied ecology. I collected the material of different forms with the help of the data base Web of Science (http://www.webofknowledge.com, last checked 01.10.2014) and in case of applied ecology related books I also used amazon versions from three different countries (www.amazon.de from Germany, www.amazon.co.uk from the United Kingdom and www.amazon.com from the United States of America, all last checked 01.10.2014). Snowball sampling with the help of reference lists from already obtained literature was also done.

How I conducted the literature search specifically, what kind of material I used exactly for different analysis and how I processed the material will be explained in more detail for every step of the analysis further below after the general explanation of methods.

2.1.2 Methods

For answering my research questions I processed different parts of my material in different ways, but all my analyses are different forms of content analyses. More specifically, I combine qualitative content analyses and quantitative content analyses to answer my research questions according to the content analysis technique of Mayring (2010). Before going into detail how exactly these analyses look like I would like to explain the differences of qualitative and quantitative content analysis and why I think it is appropriate to combine these methods here.

2.1.3 Excursion qualitative and quantitative content analysis

Quantitative and qualitative content analysis are two forms of literature analysis that both pursuit the goal of gaining knowledge by extracting information from different information sources, but how they want to gain this information is oppositional. Qualitative content analysis wants to capture the whole complexity of its study material and then search for general patterns in it. So this technique is adequate for complex material with a lot of different information. There does not have to be a lot of material because qualitative content analysis assumes that from analysing a small sample size in detail, the most central characteristics of the subject matter can be inferred (Mayring 2010).
Quantitative content analysis is chosen when there is more material, but it is not that complex respectively the researcher is just interested in a specific part of it. Thus, bigger material parts can be analysed at once, but it does not allow to go as much into detail as it is possible with qualitative content analysis, respectively even if the material would allow a detailed analysis, the amount of the material would not allow it because of effectivity reasons (Mayring 2010, Rössler 2010). Additionally, with quantitative content analysis the researcher has to know already quite specifically in what aspect of the subject he is interested in, with qualitative content analysis one can start with asking a broad research question and take in all the information provided by the material, not just the one the researcher knew about at the beginning of the analysis process (Mayring 2010; Rössler 2010).

Content analysis after Mayring (2010)
Content analysis – if qualitative or quantitative – is a commonly used technique in social sciences (Mayring 2010; Rössler 2010) and Mayring's method is just one way of doing it. But over the past 25 years this interpretation technique has proved itself in empiric social science especially for doing qualitative content analysis in a structured and comprehensible way (Steigleder 2008).

Mayring (2010) is searching for a way to overcome the conflict between both schools of thoughts and also points out that in content analysis, both methods are actually already combined since also in a quantitative content analysis, the first step is to name what you want to look for in the material which often also includes the definition of some kind of

category system. These steps are of qualitative nature, so the headstone of quantitative research is a qualitative analysis step (Mayring 2010).

In recognising the connection of qualitative and quantitative content analysis and realising the right to exist of both of them, they can be consciously combined in a content analysis for the profit of the research outcome (Mayring 2010) as I tried to do in my thesis.

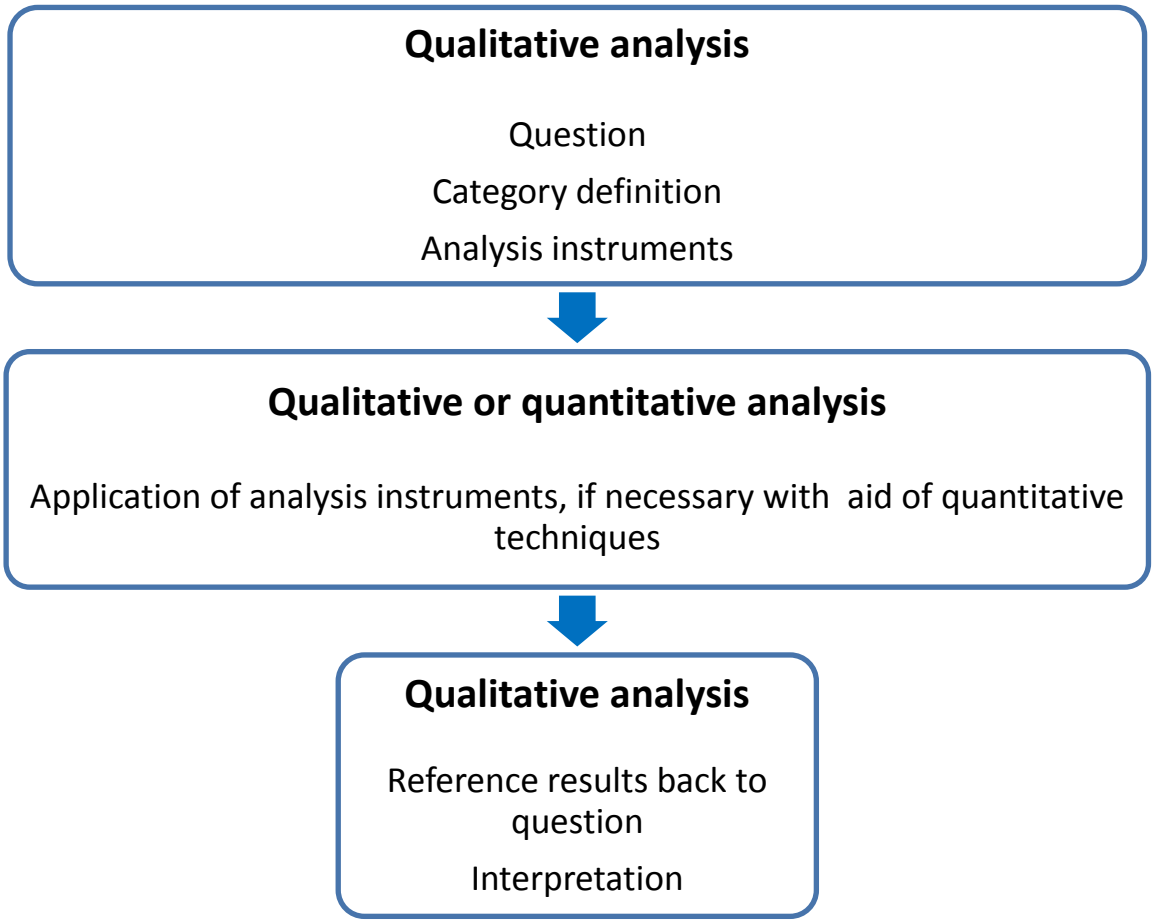

Fig. 1. Phase model for relation of qualitative and quantitative analysis after Mayring (2010)

My different analysis steps are oriented on the above scheme. While analysing it is especially important for Mayring (2010) to keep the analysis intersubjectively comprehensible. Through this, it is possible to tackle the problem that in qualitative content analysis an objective analysis is impossible especially working with complex material. Because we all think differently, we interpret material differently. Therefore, we have to at least document our analysis steps thoroughly, so other researcher can understand what we did and intersubjectively comprehend it (Mayring 2010).

For doing such an analysis after Mayring (2010) certain aspects of the documentation are especially important. Following I want to summarise the most important steps.

Material

The researcher has to document what material type he or she is using (interview transcripts, books,…) and how he acquired the material. Additionally, he or she needs to define in what part of the material content exactly he or she is interested in (plain text information, emotions expressed by the author of the material that can be inferred,…) and what part of the material is seen as one analysis unit (single words, sentences, sentences with their context,…).

Analysis

The researcher must define what kind of analysis he or she wants to conduct. There are three basic analysis techniques: Summary, explication and structuring. When doing a summary one want to create a manageable corpus of information that is still representing the basic content of the original material. When explicating, one wants to find additional information explaining an unclear material part. And when structuring, the goal of the analysis is to filter certain aspects out of the material or to apply certain criteria to the material to judge the material after those. All three methods can be freely combined.

Most content analyses contain the use of categories at certain points. There are deductive categories, meaning they are predefined, and inductive categories, meaning they are developed while doing the analysis. It has to be documented what information will be grouped into which category for which Mayring (2010) proposes to formulate a category definitions and give examples of representative material parts grouped into them. This can be done during the first cycle of the analysis and can be of help in the subsequent analysis cycles that are repeated until the researcher has grouped all relevant material and is convinced that the categories represent it.

The analysis itself has to be documented thoroughly. One way of doing this is to add a link number to every material part judged as necessary. When the material part is taken out of its context and grouped to one category, one has thereby the possibility to always go back to the original material. Adding a short summarising note about the content of the material part to

the link number can improve the understanding of why the material part has been grouped to one category (Mayring 2010).

In my analysis I try to do justice to those principles to make my analysis as intersubjectively comprehensible as possible.

2.2 Material and methods specific

2.2.1 Material and methods for analysis of development of applied ecology

2.2.2 Material and methods for specific development analysis

With this analysis step I wanted to gain information about the questions 1.1., 1.2., 1.3., 1.4. and 1.6.

2.2.3 Material

I decided to collect different written material about applied ecology and extract the knowledge provided about its history and evolution. For the material collection I used Web of Science (www.webofknowledge.com, last checked 01.10.2014) and searched for applied ecology – written in quotation marks – in the title of articles. I read the titles of the articles, kicked out the ones describing applied ecology in a specific context like mathematical modelling or pest programs and left in the ones describing applied ecology in a general context, in connection to problems or developments. After reading them I checked the list of references of the ones containing valuable information for additional interesting material. Additionally, I searched Web of Science (www.webofknowledge.com, last checked 01.10.2014) for books having applied ecology – written in quotation marks in the search engine – in the title. But to find additional material I also searched in amazon versions from three different countries (www.amazon.de from Germany, www.amazon.co.uk from the United Kingdom and www.amazon.com from the United States of America, all last checked 01.10.2014) after the same criteria and checked the first 50 results for books that include applied ecology in the title words. All books in which applied ecology was mentioned in the title as seemingly an important topic of the book, were the ones I chose. I looked through the

table of contents of the books and read the preface sections written by the author or the editors. After doing this, I decided that the preface sections and the introduction chapters – if available – seemed to contain the most valuable information of the whole book for my purpose. In appendix 1 you can find a list of the used material.

2.2.4 Methods

For doing this, I chose to work with qualitative content analysis first, to get an overview about the development of applied ecology that is as detailed as possible.
I formulated categories that would help me to group information systematically. The categories and their definitions can be found in appendix 2. The single sentences that were my analysis units were grouped with taking their context into account. If the context was necessary to understand why a sentence is judged as important, it was also taken into the category table.
I also wanted to create additional categories inductively when my categories would not take in information important to understand the development.

2.2.5 Material and methods for general development analysis

With this analysis step I wanted to gain information about the question 1.5.

2.2.6 Material

In this analysis I assumed that scientific articles that contain information about applied ecology or at least mention the term would be an indicator for the development of the importance of the science over time. So I used the title search of the data base Web of Science (www.webofknowledge.com, last checked 01.10.2014) to search in all articles in the data base for my material.
My goal was to get an overview over a long time span, but Web of Science often does not contain the abstracts and key words of old articles. And the topic search examines the title, the key words and the abstracts. That would reduce the chance of an article to be recognized when using the topic search. To avoid that this contorts my data I chose the title search.

The outcome was a frequency list of articles published from 1903 until 2010. I did not include younger articles because they do not seem to be completely loaded into the data base yet. In total I ended up with 114 articles.

2.2.7 Methods

The collected material was divided into continent affiliation according to the publishing country of the article's journal. Which countries were grouped to which continent can be seen in appendix 3.

Following, the data was plotted to be able to see and compare the development of the term applied ecology in article titles over time. Because I am interested in the general trend and not the fluctuations in certain years, I decided to group the data into five year periods, so one point on the graph represents the article number of five years, the next point moves one year forward and presents the next five year article accumulation etc. I additionally decided to show two graphs. The first one is based on the total amounts of the five year periods for the different continents. With the second one I want to balance for the different amounts of articles in the different continents to make the graphs more easily comparable. This, I divided the number of articles in one five year period of one continent by the total amount of articles published in the continent from 1904 until 2010. Here I added together all continent data that was not from Europe and North America because there was so little data available from these continents that building a percentage to compare them with North America and Europe would lead to contorted results. The chances of seeing a trend when putting the data together seemed larger.

2.2.8 Material and methods for analysis of definitions and characteristics of applied ecology

2.2.9 Material and methods for definition analysis

With this analysis step I wanted to gain information about the question 2.4.

2.2.10 Material

A definition is the accurate determination of a term through disassembly or explanation of its content (Duden 2010). I searched for such definitions of applied ecology and found two, one in a book and one in an article. Further information about the material I have read completely and did not find definitions can be found in appendix 1.

2.2.11 Methods

I compared the definitions I had to find similarities. This is in its basis a qualitative content analysis, but because the material amount was so small I did not use the documentation techniques I used for the bigger amounts of data.

2.2.12 Material and methods for characteristics analysis

With this analysis step I wanted to gain information about the questions 2.1., 2.2., 2.3., 3.1. and 3.2.

2.2.13 Material

For this step of the analysis I used the material from the books with applied ecology in the title. A list can be found in appendix 1.
I wanted to use books because I assumed that they would give me the most complete overview of applied ecological research in contrast to most papers just focussing on certain aspects of applied ecology. So by using the book material I would get an overview about applied ecological characteristics in a time-effective way.

2.2.14 Methods

To answer my research questions I did a qualitative content analysis. I wanted to use the material to answer a lot of my research questions, so I decided to approach some with inductive and some with deductive category formalisation.
For finding out about the relation of ecology to other disciplines and parts of society I formulated categories with the help of the information from the definition analysis and based on the research questions I wanted to answer. These categories can be found in appendix 4.
I did the same for finding out about the problems of applied ecology, their causation and the reasons they exist. But I added a second step of inductive category formulation to give the information a structure. These categories can be found in appendix 5, 6, and 7. Furthermore, I used these categories to look for even more general patterns of applied ecology problems by summarising categories based on their common attributes.
The categories of the analysis of the goals are based on the results of the problem analysis and can be found in appendix 8. For collecting the different tasks of applied ecology I made a list of all the sentences containing information about it and then formulated categories. They can be found in appendix 9.

2.2.15 Material and methods for analysis of applied ecology with other disciplines and between continents

2.2.16 Material and methods for development analysis of applied ecology in comparison with other disciplines

With this analysis step I wanted to gain information about the question 1.6.

2.2.17 Material

At this point of the analysis I wanted to work with material from journals that publish applied ecology, pure ecology and conservation biology science. The previous analysis showed that applied ecology originates from pure ecology and conservation biology shares with applied ecology an important research topic. So material from journals might help to examine if they develop comparably. I decided to use articles from the Journal of Applied

Ecology, published in the United Kingdom (http://www.britishecologicalsociety.org/publications/journals/, last checked 09.11.2014) and the Journal Ecological Applications, published in the United States of America (http://www.esajournals.org/, last checked 09.1102.14) as my material representing applied ecology research in Europe and North America. The mission statements of both journals fit to the characteristics of applied ecology that I found in my analysis steps before and are comparable to each other (http://www.journalofappliedecology.org/view/0/aimsAndScope.html, last checked 09.11.2014; http://esapubs.org/esapubs/journals/applications.htm, last checked 09.11.2014). The five year impact factors from the Journal Citation Reports are with 5.864 for the Journal of Applied Ecology and 5.150 for the journal Ecological Applications comparable, too (http://admin-apps.webofknowledge.com/JCR/JCR, last checked 09.11.2014)

Both journals had another advantage, namely that they the Journal of Applied Ecology shares a publisher with the Journal of Ecology and the Journal of Animal Ecology (http://www.britishecologicalsociety.org/publications/journals/, last checked 09.11.2014) and the journal Ecological Applications shares a publisher with a journal called Ecology (http://www.esajournals.org/, last checked 09.1102.14). The mission statements of the Journal of Ecology and the Journal of Animal Ecology taken together are comparable with the mission statement of Ecology http://www.journalofecology.org/view/0/aimsAndScope.html, last checked 09.11.2014; http://www.journalofanimalecology.org/view/0/aimsAndScope.html, last checked 09.11.2014; http://esapubs.org/esapubs/journals/ecology.htm, last checked 09.11.2014) as well as their five year impact factors with 6.477 for the Journal of Ecology, 5.435 for the Journal of Animal Ecology and 6.421 for Ecology (http://admin-apps.webofknowledge.com/JCR/JCR, last checked 09.11.2014).
This gives me an opportunity to compare how the publishers split between the research they publish as applied ecology and the one published as pure ecology.

The conservation journals I chose are Biological Conservation published in the United Kingdom (http://www.journals.elsevier.com/biological-conservation/, last checked 09.11.2014), with a five year impact factor of 4.703 (http://admin-apps.webofknowledge.com/JCR/JCR, last checked 09.11.2014) and Conservation Biology published in the United States of America

(http://onlinelibrary.wiley.com/journal/10.1111/%28ISSN%291523-1739, last checked 09.11.2014) with a five year impact factor of 5.427.
The mission statements of both journals are also comparable (http://www.journals.elsevier.com/biological-conservation/, last checked 09.11.2014; http://onlinelibrary.wiley.com/journal/10.1111/%28ISSN%291523-1739/homepage/ProductInformation.html, last checked 09.11.2014). Even though the journals do not have the same publishers than the other journal, I still want to use them because it seems the best opportunity to get an overview about differences and similarities between the sciences and the continents.

Web of Science (www.webofknowledge.com, last checked 01.10.2014) helped me to find my material and I took in all articles published in the journals between 1991 and 2010. I did not use older data because the journal Ecological Applications is just available from 1991 on.

Following, a table presenting the amount of material I worked with:

Tab. 1. Amounts of articles found in the named journals between 1991 and 2010 with the help of Web of Science (www.webofknowledge.com, last checked 01.10.2014).

Journal of Applied Ecology	Ecological Applications	Journal of Ecology and Journal of Animal Ecology	Ecology	Biological Conservation	Conservation Biology	Total amount of articles
2136	2661	3893	5475	4397	3318	21880

2.2.18 Methods

I joined the material of the Journal of Ecology and the Journal of Applied Ecology because they represent pure ecology research in Europe together. Then I divided the amount of articles published in a journal per year by the amount of articles published in a journal in total between 1991 and 2010 and plotted the data. This way, I was able to see the increase

and decrease of articles published in the different journals over time without having to take into account that some journals generally publish more articles than others.

2.2.19 Material and methods for characteristics analysis of applied ecology in comparison with other disciplines and between continents

With this analysis step I wanted to gain information about the questions 3.3. and 3.4.

2.2.20 Material

I decided to work basically with the same material than in the previous analysis step, but this time I wanted to use the words from the titles of the articles for my analysis. I still use the whole material from 1991 to 2010.

2.2.21 Methods

With the help of the program R (Version 3.1.1) and the tm package (further information in Feinerer 2014) I conducted a valence analysis. I wanted to find the ten most used terms in all the article titles for the different journal entities (Journal of Ecology and Journal of Animal Ecology were still analysed together). I chose to use ten terms because when plotting the term frequencies for the different journals, at the tenth word most curves are roundabout in the middle of their decrease phase.
For this analysis I modified my data to get more meaningful results by deleting all numbers, change upper cases to lower cases, delete quotation marks and punctuations, replace hyphens by a blank line and delete commonly used words like on, at and of with the help of the tm package. Additionally, I decided to stem the words, so they would be reduced to their word stem. This joins words with the same word stem, so words written in singular and plural, but also nouns, verbs and adjectives etc. if they have the same word base.

After these modifications I used the tm package to find out what the most used ten terms per journal entity were and transferred them to a table ranking the terms from the highest to the lowest frequency.

2.2.22 Material and methods for development analysis of applied ecology between continents

With this analysis step I wanted to gain information about the questions 3.3. and 3.4.

2.2.23 Material

The basic material is the same for this analysis step than for the previous one, but this time I just used the titles from the articles from the Journal of Applied Ecology and the journal Ecological Applications. I also just use the material from the periods 1991-1995 and 2006-2010.

2.2.24 Methods

The method used is basically the same than in the previous analysis because the goal of creating a list of the ten most important terms is the same and the process of compiling these lists is also the same. But this time I just use the applied ecology journals and I do not use the whole 20 year period available, but just the first five years and the last five years. Then I present the terms in a table to make them visually comparable.

3. Results

3.1 Development of applied ecology

3.1.1 Specific development analysis

When trying to gather written material concerned with the history of applied ecology one realises fast that there is not much material out there. Egerton notes that the "history of applied ecology has never before been comprehensively examined" (Egerton 1985, p.103). But the material available gave at least a rough picture of its development.

Before the formal organisation

Before there was an organized field of applied ecology, there were already people investigating applied ecological problems (Egerton 1985). Ecological knowledge was for example applied for practical purposes like plant production (Fernow 1903) and it led to the development of agriculture, fisheries, animal husbandry, medicines and other occupations (Ambasht & Ambasht 2003). Already in the 1880s there was research concerning the purity of drinking water going on that according to Egerton fits in the profile of applied ecological research (Egerton 1985).

Time of formal organisation

The time of applied ecology's formal organization varied from country to country in contrary to pure ecology which was formally organized in the turn of the 20th century (Egerton 1985). Applied ecology's formal organization followed later in Great Britain in the year 1949 after the government had established the Nature Conservancy, and in the U.S. after the National Environmental Policy Act was passed in 1969 (Egerton 1985). But Egerton assumes that applied ecology in the U.S. was not intellectually behind Great Britain (Egerton 1985). Also other sources put the development of applied ecology as a discipline chronologically behind pure or general ecology. Douglas (1974) describes that the focus in modern ecology was laying mainly on descriptive work meaning the recording of facts and

the description of relationships of organisms and their environment. He sees that as pure science because it is content to discover how nature works. But no attempt was made to translate the gained knowledge into practical actions from which humans could profit and that would make life on earth better (Douglas 1974). Here applied ecology comes in as the "tool that science is offering to individuals and nations so that they can arrest their dangerous courses and turn to restoration and conservation while there is still perhaps time to do so" (Douglas 1974, p. 24). Douglas also writes while describing the development of applied ecology that "one might almost say that ecologists have come down of their ivory towers and are mingling with the populace in order to place the knowledge accumulated at great effort and cost at disposal of every man, woman and child so that it can be used in practical ways to make life happier and give back to harassed and weary populations the goal of rehabilitated environment and harmony in their daily routine or surroundings" (Douglas 1974, p. 24). After the focus of ecological research lay on population and community analyses in the first part of the 20th century, the development in direction to applied ecological research grew from then on and according to Douglas (1974) in the 1970s most researcher place equal emphasis on pure and applied ecological research.

So ecology is not a discipline apart from the real world anymore, but through applied ecology available for everyone (Douglas 1974). It is different from the original form of ecology in that sense that it is interested in using the knowledge gained (Douglas 1974). However, how and for what the knowledge is used can vary and has varied over time (Douglas 1974).

Development of applied ecology over time

Reading Milner-Gulland *et al.* (2013) it seems that they see the development of applied ecology maybe a bit more pessimistic respectively slower than Douglas (1974) that assumes that in the 1970s ecologists saw pure and applied ecology as equally important. Milner-Gulland *et al.* (2013) – who base their knowledge about applied ecological research mainly on the research history of the Journal of Applied Ecology – state that in the 1960s applied ecology was the poor kinship of fundamental ecology which was viewed as more glamorous. The goals in this decade laid on improving productivity of especially agricultural ecosystems. For example a possible impact of agriculture on species conservation was indeed realised, but not further pursued yet (Milner-Gulland *et al.* 2013). Researchers also investigated possibilities for biocontrol in tomatoe root rot, estimations of carbon stock,

understanding effects of mycorrhiza on coffee or engaged in ways of measuring roots in a sample (Milner-Gulland *et al.* 2013). This shows that production of resources were a big topic and also the development of research techniques was important.
Ormerod (2003) sees the focus of applied ecology in the 1960s a bit wider. He states that applied ecology was about conservation, management, control, development and use of natural resources, at least according to the opinion of the Journal of Applied Ecology. Furthermore, he concludes that topics like the recovery and restoration of resources that were degraded by human usage in the past were less emphasised (Ormerod 2003). The importance of these topics grew stronger over the next 40 years until they got "implicit in the philosophy of applied ecology" (Ormerod 2003, p. 44) meaning they are part of the goals now.
Besides, in this post-WWII-period the numbers of ecology students grew and the support of scientific research, including pure and applied ecology research, grew, at least in the U.S. and Canada, too (Egerton 1985). These ecologists were facing industrialisation and pollution which created a wish for a better environment. That made them eager to use ecological knowledge to make contributions to the society concerning resource management (Egerton 1985).

Since the 1970s were a decade of expansion of agriculture and modernization, the concern about pests lowering crop productivity was high (Milner-Gulland *et al.* 2013). So the focus of applied ecological research lay on gathering missing basic information about pest species of economic relevance (Milner-Gulland *et al.* 2013) which fits to Egerton's (1985) statement that pest control is a major concern of applied ecology. So improving productivity was still one of the major goals (Milner-Gulland *et al.* 2013).

Also in the 1980s the main goal was not altered. Applied ecological research still focused on pest species in agriculture, but researchers now worked more with models of their population dynamics including information about the affected crops to predict possible damage from the pest species. Those models became more realistic in this decade. Applied ecologists also began to take into account species that might work as control agents of the pest species in their research (Milner-Gulland *et al.* 2013).

In the 1990s applied ecological research became wider because conservation started to play a stronger role. Consequences of agricultural management on biodiversity and nature conservation were supported by quantitative evidence (Milner-Gulland *et al.* 2013). The fact

that possible consequences have been realised already in the 1960s (Milner-Gulland *et al.* 2013) and that Douglas (1974) states that people started to realise the negative impact of humans on their environment and the necessity of conservation starting in the 1950s up to the 1970s indicates that the will of applied ecology to concern itself with such themes was there earlier. However, it seems it took some time to widen the goals of applied ecology to integrate conservation respectively to put this goal into practice. Ambasht & Ambasht (2002; 2003) also assume that two global conferences held by the United Nations on conservation and development in 1972 and 1992 with their focus on conservation issues were an important push for applied ecology. So it really seems that the importance of conservation rose already in the 1970s, but for Ambash and Ambash (2002; 2003) the conference in 1992 seems to be the more important date since they use both dates in their applied ecology book from 2002, but just the younger date in their other applied ecology book from 2003. The already mentioned growth of restoration ecology connected to the field of applied ecology from the 1960s to the 2000s (Ormerod 2003) also illustrated the slow process in direction to more importance of conservation.

In the 1990s the Journal of Applied Ecology also refocused on its main goals of which one is to make research useful for and available to management (Milner-Gulland *et al.* 2013). Since the Journal of Applied Ecology is an important publisher of applied ecological research (Milner-Gulland *et al.* 2013) this might also indicate a refocusing of applied ecology research in general, concentrating even more on its main goal of putting ecological knowledge into practice.

In the 2000s applied ecology went even more into the direction of conservation and focused on biodiversity studies (Milner-Gulland *et al.* 2013). Milner-Gulland *et al.* (2013) think that this development reflects the global interest on biodiversity conservation in landscapes that are more and more influenced by human activities. Still agriculture plays an important role in this growing topic, because now research is done with the goal of maintaining or enhancing biodiversity in agricultural landscapes (Milner-Gulland *et al.* 2013). Also the pressure of the public and funding agencies holds applied ecology accountable "in a time when the challenges in applied ecology have never been greater" (Thomas & Blanford 1999, p.71). In general, this is a decade marked by a "dramatic growth of applied ecological research" (Memmott *et al.* 2010). This observation is in line with the growth of the Journal of Applied Ecology in the first half of the decade described by Freckleton *et al.* (2005). They

also state that the impact factor of the journal has increased and that the submission of papers has doubled which they interpret as an increase in high-quality applied ecological papers (Freckleton *et al.* 2005). In any case, it illustrates the growth of the applied ecology research field. They also say that the interest in effects of climate change on ecosystems was rising especially in the mid of the 2000s and that they want to encourage more submissions to the Journal of Applied Ecology concerning the topic (Freckleton *et al.* 2005). Global change is connected to conservation, but also to the use of resources and seems to be a theme relevant for achieving the harmony Douglas (1974) was talking about, so its growing importance seems to fit applied ecology's profile.

In their book from 2014 Verdade, Lyra-Jorge & Piña, the editors, explain that "increasingly, applied ecologists include human actions as integral to the system they study and seek to characterize the relationship between human actions and biological responses" (Verdade, Lyra-Jorge & Piña 2014). They also state that humans are recognized as a major ecological factor modifying the environment for several decades, but studies about human dimensions lagged behind studies on wildlife and ecosystems (Verdade, Lyra-Jorge & Piña 2014). Addressing environmental challenges caused by humans and developing solutions to create the harmony between nature and people is not just the main target of applied ecology for Douglas (1974), but also for Verdade, Lyra-Jorge & Piña (2014).

General development over time

Milner-Gulland *et al.* (2013) summarise that there has been a major shift in focus in applied ecology over the last five decades. They underline this with stating that in Journal of Applied Ecology papers the use of terms like policy and conservation increased over the last decades and even new words like biodiversity popped up or increased strongly in use, like the term invasive did in the 1990s. Every journal article contains either the term policy, management or recommendation today. But agricultural terms like crop and pesticide decreased. Based on this they state that there was a strong focus on productive ecosystems, their management and potential economical gains through application of ecological knowledge in the early years of the Journal of Applied Ecology, but that the focus went away from those systems over the last years (Milner-Gulland *et al.* 2013).

To Milner-Gulland *et al.*'s (2013) summary of the development of applied ecology in the Journal of Applied Ecology fits the statement about the development of applied ecology that

de Pablo & de Agar (2005) give. They write that the formalisation of applied ecology – that could be also called the goals or main topics of it – changed from focus on nature use, development and the idea of unlimited resource consumption to a focus on limitation and the sustainable use of nature which is they see as the more complex and holistic concept (de Pablo & de Agar 2005). According to them, the current shape of applied ecology is concerned with how nature functions and with the goods, resources and services it provides, but it realises especially how much all of this depends on how nature is used by society (de Pablo & de Agar 2005). De Pablo & de Agar (2005) see the society as responsible for regulating the system and solving environmental problems which is for them part of the concept of applied ecology today. People are also a central part of applied ecology for Verdade, Lyra-Jorge & Piña (2014) who describe that viewing humans as an important factor in the study system becomes more common.

Development of applied ecology and other disciplines

Besides this description of the development of topics of applied ecology over time the authors also talk about the history of applied ecology connected to the history of other disciplines. It was already mentioned that applied ecology is related to pure or basic ecology (Milner-Gulland *et al.* 2013), that applied ecology seems to build up on and utilise the basic knowledge from pure ecology and that applied ecology achieved the same status then pure ecology over time (Douglas 1974). The connection to restoration ecology has already been mentioned, too, and that it developed in parts through and with applied ecology (Ormerod 2003). The development of urban ecology is also connected to applied ecology (Richter & Weiland 2012, Ormerod 2003). Egerton (1985) gives a whole list of related disciplines like wildlife management, public health and forestry developing with applied ecology, but he sees the applied ecological research more as part of the disciplines or calls their research applied ecological research, so it stays unclear if he sees applied ecology as part of the other disciplines, influencing them, or developing next to each other. Verdade, Lyra-Jorge & Piña (2014) write that the connection between social science research and applied ecology grew stronger over the years and should continue to grow. So applied ecology is a science that is influenced by and has influenced a whole bunch of other disciplines. But the exact relation to the other disciplines (sister disciplines, superior disciplines, sub-disciplines,…) is not clearly stated by the authors.

3.1.2 Summary

Applied ecology was formally organised in the late 1940s in Great Britain and in the late 1960s in the U.S. However, applied ecological problems were already examined before that time. It developed out of pure ecology research because ecology did not manage to make a use out if its research results for the society. So applied ecology took over this task.

It seems that applied ecology started out with focussing on productive ecosystems trying to improve the best way of using them. This was especially important in the 1960s. In the 1970s agricultural productivity was still a big topic and in the 1990s, too, just that the focus changed stronger on creating models. Conservation orientation was already in the 1960s a part of applied ecology's self-concept, but it took time until this was reflected in actual research projects in the 1990s. The 2000s focus even more on conservation, especially in the context of biodiversity. In the 2010s sources begin to mention the social aspect of applied ecology stronger than before, e.g. they focus on the connections of humans with their environment as an important part of applied ecology (de Pablo & de Agar 2005). That seems to fit to the "more complex and holistic [ideas, Ed.]" (de Pablo & de Agar 2005, p. 80) applied ecology promotes today. But the idea of living in harmony with nature is like conservation not a new one.

1.6. How did applied ecology develop compared to related disciplines?
How exactly the development of disciplines related to applied ecology takes place, but through the material it gets clear that applied ecology is influenced by and influences other science forms like pure ecology, restoration ecology and urban ecology.

3.1.3 General development analysis

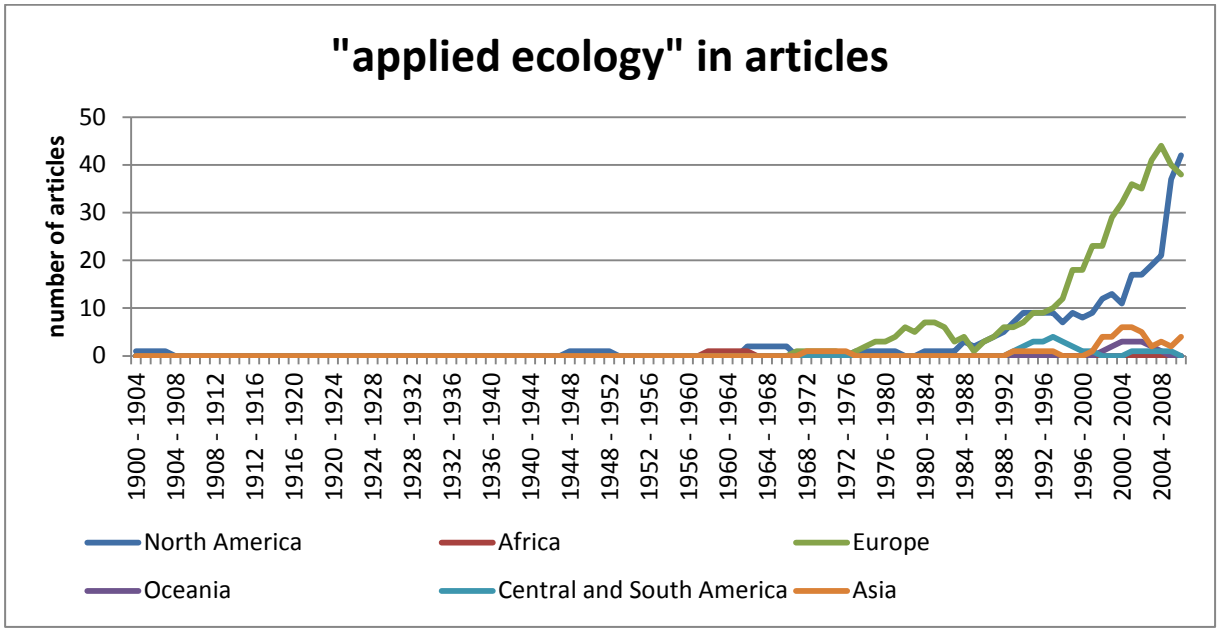

Fig. 2. Development of the amount of articles that have the term applied ecology in the title. The graph shows the article number in five year periods per continent from 1991-2010.

In this first graph we see that in Europe and North America there is an increase in the journals mentioning the term applied ecology.
In Europe, the first article that mentions applied ecology in the title is found in 1971. From then on we see an increase of the term. There is an increase and decrease phase from the late 1970s over the 1980s, but after that period the increase seems to be quite stable. The next decrease that is caused by more than one article less than in the five year period before can be observed in the late 2000s.

The development in North America is comparable to Europe in that sense that we see a general increase of the papers mentioning applied ecology. The first paper mentioning applied ecology is published already in 1903, but a real increase in numbers can be observed first in the late 1980s. First, the number of papers is comparable with Europe, but in the late 1990s more papers from Europe mentioning applied ecology can be found. This turns in the late 2000s.

From the other continents the number of papers is low so it is hard to draw conclusions from the development. The number of paper increased during the last two decades, but a clear uptrend is not detectable. In comparison to North America and Europe the paper numbers are still low.

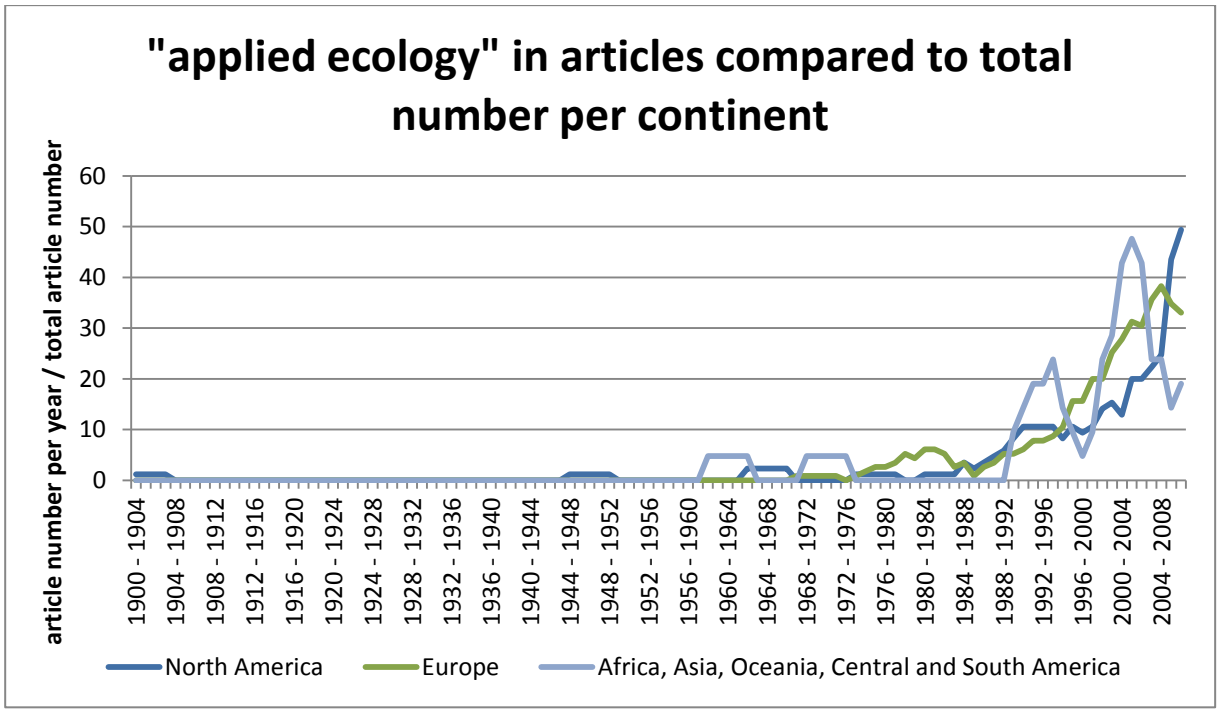

Fig. 3. Development of the amount of articles having the term applied ecology in the title. The graph shows the article number in five year periods per continent divided by the total article number per continent from 1991-2010.

Figure 3 shows the percentage of the total article number that was published on one continent between 1900 and 2010 in five year periods.
In North America and Europe we see a generally comparable increase of articles published compared to the total amount published in North America and Europe over the whole time interval. The article numbers published per five year period increase in Europe in the late 1970s, break down and rise again together with the article numbers in North America in the late 1980s. However, the increase of the papers in North America compared to Europe in the last half of the 2000s seems stronger than in Europe.

The development for the other continents does not look as consistent as in North America and Europe. There are two peaks around the beginning of the 1960s and the beginning of the

1970s, but the main increasing period starts a bit later than in North America and Europe at the beginning of the 1990s. In contrast to North America and Europe there is no steady increase, but strong increases with sudden breakdowns. But it can be summarised that from the beginning of the 1990s to the end of the 2000s the percentage of papers with the term applied ecology in it divided by the percentage of the total paper number in these continents between 1900 and 2010 increased in the titles of articles not published in Europe and North America.

3.1.4 Summary

Summarising the results from both analysis steps, it seems that the development of applied ecology is comparable between Europe and North America, but different in the other continents.
First of all, this is caused by the different amounts of titles with applied ecology in it because North America and Europe do not have a lot, but still more than the other continents.
Secondly, the amount of titles with the term applied ecology in it starts to rise in North America and Europe around the late 1980s, but in the other continents there are also more articles, but not a comparable continuous rise on a smaller scale.
The part of the analysis where I checked for the amount of papers published over time compared to the total amount published showed that in the other continents there is an increase of papers in the early 1990s, but fluctuations are quite high, so it is hard to say something more specific.

Comparing North America and Europe we see that in Europe the amount of papers with applied ecology in the title rises already in the late 1970s. Admittedly, it is followed by a period of decrease and paper numbers in North America and Europe rise together in the late 1980s, so the general development seems comparable. But the amount of articles published in Europe starts to be higher than in North America in absolute numbers which could be an indicator for applied ecology research to be bigger in Europe than in North America. However, in the end of the 2000s the use of the term decreases in Europe, so now applied ecology research might me at the same level in both countries.

The growth of applied ecology research in North America especially over the last decade can be also seen in figure 3. Compared to Europe, North America published in recent times a higher amount of articles with the term applied ecology in the title compared to the total amount of those articles published.

So inferred from these analysis steps, applied ecology research develops comparably in Europe and North America even though in North America there seems to be a stronger growth in the past years. The other continents do not publish as many articles as North America and Europe, so their development seems to be compared to those continents less distinctive. The development course itself is also hardly comparable, especially caused by the strong fluctuations of the amount of articles published between the five year periods compared to the total amount of articles published.

3.2 Definition and characteristics of applied ecology

3.2.1 Definitions of applied ecology

The two definitions I work with define applied ecology as follows:

"In applied ecology, which means simply the practical use of ecological knowledge, to solve both daily and long-term problems, we have the means of improving and maintaining all that we love best in the world around us" (Douglas 1974, p. 14)

and

"Applied ecology studies organisms of practical importance and attempts to use the theoretical insights and empirical concerns of academic ecology in the solution of specific problems of environmental management" (Slobodkin 1988, p. 337).

These definitions can be joined and summarised to combine the different aspects that they describe:

1) Applied ecology's basis is ecological knowledge respectively the knowledge accumulated by academic ecology.
2) Applied ecology studies organisms of practical importance.
3) Applied ecology uses the knowledge in a practical manner or in a context of management.
4) Applied ecology does these things to solve problems. These problems can have different time dimensions and they can be problems of environmental management.
5) Applied ecology is doing all that to fulfil certain goals. Those goals are connected to what humans appreciate in the environment.

3.2.2 Summary

Summarising the definitions of Douglas (1974) and Slobodkin (1988) applied ecology means the study of organisms and the use of ecological science to search for solutions for daily and

long-term problems especially of environmental management to improve and maintain the parts of our environment that we appreciate. Knowledge used and produced by an applied ecologist must be of practical relevance.

3.2.3 Characteristics of applied ecology

3.2.4 Applied ecology and other disciplines

3.2.5 Applied ecology and ecology

Ecology as the basis of applied ecology

Applied ecology bases its efforts to find solutions for problems on already existing ecological knowledge (Douglas 1974; Hayward 1976; Beeby 1993; Newman 2000; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003; Mc Pherson & De Stefano 2003; Richter & Weiland 2012; Verdade, Lyra-Jorge & Piña 2014). Several authors use a variety of different expressions to state that: Applied ecology is according to the authors concerned with the application of ecological concepts (Beeby 1993; Ambasht & Ambasht 2002), ecological ideas (Beeby 1993; Ambasht & Ambasht 2002), ecological knowledge (Douglas 1974; Ambasht & Ambasht 2003; Mc Pherson & De Stefano 2003; Verdade, Lyra-Jorge & Piña 2014), ecological principles (Douglas 1974; Hayward 1992; Beeby 1993; Mc Pherson & De Stefano 2003), ecological theory (Beeby 1993; Verdade, Lyra-Jorge & Piña 2014), ecological methods (Douglas 1974; Verdade, Lyra-Jorge & Piña 2014) or just plain ecological findings (Richter & Weiland 2012), and ecology (Hayward 1992; Ambasht & Ambasht 2003).

The relation of ecology and applied ecology

When applied ecology and theoretical ecology are both mentioned by the authors in the material, they separate between both subjects and talk about them as if they are sister disciplines (Douglas 1974; De Santo 1978; Beeby 1993, Newman 2000).

De Santo's (1978), for example, presents a figure with several different areas of specialisation and shows the most contrasting topics – like for example natural system opposed to manipulative system or clean opposed to polluted – next to each other. In this

scheme he also presents theoretical and applied ecology in this way, but also states that they are connected. Ecology is the term summarising the two sub-disciplines theoretical and applied ecology (De Santo 1978).

Douglas (1976) seems to follow the same structure. His overall-term that summarises sub-disciplines is called ecology, like seen here: “For the sake of convenience ecology is generally divided into a number of sub-divisions” (Douglas 1976, p. 21). However, De Santo (1978) describes that the difference between pure and applied ecology – which are the terms he uses – is not really counted as a simple sub-division, but as a broader concept not affected by any of the sub-divisions (Douglas 1976). He sees pure and applied ecology as two sides of one coin, meaning “a coin has two sides with different image on each one, just as ecology has two branches – pure ecology, which records facts and defines principles, and applied ecology which puts into practice the knowledge gained” (Douglas 1976, p. 23). That also illustrates that what Douglas (1976) calls pure ecology is the basis or the prerequisite for applied ecology for him.

No other author states the differentiation between applied ecology and theoretical or pure ecology so clearly, but since De Santo (1978) is not going into detail what he actually means by theoretical ecology we can just out of the context assume that both authors mean more or less the same with the two different terms. Other authors also separate between science that seem more of a theoretical, not so problem oriented nature and applied science. Like Newman (2000) who uses the words pure science and fundamental science like synonyms and states that “fundamental science is crucial to tackling these [applied science, Ed.] problems” (Newman 2000, p. 4). So there is also some kind of separation and the fundamental science is necessary for the applied one. Newman (2000) does not state it as clearly as Douglas (1976) and De Santo (1978), but the way he uses the term ecology implies that also for him it is a term aggregating pure and applied science.

Beeby (1993) uses the terms theoretical ecology and ecological theory in the same context and differentiates this from applied ecology and practical ecology which seems to be the same for him. He states that his book is about “the interface between theory and application, attempting to show how each can illuminate the other” (Beeby 1993, p. x). This shows that there can be not just an influence from theoretical to applied ecology, but the influence can also be the other way around.

For Ambasht & Ambasht applied ecological approaches are different from “classical theoretical ecology methods” (Ambasht & Ambasht 2002, p. x). This differentiation between the classical, potentially older method and the new applied ecological thinking can be also

found in Douglas, who also notes that in pure ecology "virtually no attempt was made to translate the facts observed or the discoveries made into practical actions which could result in identifiable benefits for life on earth" (Douglas 1974, p. 17). So after Douglas' (1974) statement, before applied ecology developed, ecology was just consisting out of pure ecology. Ambasht & Ambasht (2003) agrees and blames the discipline ecology for not being able to prevent environment related human problems. They see applied ecology as a way to make up for this miss (Ambasht & Ambasht 2003). Additionally, this illustrates that they use the term ecology the way other authors use pure, fundamental or theoretical ecology. This term use causes the impression that applied ecology is seen as something separated from ecology standing as a second discipline next to it.
However, Richter & Weiland mention that urban ecology shifted towards "investigating the applicability of research findings" (Richter & Weiland 2012, p. 4) illustrating that for them, applied aspects are a part of ecology. This term use is oppositional to the term use of Ambasht & Ambasht (2003), but might in this case explain that they Richter and Weiland (2012) often talk about ecology, not applied ecology, when it comes to problem solving. This also shows that the term ecology is sometimes also used synonymous with applied ecology.

The mentioned authors do sometimes use different terms for one subject in the same text and or they do use one term for describing different subjects. However, compared to the material written by Mc Pherson & De Stefano (2003), all other authors use terms relatively consistently. Even though Mc Pherson & De Stefano state in their title that their book is about applied ecology and natural resource management, the book seems to be more about what Douglas (1974) would call pure ecology and resource management. They use the term applied ecology, but sometimes synonymous with management, sometimes with pure ecology. It never gets clear what it actually is, but it gets clear that the authors want to combine ecology and management to something Douglas (1974) would call applied ecology even though the discipline already exists. But they do not make the connection between the discipline that is missing in their eyes and the discipline of applied ecology (Mc Pherson & De Stefano 2003).

3.2.6 Summary

Leaving out the material of Mc Pherson & De Stefano to look for general patterns found in all material – or at least general patterns some authors mention and others do not disagree with – we can find the following common denominators:

Assuming that theoretical ecology, pure ecology etc. mean the same thing, this is the sister discipline of applied ecology. It seems to provide the ecological knowledge applied ecology builds up on. This, both disciplines are strongly related and can influence each other, but they are different in the kind of knowledge they provide. Ecology can be seen as a term summarising these disciplines.

This information is mostly based on the material Douglas (1974), De Santo (1978), Beeby (1993) and Newman (2000) since these are the sources using ecology, applied ecology and the different terms for theoretical ecology in a seemingly consistent way. In other material we do not find this consistency of use. One common variation is for example the use of the word ecology in a context where theoretical ecology was used before.

3.2.7 Applied ecology and management

All authors use the term management in a context that makes clear that management is something happening after important scientific knowledge has been accumulated (Douglas 1974; Hinckley 1976; De Santo 1978; Hayward 1992; Beeby 1993; Newman 2000; Ambasht & Ambasht 2003; Mc Pherson & De Stefano 2003; Richter & Weiland 2012). So it seems to be the institution or discipline actually responsible for supervising the implementation of solutions into practice. The authors disagree to the degree of how much applied ecology is involved in this process.

Two of the references use the term management in a way that shows that the knowledge accumulated by applied ecology can be useful for management (Hinckley 1976; Ambasht & Ambasht 2003). Ambasht & Ambasht mention for example that applied ecologists provide "necessary information required at the early stage of planning […] and […] management programs" (Ambasht & Ambasht 2003, p. xi).

Beeby (1993) states that applied ecology makes contributions to management, so applied ecological information is seen as useful in this context. The formulation leaves it unclear how far these contributions go.

Additionally, there are more clear connections to management. When Beeby explains what population ecology is he mentions that "applied aspects include the management of populations for exploitation […], for conservation […] and control" (Beeby 1993, p. 5). The development of plans applied ecology can be involved in (Richter & Weiland 2012; Verdade, Lyra-Jorge & Piña 2014) is a typical management task. Mavrodiev's (1999) move of getting actively involved in applying his research suggestions could be seen as some form of management because he had to organise the process of implementing his solutions.

However, out of the material it is not possible to finally conclude how much applied ecology is connected to management or in how far applied ecology is management or not. Beeby (1993), for example, formulates so unclear that single sentences from him could be interpreted completely differently than others and Mc Pherson & De Stefano (2003) does not give a clear statement about what management is in relation to applied ecology either.

3.2.8 Summary

It seems – after looking at how the authors connect applied ecology and management – that applied ecological knowledge shall be used by the management which seems to be seen as the institution responsible for getting things to work in practice. How the knowledge gets there and if management can be seen as an additional task of applied ecology is unclear. A statement none of the authors would disagree with could be that applied ecology can have management tasks when management is necessary and the involvement of applied ecology is necessary for solving problems.

3.2.9 Applied ecology and other disciplines

Applied ecology has connections to natural sciences (Douglas 1974; Hinckley 1976; Hayward 1992; Newman 2000; Ambasht & Ambasht 2002), social sciences (Hinckley 1976; De Santo 1978; Hayward 1992; Richter & Weiland 2012; Verdade, Lyra-Jorge & Piña 2014) and political sciences (Hinckley 1976; Beeby 1993). Additionally, applied ecology is also connected to the economy (Hayward 1992; Ambasht & Ambasht 2003; Sakhare & Vasanthkumar 2011; Richter and Weiland 2014), industry (Douglas 1974; Hinckley 1976; Ambasht & Ambasht 2003) and development (Douglas 1974; Ambasht & Ambasht 2003) as well as politics (Hinckley 1976; De Santo 1978; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003; Mc Pherson & De Stefano 2003; Sakhare & Vasanthkumar; Richter & Weiland 2012), legislative power (De Santo 1978; Beeby 1993; Sakhare & Vasanthkumar 2011) and fields related to natural resource production like agriculture and forestry (Hinckley 1976; Beeby 1993) and resource conservation (Douglas 1974). Also to medicine (Hinckley 1976), logistics (De Santo 1978) and even to religion (De Santo 1978) are connected to applied ecology. A general connection to people is also mentioned (Hinckley 1976; De Santo1978; Verdade, Lyra-Jorge & Piña 2014).

The sheer amount of different disciplines somehow connected with applied ecology shows that applied ecology has to be a versatile discipline and Hinckley (1976) states that this is exactly what applied ecology is designed for. De Santo (1978), Hinckley (1976) and Sakhare & Vasanthkumar (2011) use the term interdisciplinary describing the relation of applied ecology to many other disciplines and for Ambasht & Ambasht applied ecology is the "most important unifying science" (Ambasht & Ambasht 2002, p. ix).

Verdade, Lyra-Jorge & Piña (2014) state that applied ecology is not just connected to a lot of disciplines, it is also dealing with a lot of topics: "Applied ecology [is, Ed.] an umbrella term under which many scientific topics are pursued" (Verdade, Lyra-Jorge & Piña 2014, p. v). Beeby agrees in writing that "applied ecology is not one subject but several" (Beeby 1993, p. x). Therefore, applied ecologists need to be "mentally agile" (Newman 2000, p. 4).

3.2.10 Summary

So we can maybe summarise this with the words of Hinckley who wrote that "ecologists, in their attempt to understand relationships, must draw on the knowledge and techniques of many scientific disciplines" (Hinckley 1976, p. 3) and De Santo (1978) saying that the "idealized ecologist must be well founded in the sciences in order to master the field, [but, Ed.] he or she must also be conversant in other fields as well."

3.2.11 Problems of applied ecology

3.2.12 Types of problems in applied ecology

Applied ecology problems are described by the authors as real (Hayward 1992) and existing in the real-world (De Santo 1978) or with relevance for practice (Douglas 1974, Mavrodiev 1999). De Santo (1978) additionally states that applied ecology deals with daily problems, but Douglas (1974) talks next to daily also about long-term problems.

Next to those general factors that can be inherent to all applied ecology problems, applied ecology problems can be grouped according to the topics they are concerned with. The following category system seemed to summarise the content in the best way possible. Important relations of categories and annotations to the way of grouping are also given. For further information about the category definitions see appendix 5.

Pollution

Pollution can occur in different forms. There can be air pollution through e.g. CO2, SO2, NOx and O3 (Ambasht & Ambasht 2002), toxic materials released into the environment (Ambasht & Ambasht 2003), water pollution by not further explained pollutants (Hinckley 1976; Richter & Weiland 2012), fumes from smelters (Douglas 1974) and a especially severe or at least fast type of pollution by radioactive material (Mavrodiev 1999). Additionally wastes and the problem of waste disposal which can cause pollution are mentioned (Mavrodiev 1999; Sakhare & Vasanthkumar 2011).

Environmental change

Environmental change is a category summarising a lot of aspects that change in the surroundings of humans and are of concern to them or at least to the book authors.
Some authors mention the problem of climate change (Ambasht & Ambasht 2002; Newman 2000; Sakhare & Vasanthkumar 2011; Richter & Weiland 2012) and the depletion of the ozone layer (Mavrodiew 1999; Sakhare & Vasanthkumar 2011). But also problems with the change of other environmental properties like the quality and quantity of soil which can deform, erode and lose nutrients (Douglas 1974; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003) and the quality and quantity of water or more specific rain which can become scarce and cause drougths, but there can be also floods and upwellings (Douglas 1974; Ambasht & Ambasht 2003; Richter & Weiland 2012). Also the process of desertification is viewed as a problem (Douglas 1974).
Next to those quite concrete change descriptions, it is also mentioned that the change of land use can cause problems (Ambasht & Ambasht 2002).

Destruction

Other problems mentioned – strongly linked to the environmental change category – are biodiversity loss (Douglas 1974; Ambasht & Ambasht 2002; Sakhare & Vasanthkumar; Richter & Weiland 2012; Verdade, Lyra-Jorge & Piña 2014) and species extinction (Douglas 1974; Newman 2000; Ambasht & Ambasht 2002; Richter & Weiland 2012; Verdade, Lyra-Jorge & Piña 2014).

Exploitation

The exploitation of nature (Douglas 1974) or exploitation of biological resources as Newman (2000) puts it more precisely is clearly related to the environmental change and exploitation category, but I separated it because exploitation of resources has a different notion because the connection to human needs is clearer. Many different things can be exploited, forests are one of them (Douglas 1974; Ambasht & Ambasht 2002), exploitation of fish stocks is another topic mentioned (Mavrodiev 1999; Newman 2000).

Pests, weeds and diseases

Problems with those factors were put into an own category also mainly because of the human judgment value connected to them. In case of the diseases mentioned in the context of pests and weeds (Newman 2000) this might seem a bit disproportionate, but it seems to fit

better in this than in one of the other categories because the notion that one part of the environment is judged as negative by humans is the same. What kind of pests, weeds and diseases are meant by this is just in parts specified by Douglas (1974) who states that insect pests are the problem.

Invasive species

One might call invasive species potential pest species, but since this connection was not made by any of the authors and invasive species are closer defined as the "general troublemaker-collection" in the above category by clarifying that the species were not in the habitat before, I put them separately to point the last mentioned fact out.
The two named authors mention that the introduction or appearance of species previously unknown in an ecosystem can cause problems (Mavrodiev 1999; Ambasht & Ambasht 2002). Mavrodiev also names a certain species *Mnemiopsis leidyi* as problematic for the Black Sea ecosystem, but both authors do not go into further detail.

Productivity loss

Productivity loss as an encroaching category is clearly describing an anthropocentric problem. Also the problem of the loss of ecosystem services based on biodiversity (Verdade, Lyra-Jorge & Piña 2014) belongs in this category.

Human population growth

Also a form of change, I still thought it makes sense to mention the population growth of humans separately. The changes in human population have two dimensions because the change happens in also in distribution, not just in abundance (Hinckley 1976) meaning that there is not just a population increase (Newman 2000), but some places of the earth are overcrowded and some others are left barely inhabited (Douglas 1974).

Human health and security

Why these problems are important to humans is self-explanatory. I summarised topics concerned with health and with security not just because of the thematic connection, but also because of their high relevance for humans.
Keeping humans healthy (Hinckley 1976; Richter & Weiland 2012) and save (Sakhare & Vasanthkumar 2011) is generally described as a problem. But more concrete or more severe also the problem of humans face is starvation and malnutrition (Douglas 1974) is mentioned.

Ignorance

Next to the more concrete environment or human related problems mentioned before, applied ecology is facing a problem concerning the interaction between humans respectively the lack of it. Applied ecology is facing the challenge that other disciplines like economy (Ambasht & Ambasht 2002) do not make use of the insights provided by it. Also Mavrodiev describes that even though recommendations for better practice were given out, there was nobody to implement them (Mavrodiev 1999) and Douglas (1974) also mentions that the decision makers did not understand the situation and therefore did not make the necessary decisions to solve the extant problem.

But despite of these experiences, ecology is making the same mistake, too. McPherson and De Stefano (2003) mention that ecologists do not take management sufficiently into account when doing research.

Political system

Douglas (1974) explains that the "doctrine of unlimited growth" (Douglas 1974, p. 24) is not known in nature and a misbelief. Even if I am anticipating to the next chapter here, I want to mention that the author thinks that it is a problem because it causes severe environmental damage (Douglas 1974) so the reader might understand why I mention this here.

Mavrodiev (1999) goes in the same direction when he criticises the uncontrolled resource use based on no scientific principles in the name of progress.

3.2.13 Causes of problems in applied ecology

Following, I am going to talk about every category separately, tell if the authors mention causes for the problem and if yes which ones.

Pollution

All authors name humans and human actions as the cause of pollution, but in different ways. Ambasht & Ambasht (2002) state that "rapid industrialisation, lure of financial gains, and commercialisation activities" (Ambasht & Ambasht 2002, p. ix) – thus human activities connected to economy – are responsible for pollution and other problems that will be broached below. Douglas is also talking about "industrial pollution" (Douglas 1974 p. 29) and gives an example of industry related pollution through fumes killing of forest around the

mine where the fume escaped from (Douglas 1974). Hinckley (1976) goes in the same direction by talking about man-made chemicals polluting the environment. Newman (2000) also raises the topic of polluting chemicals and adds that he is sure that more humans means more production of these substances, too. The relation of human population increase and pollution is also brought up by Verdade, Lyra-Jorge & Piña (2014) who base this on the example of the growth of Indian mega-cities and the simultaneous increase of environmental problems, especially air and water pollution, there.

Newman (2000) also thinks that chemical pollution might be caused by pest control with chemical substances, which means that not just industry and population growth as such are responsible for pollution, but also agricultural activities. Mavrodiev (1999) goes into the same direction by stating that the pollution in the future will be especially caused by the industry – particularly the chemical industry – agriculture, but also developments in the energy sector and transport, and that this will especially affect the quality of air and drinking water. He also mentions human wastes as possible pollutants (Mavrodiev 1999) in which case it is clear that humans are responsible for the pollution.

So humans are the cause of their pollution problems through many different activities, but the pollution problem can be enhanced or redistributed by natural processes like the sea current and winds (Mavrodiev 1999) distributing pollution away from their source.

Environmental change and destruction

Environmental change

Climate change is caused by human activities according to Ambasht & Ambasht (2002), Mavrodiev (1999) and Newman (2000). Ambasht & Ambasht (2002) blame industrialisation and focus on financial gains for the climate change, Newman (2000) puts it a bit more concrete by blaming the increase in fossil fuel use. Mavrodiev (1999) probably includes these causes when explaining that he sees global warming and also the ozone hole as fatal effects caused by human interferences in natural processes that are lacking a scientific basis. He also includes that the outcomes of such human behaviour are unpredictable (Mavrodiev 1999).

Douglas (1974) mentions the ignorance of ecological principles also as a cause for the soil becoming unable to store water. Connected to water problems, it is also interesting, that Newman (2000) points out global climate change as one possible cause of changes in rainfall, since this shows that one human caused problem can cause another problem. Also overgrazing and changes in forest can potentially affect rainfall which shows once again that

there can be different causes for one problem, but all these causes are in this case human related. This is also illustrated by Douglas' (1974) comment that water related problems occur because of the growing need of a growing industry for it.
It was already mentioned that human interference in natural processes can cause problems (Mavrodiev 1999). Douglas (1974) thinks so, too, and states that "the basic cause is, of course, neglect of fundamental ecological principles" (Douglas 1974, p. 27). The problems caused he mentions related to this category are connected to soil erosion and destruction, water problems related to quality and quantity as well as the problem of desertification.

Destruction

Ambasht & Ambasht (2002) also mention industrialisation and the focus of financial gains as the cause of environmental degradation and habitat destruction, as well as biodiversity loss and species extinction. They also point out concrete human actions causing species extinction like habitat destruction, invasive species introduced by humans and deforestation (Ambasht & Ambasht 2002). According to Richter & Weiland (2012) biodiversity is also endangered by local land use practices or more broadly put socioeconomic activities. They also mention like Ambasht & Ambasht (2002) that species extinction can be connected to the introduction of species foreign to the habitat (Richter & Weiland 2012) which is also confirmed by Douglas (1974). I will go into this later. In Mavrodiev's (1999) text it gets clear that also pollution is responsible for the destruction of the environment. What the causes of pollution are has already been explained.
Douglas (1974) puts it broader when he states that species extinction and the hereby caused biodiversity loss are caused by more and more activities that humans conduct in the world. Globalisation is also mentioned as a part of the cause (Richter & Weiland 2012). Also Verdade, Lyra-Jorge & Piña (2014) imply that humans are responsible for habitat and population reduction and explain that their impacts on the environment are responsible for the loss of ecosystem services what will consequently lead to ecosystem damage.

Exploitation

The term exploitation itself implies that humans are responsible for it. But Douglas (1974) points it out clearly by giving examples of exploitation by mines causing serious environmental damage. Newman (2000) assumes that with increasing human population the human caused pressure on natural resources will increase even more and makes herewith also the cause of the problem clear. The resources Newman (2000) talks about are energy,

water, timber, food and chemicals and soil which and he calls more broadly land and oceans resources that will be even more danger. That humans are responsible for the exploitation of forests (Ambasht & Ambasht 2002) and fish stocks (Mavrodiev 1999) is also stated.

Pests, weeds and diseases

Pests and diseases can spread because humans enhanced the conditions for their growth and dispersal through any kind of monocultures that do not offer any variety (Douglas 1974). Also nature exploitation is given as a cause of the spread of crop-destroying insects and fungi (Douglas 1974), probably as a more general term for the problem cause which is planting monocultures. An even more general way to put it is blaming the equilibrium shift in the ecological balance of the environment, as Douglas (1974) puts it, for the pest and disease outbreaks. But it gets also clear, that Douglas (1974) sees humans responsible for this shift by exploiting the environment, whereby we went round in a circle and are back at the main problem cause which is human behaviour.

Invasive species

The problem of invasive species can be caused by humans when they introduce exotic species without thinking ahead and careful considerations (Douglas 1974). Ambasht & Ambasht (2002) also just talk about invasive species that were introduced by humans without predators. By talking clearly about humans introducing of new or exotic species it becomes clear that the authors talk about cases where humans are actively involved in the process, not just indirectly easing the spread of the species. As already mentioned this can cause the extinction of species that have lived in the habitat originally (Douglas 1974; Ambasht & Ambasht 2002)

Productivity loss

Douglas (1974) states, that there are productivity losses because humans have caused “an upset in the balance of nature” (Douglas 1974, p. 27) by modifying natural conditions. This can for example happen by introducing invasive species (Douglas 1974). He states further, that if this upset of the balance happens at a large scale and the downsides of the modifications that happened are not taken care of, the land productivity is a common consequence (Douglas 1974). But as the basic cause of the problem he names the “neglect of fundamental ecological principles” (Douglas 1974, p. 27) that lead to a great part of the other problems described in the above chapter, which cause the productivity loss (Douglas 1974).

Human population growth

Even though human population growth is the cause of a variety of problems and even their basic driving force (Newman 2000) none of the authors gave a reason for this development. But that the reasons have to be human-related to a great extend seems to be self-explanatory. However, Douglas (1974) talks about the problem of overcrowding that I also put in this category. He blames the exploitation of resources and sees overcrowding of one area while another one is not used as one problem caused by it and attributes it to the disturbance of the ecological balance (Douglas 1974) that I also mentioned before.

Human health and security

Douglas (1974) uses the same argumentation blaming resource exploitation and making a connection ecological equilibrium disturbance for starvation and malnutrition as has been explained above in the case of human population growth problem. Verdade, Lyra-Jorge & Piña (2014) add that the growth of cities can cause health risks that are not just caused by poor sanitary conditions, but also pollution of air and water.

Ignorance

The problem that ecological knowledge is ignored by economics exists because both would be necessary "for a proper growth and development without destruction" (Ambasht & Ambasht 2002, p. ix) and the problems applied ecology is dealing with cannot be solved when the people with the power do not understand them (Douglas 1974) and do not implement solutions (Mavrodiev 1999). But despite the problem of people not being able to implement what they do not understand it is not clear what causes the disuse of knowledge.

Political system

None of the authors explains what exactly causes the problem of political systems focussing on the dogma of growth.

3.2.14 Reasons for problems in applied ecology

After talking about what kind of problems exist that applied ecology deals with and listing some of the causes of those problems, it would be also interesting to focus the interest more specifically on why the problems are actually perceived as problems respectively what the human interest behind those problems is that lead to their formulation. Because of the relations of the categories I also stated when there is a clear connection between the different reasons for the different problems.

Pollution

Ambasht & Ambasht (2002), Douglas (1974) and Hinckley (1976) state that pollution is a threat to human health which seems to be a quite straightforward reason to view it as a problem. Douglas (1976) and Hinckley (1976) name especially pollutants entering the food chain as problematic. But also water, soil and air pollution are named in this context (Douglas 1974) and Douglas (1974) also includes welfare and concern about "future happiness of all living creatures" (Douglas 1974, p. 29) as reasons for viewing pollution as problematic.

Environmental change

Ambasht & Ambasht (2002) state that global climate change causes a threat to human health.

Destruction

Environmental degradation, habitat destruction as well as the extinction of species and biodiversity loss cause threats to human health concerning to Ambasht & Ambasht (2002). They also state that the degradation of tropical rainforest is impacting human societies and economies negatively, but the impact is not further specified (Ambasht & Ambasht 2002). This shows that humans judge environmental destruction as being negative.

Verdade, Lyra-Jorge & Piña (2014) think that habitat destruction and population reductions are problematic to humans because through this ecosystem services get lost. The reasons for problems of human population growth might be also relevant here.

Exploitation

Exploitation is a topic for which no additional information could be found. Because of the thematic relation of exploitation to environmental change, productivity loss and destruction, the statements for this category might be relevant here, too.

Pests, weeds and diseases

Also in case of this problem I cannot give any further information because there is none given by the authors. The connection to bad effects on productivity has been described before and if humans do also see the processes caused by them as bad in themselves is not stated.

Invasive species

Invasive species can have a bad effect on other species which can reduce species diversity and efficiency (Douglas 1974). In the course of the text, Douglas (1974) talks about resource production, so it can be assumed that the author sees invasive species as a problem for humans because they can reduce the productivity of ecosystems.

Productivity loss

That the reasons for humans seeing productivity loss as a problem are just described by Verdade, Lyra-Jorge & Piña (2014) is not entirely true, since all authors talking about productivity loss as a problem could be mentioned here. Because why productivity loss is a problem is self-explanatory.

Still, at this point, I would just like to add a statement of Verdade, Lyra-Jorge & Piña (2014) in which they go further than stating the obvious human reason for the problem in connection to ecosystem service loss which is also part of this category as – somehow – an indirect form of losing productivity next to other losses. After describing different human impacts on the environment causing the loss of ecosystem services, the authors state that this loss causes the decay of complete ecosystems and that both of these aspects are “more and more acknowledged by practitioners, decision makers, and society in general” (Verdade, Lyra-Jorge & Piña 2014, p. v). So these different groups of people do not just recognise the loss of ecosystem services as a problem that fits into an anthropocentric way of thinking, but also the value of the ecosystem as such depending on those.

Human population growth

Newman (2000) describes that human population increase is accompanied with an increasing pressure on basic resources which means that it will be harder to provide those. The need of food and timber might be hard to satisfy (Newman 2000) which shows that human population growth is a problem for humans because more humans need more resources. Newman (2000) continues his argumentation line with mentioning that this growing need for resources could lead to land use changes and more intensive soil and pest management which could result in endangering species and their habitats. He also thinks that human population increase means a higher production of chemicals that can pollute the environment (Newman 2000). Because he states these different threats to the environment after talking about anthropocentric human interests related to resource needs, in this context it should be justified to make the assumption that Newman grants the environment an intrinsic value respectively Newman sees human population growth and the consequent environmental problems not just as a problem because humans have disadvantages from that, but he sees the reason of the problem laying in the destruction of nature itself. This means that Newman (2000) also states arguments reflecting a biocentric worldview.

Human health and security

Why humans see threats to human health and security as a problem is – if possible even more than the loss of productivity – self-explanatory.

Ignorance

The reason why it is a problem for humans when knowledge gets ignored is not further evaluated by the authors.

Political system

Douglas (1974) states that he sees the dogma of unlimited growth as a problem because it causes environmental destruction and at one point it will "turn upon them [its advocates] and those who lead and destroy them all" (Douglas 1974, p. 24). Out of the context it gets quite clear that he does not implicitly feel sorry for these advocates, which means he thinks the political system is also a problem because of its detrimental effect on the environment even though more human centred reasons might be in play here, too.

Mavrodiev (1999), the other author criticising the progress dogma, blames it for propagating the "uncontrolled and non-scientific usage of planet's resources" (Mavrodiev 1999, p. xiii).

Out of the word usage it gets clear that he has the interest of humans in mind to use the resources also in the future.

3.2.15 Summary

Problems seem to be an important part of applied ecology because all authors mention that applied ecology deals with them. Also the orientation on real-world problems and the consideration of short- and long-term problems is mentioned.
The types of problems existing are diverse and interwoven with each other as illustrated by the different categories and their descriptions. Environmental change and destruction obviously deal with environmental impacts and it gets clear that those impacts – no matter if they cause an ongoing and gradual change in the system or more a static direct impact – are caused by humans. Natural processes might enhance or shift the impact of human influence especially in case of environmental change scenarios and these impacts of on the environment might be not planned (in contrast to destruction scenarios where the impact on the environment in a certain area is obvious). Still, humans are the main responsible persons. Pollution is also a more indirect influence because it is one of the things that just happen without being planned. Exploitation in contrast is a planned impact on the environment. Nevertheless, the fact that humans are responsible for both stays the same. The problem of invasive species does not have to be human caused, but the authors just mention cases where the introduction of the species by humans was the case. The invasive species problematic is – when looking at the environmental impacts that are judged as negative – comparable to the ones of pests, weeds, and diseases. But the problem of pests, weeds, and diseases is basically not caused by human impacts even though such impacts might enhance their effects on the environment judged as negative by people.
Out of those described problems, problems like productivity loss and human health and security can arise, or the latter can be the main cause why the former have been judged as problems in the first place.
So all mentioned problems are somehow related to the environment and human expectations on it. Even the problem of human population growth can be seen that way since this is not described as a problem per se, but in connection to the environment presumably not being able to cope with it (implicating it is actually more the cause of problems that a problem itself). And also the problem of knowledge ignorance and the problems with political

systems being based on the dogma of unlimited growth just exist because of environmental issues that underlie them.

To summarise, there are basically two kinds of problem causes:
1) The problem arises because humans impact the environment (for example in case of pollution, environmental change and destruction and exploitation) or
2) the problem arises because the environment impacts humans (for example in case of pests, weeds and diseases)
The authors furthermore make clear that why humans acknowledge certain environmental related problems is often because of economic and social reasons. For example, the authors describe environmental degradation and destruction and later name why this is a problem, e.g. because of human health concerns or food production problems. But the environment itself can be also granted an intrinsic value.

So basically, applied ecology is dealing with problems related to economics (e.g. productivity loss), social issues (e.g. human security and problems with the political system) and ecological concerns, or to put it more broadly problems that arise based on an anthropocentric worldview (social and economical problems) and problems that arise based on a biocentric worldview (ecological problems).

3.2.16 Goals of applied ecology

The general and probably most central goal of applied ecology is that applied ecological science wants to solve problems. This might seem self-explanatory, but in case of applied ecology and the problems the science deals with – that are of practical nature as we heard before – it is an important attribute discriminating it e.g. from more theoretical ecological research. All but one author mention that applied ecology is searching for solutions for problems (Douglas 1974; Hinckley 1976; De Santo 1978; Hayward 1992; Beeby 1993; Mavrodiev 1999; Newman 2000; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003; Mc Pherson & De Stefano 2003; Richter & Weiland 2012; Verdade, Lyra-Jorge & Piña 2014) and what kind of problems they mean has been described already. As Douglas (1974) puts it “applied science means putting specific knowledge to use for definite purposes, other than its own end” (Douglas 1974, p. 23). This means applied ecology wants to solve

problems ‘for real’, not just solve a (theoretical) question what might create more ‘real’ problems than it solves in the end. I will go into the difference between theoretical and applied ecology later, but for now it is important to state that applied ecology is according to the analysis material a solution-oriented science.

So let us go a bit more into detail with what kind of problems applied ecology is concerned with. Since we just learned that we can group the problems of roughly in economic, social and ecological problems, I decided use this scheme for explaining the goals of applied ecology assuming that the goals are related to the problems. A more detailed category definition can be found in appendix 8.

Ecological goals

Some authors mention general goals concerned with environmental protection like nature conservation (Douglas 1974; Hinckley 1976; Beeby 1993; Newman 2000; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003; Richter & Weiland 2012). Habitat restoration (Douglas 1974; Beeby 1993; Newman 2000) is another ecological goals. The conservation of endangered species (Hinckley 1976; Beeby 1993; Newman 2000; Ambasht & Ambasht 2003) and the conservation of biodiversity (Newman 2000; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003; Richter & Weiland 2012) are goals that seem to fit thematically to the first mentioned ones. Another conservation related goal is the one of conserving biological processes (Ambasht & Ambasht 2003) which is kind of nature conservation, but with a clear focus on the processes, like the goal to conserve endangered species is concerned with specific organisms. The goal of pollution abatement is mentioned, too (Hinckley 1976; Newman 2000; Ambasht & Ambasht 2003) and Newman (2000) even mentions the goal of halting global warming.

Economical goals

One economical goal is the utilization of nature (Douglas 1974; Hinckley 1976; Beeby 1993; Mavrodiev 1999; Newman 2000) and Douglas (1974) even states that applied ecology is most of the times concerned with utilitarian usage of scientific knowledge. However, it might be interesting that Beeby (1974) and Mavrodiev (1999) use the term exploitation to describe this goal without a negative connotation. Related to this goal are the goals of resource development meaning “the fullest development of resources to the benefit of all” (Doulas 1974, p. 20) and resource production meaning the sustainable production of for

example crops at a profitable level (Douglas 1974; Newman 2000). Additionally, there is the goal of controlling the environment which is mentioned in this case in connection with controlling impacts that can be bad for the economy, e.g. pests (Beeby 1993), Newman (2000) mentions additionally weeds and diseases, in this case not relating to human ones. Because all mentioned authors see the use of nature based on scientific information or in connection to conservation directly, maybe the goal of development without destruction mentioned by Ambasht & Ambasht (2002), Hinckley (1976) and Mc Pherson & De Stefano (2003), would be a goal all of the other authors in this category would agree on.

Social goals

The topic of control is also important when it comes to social goals, in this case the goal to control human diseases (Douglas 1974) and protect human health in general (Hinckley 1976). Solving water conflicts is another goal mentioned (Richter & Weiland 2012) that can be seen as a social goal. But Newman (2000) also states that applied ecology "can help with resolutions of conflicts" (Newman 2000, p. vii) for example related to different land use alternatives.

Overall goal

The ecological, economical and social goals mentioned are summarised by some authors in one goal, the goal of creating harmony between people and environment (Douglas 1974; Hinckley 1976; Mc Pherson & De Stefano 2003; Richter & Weiland 2012; Verdade, Lyra-Jorge & Piña 2014). Mavrodiev (1999) calls it a bit more drastic ruling nature scientifically and thus points out that this harmony does not have to mean the exclusion of human influence, but because of his focus on scientifically based decision-making he seems to mean basically the same than the authors using more soft terms like harmony. Ambasht & Ambasht (2002) just name it "socio-economic and environmental goals" (Ambasht & Ambasht 2002, p. 21) without finding a new term for it as well as Verdade, Lyra-Jorge & Piña (2014) stating that "sustainable and resilient ecosystems need to maintain its ecological structure and function over time while continuing to meet societal needs and expectations" (Verdade, Lyra-Jorge & Piña 2014, p. v). Newman (2000) who is not directly addressing this subject might be add or underline that it is also about the harmony between people.

This category is a collection of the author's statements that fit to all the other three categories and have a connecting undertone. Douglas (1974) and Verdade, Lyra-Jorge & Piña (2014)

are talking about the goal to “create a harmonized interaction between people and nature” (Verdade, Lyra-Jorge & Piña 2014, p. v) or to “make life happier and give back to harassed and weary populations the goal of […] harmony in their daily routine or surroundings” (Douglas 1974, p. 24). Authors also talk about the improvement of life in connection to taking care of nature (Douglas 1974; Richter & Weiland 2012) and making things better for all people and species in the world (Mc Pherson & De Stefano 2003). In Douglas (1974) – despite all harmony wishes – the focus on human interests still stays clear because he talks about “improving and maintaining all that we love best in the world around us” (Douglas 1974, p. 14). But nevertheless, the respect of living things should be the base of existence according to Douglas (1974). So the main goal could be also formulated after Hinckley who mentions the goal to “work for a better world” (Hinckley 1976, p. 4).

3.2.17 Summary

Apart from the overall goal of solving problems related to environmental factors, there are more specific goals mentioned in the material. A lot of goals are related to environmental protection, even though – as we learned from the problem chapter – the goals might exist partly just because it is a requirement for the overall goal of achieving to live in harmony with nature that is expressed by a lot of authors in one way or another. Still, the wish to protect the environment stays the same. But the wish to control the environment to a certain degree to achieve economic and social goals is also there.
Still, even when talking about the utilisation of nature, all authors mention this somehow in the context of doing it in a scientifically sound way or mention this should not destroy the environment. So the goal of creating harmony between humans and the environment and working for a better world seems fitting to summarise what applied ecology is aiming for.

3.2.18 Tasks of applied ecology

We already covered the topic of applied ecology being responsible for finding solutions to real-world problems that can be of short- and long-term characteristic with the goal of creating harmony between humans itself and humans and the environment. But we have not talked about how the process of finding solutions is working in applied ecological research. In the following text I want to make up for that.

Collect existing information

One task of applied ecology the authors mention is the collection of already existing information that can help for solving the problem (Beeby 1993; Mavrodiev 1999; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003; Richter & Weiland 2012) which makes sense taking into account that applied ecology is based on ecological knowledge already there.

Most of the authors describe that applied ecology uses general information about ecological principles, methods and theories to understand the concrete situation confronted with and that applied ecology discusses how the already existing ecological principles can be best applied to the problem at hand (Beeby 1993; Mavrodiev 1999; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003; Richter & Weiland 2012). The active collection and review of this information is part of the job (Mavrodiev 1999; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003). Here, applied ecology is especially concerned with information about or useful for specific systems (Ambasht & Ambasht 2002; Ambasht & Ambasht 2003; Richter & Weiland 2012).

Ambasht & Ambasht (2003) also talk about the identification of knowledge gaps that might prevent the applied ecologist from tackling the problem, in their case from making accurate predictions.

Gain new information

Applied ecology is not just working with information derived from already existing data from studies done before, if necessary it also collects its own data. One sort of data collection is monitoring ecological processes (Mavrodiev 1999) also with the purpose of getting more information about one specific influence factor like described by Beeby (1993) who talks about the monitoring of pollution. But data can also be collected in other ways, for example by conducting experiments (Beeby 1993). Beeby (1993) says that "applied ecology also offers some scope for large scale experimentation on ecosystems, using controlled experiments in the restoration of degraded habitats" (Beeby 1993, p. 7). So through studies and data collection, like also described from Douglas (1974) and Mavrodiev (1999), researchers can get more information about an ecosystem. In Douglas' words, "on the applied side of ecology, studies of individuals, communities and their habits and institutions are closely linked with those of utilisation of resources, conservation and population increase" (Douglas 1974, p. 31) confirming once more that applied ecology – also when collecting data – keeps the real-world problems it wants to solve in mind. However

"management decisions cannot be postponed until complete scientific information is available on an issue" (Mc Pherson & De Stefano, p. 12) which means that there is a limit of information that has to be gained.

Develop tools and techniques

Logically, when applied ecology is also collecting data itself, it is also responsible for analysing it (Mavrodiev 1999; Mc Pherson & De Stefano 2003; Richter & Weiland 2012) with different analytical tools and techniques (Mavrodiev 1999; Mc Pherson & De Stefano 2003) to be able to assess the given situation. But applied ecology is not just responsible for finding out about tools and techniques that could be useful, but also for refine them or develop new ones (Douglas 1974; Beeby 1993; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003; Mc Pherson & De Stefano 2003; Richter & Weiland 2012).

One kind analytical tool that helps to understand the system and is developed by applied ecologists is a model (Beeby 1993; Mavrodiev 1999; Newman 2000; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003). Models are developed to describe ecosystems or ecosystem parts. Through this, it is also possible to make predictions about the probable future development of the environment (Beeby 1993; Mavrodiev 1999; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003).

And to understand the system not just analytical tools and techniques are used and developed, but also more technology-based approaches are used, like finding tools for specific purposes (Ambasht & Ambasht 2002). Ambash and Ambash (2002) talk about "midterm corrections of old technologies and reformation of new ones" (Ambasht & Ambasht 2002, p. ix) and the development of techniques that enable humans to get more precise information about their environment, for example by developing a tool to measure vegetation cover (Ambasht & Ambasht 2003).

Tools and techniques are also developed not just to understand the system, but to be of concrete help in problem-solving, like the remediation of degraded areas like mine-voids and ecosystems like wetlands (Ambasht & Ambasht 2003). Douglas (1974) even calls applied ecology a technology and a tool itself. He thinks beyond the research state "the applied aspects [of ecology] take over, after a period of development, and the discoveries are made to serve practical ends in the fields of technology or general consumption" (Douglas 1974, p. 23) which underlines applied ecology's responsibility to develop things with real-life use.

Richter & Weiland (2012) also broach the topic of such technologies when talking about applied ecology developing techniques that enable the researchers to give out flood warnings. This also shows that this technologically based approach is can also be useful for making predictions.

Develop good practice suggestions

Newman (2000) states that sometimes applied ecological science can "suggest solutions to ecological problems: for example, ways of controlling diseases or minimizing the effects of pollution" (Newman 2000, p. vii). Those solutions can be also called good practice suggestions meaning based on the gathered information applied ecology gives advices for practical actions that will solve the concrete problem at hand or at least decrease it (Douglas 1974; Beeby 1993; Mavrodiev 1999; Newman 2000; Ambasht & Ambasht 2002; Ambasht & Ambasht 2003; Richter & Weiland 2012). Some authors mention those good practice suggestions being provided in form of a framework that should be followed (Richter & Weiland 2012) or a plan that should be implemented (Richter & Weiland 2012; Verdade, Lyra-Jorge & Piña 2014).

Distribute knowledge

Mavrodiev (1999) mentions writing a manuscript providing good practice information and some of the authors actually mention writing the book to distribute not directly concrete good practice suggestions, but general knowledge about problem solving possibilities (Douglas 1974; Hinckley 1976; Mavrodiev 1999; Newman 2000; Ambasht & Ambasht 2003; Verdade, Lyra-Jorge & Piña 2014). Douglas (1974) makes clear that his book is for him a possibility to reach out to the people where the knowledge applied ecology has gathered should go according to him. He views every human being as an ecologist and thinks "it is the task of ecology, especially in its applied form, to supply both the knowledge, and the practical guidance on how to use it, so that we can all play our parts in achieving more harmonious and satisfying lives and conserving and enhancing the environments around us" (Douglas 1974, p. 20).

Ambasht & Ambasht (2002) are also convinced that especially information about future predictions can be useful for policy makers, but they do not specify how the information shall get to them. The same with Newman (2000) who states that applied ecology shall "inform decision-making processes that regulate human activities" (Newman 2000, p. vii),

but does not say how this shall work. Beeby (1993) is also talking about models that can make predictions being able to facilitate decision making processes and Hayward (1992), Hinckley (1976) and Mc Pherson & De Stefano (2003) state that applied ecology can be useful for management, but it also does not get clear how the gathered knowledge should get to them and in what form (models, ready-to-use plans,…) and how. De Santo (1978) also does not go into detail concerning this problem, but he states that "the significance of an ecologist's career should be largely measured by the ability the ecologist has to communicate and understand" (De Santo 1978, p. 5) illustrating that for him communication is a key.
Mavrodiev (1999) was facing the problem that nobody was there to implement the recommendations of his study group, so they formed an own company to be able to implement the recommendations themselves which might be a hint in the directions that applied ecologists have to be active themselves to make their suggestions work in practice.

3.2.19 Summary

So we learned that applied ecology is first gathering the information about a system already available and then assesses which additional information it still needs to be able to understand it deep enough to find a problem solution. When there is still information missing, applied ecology can conduct own studies to fill this information gap. If there is information necessary for closing the knowledge gap missing, applied ecology is also concerned with closing this knowledge gap. Mentioned in this context are methods with an analytical and technological approach, but also the execution of experiments that cannot be just grouped in one of those categories.
So after the system is understood to a necessary degree, the problem solving part starts. The methods used to understand the system can now be of practical use. Analytical models explaining the system can also be used for predictions. Nature observation can be turned into experiments that might lead to information about reactions of nature on different impacts. Technological tools for understanding nature might be useful for influencing it. If not, new methods have to be found go gain information about the development of the system under certain influences. With this information applied ecology can make good practice suggestions and develop plans and guidelines. It can transfer the found information to

management, but it can also get active itself and try to take the management in its own hands.

That many authors connect applied ecology also to understanding basic questions about the system of concern might be a interesting, and – with knowing that applied ecology wants to solve problems – it seemed surprising, that not all authors were including the task of developing clear guidelines for practical use, but they seemed really focussed on making models to predict the future as if that would be a solution. That might be partly due to the connection of applied ecology to ecology and management that I am going to explain below.

3.3 Applied ecology in comparison

3.3.1 Development of applied ecology in comparison with other disciplines

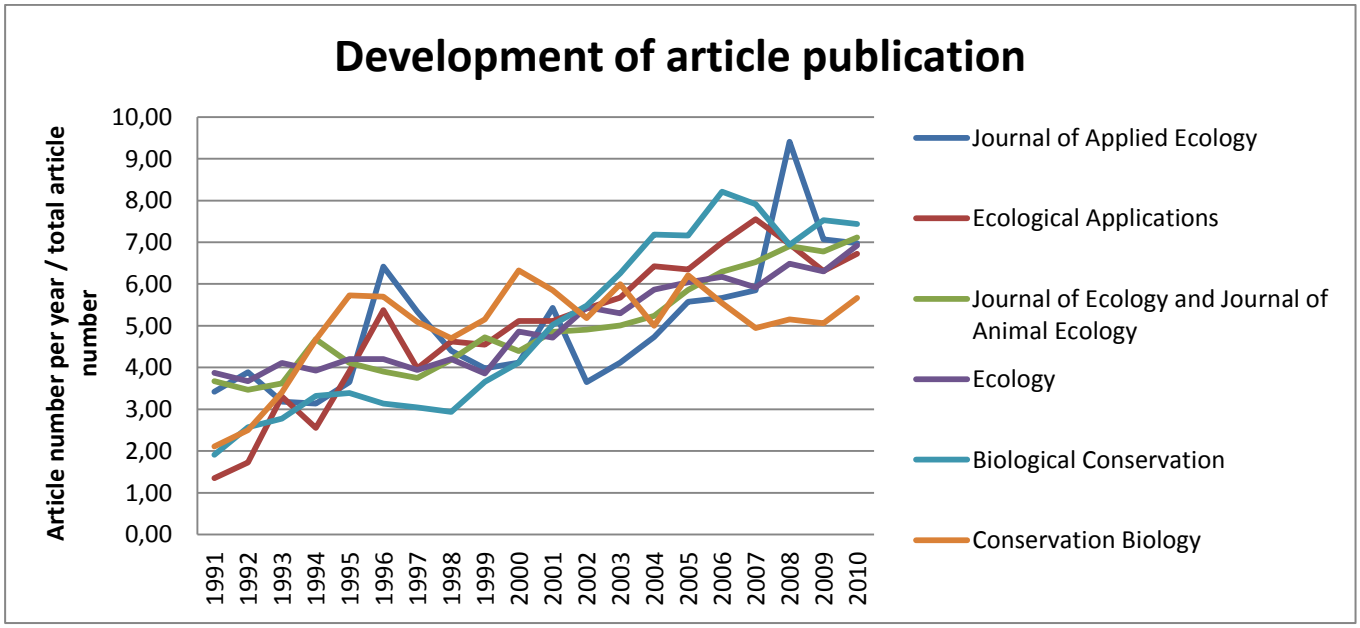

Fig. 4. Development of article publication in the six journal entities. The graph shows the article number per year per journal entity divided by the article number from 1991-2010 per journal entity.

We see in figure 4 that the percentage of article published of the total number of articles is in all journals higher in recent years. So all journals publish more papers now than in the 1990s, which indicated a general upwards trend. From the applied ecology journals we could anticipate this development since it fits to the rise of the use of the term applied ecology that has already been demonstrated and it seems the other disciplines develop the same way. Just the strength of it might differ a bit, for example looking at the journal Conservation Biology which published in the 2000s always more or less around 5 and 6 percent of its total papers published every year. Other journals show peaks and breakdowns, but all journals publish at the end of the 2000s more articles than on the early 1990s which seems to be the central message here.

3.3.2 Summary

The increase of articles published in the different journal entities seems to be comparable. This can be seen as an indicator that applied ecology research increases in a comparable speed in Europe and North America and that the sciences applied ecology, pure ecology and conservation biology develop at a comparable speed.

3.3.3 Characteristics of applied ecology in comparison with other disciplines and between continents

Following, I would like to present the list of the most frequently used words in the six journal entities between 1991 and 2010.

Tab. 2. The ten most frequently used words in article titles of the mentioned journals between 1991 and 2010 ordered from the most frequently to the less frequently used words. * symbolises that the term is stemmed. Terms without * contain their singular and plural forms.

Journal of Applied Ecology	**Ecological Applications**	**Journal of Ecology and Journal of Animal Ecology**	**Ecology**	**Biological Conservation**	**Conservation Biology**
effect	forest	popul*	effect	conserv*	conserv*
popul*	effect	effect	plant	popul*	speci*
model	model	plant	speci*	forest	effect
manag*	use	speci*	predat*	effect	popul*
use	manag*	forest	forest	habitat	forest
speci*	ecosystem	dynam*	communiti*	speci*	habitat
habitat	speci*	size	popul*	use	biodivers*
plant	popul*	communiti*	dynam*	manag*	use
forest	ecolog*	growth	model	landscap*	manag*
control	habitat	variat*	ecolog*	bird	bird

Looking at the two applied ecology journals it is interesting to see, that in both journals the word stems effect, popul*, forest, model, manag*, use, speci* and habitat show up in the top 10 used words or more correct word stems. The Journal of Applied Ecology has additionally plant and control in the top ten, Ecological Applications has ecosystem and ecology*. Even the ranking is comparable in parts, for example looking at effects on the first place in the Journal of Applied Ecology and on the second in Ecological Applications, and on manag* on the 4th place and use on the 5th place in the Journal of Applied Ecology and vice versa in Ecological Applications. The term model is even on the same 3rd place.
But even without these ranking similarities the overall picture indicates that both journals seem to publish articles with a comparable content when we assume that the content is illustrated by the key words mentioned in the title. The words different in both journals do not really manage to becloud this picture, also because the word control can be seen thematically in connection with manag* and use, and the word plant does not seem to be far away from ecosystem and ecology*, in spite of being a term describing a specific part of an ecosystem, not the ecosystem itself.

In the pure ecology titles we can see that seven terms show up on the American and European journals which are popul*, effect, plant, speci*, forest, dynam* and communiti*. The Journal of Animal Ecology and the Journal of Ecology have additionally the terms size, growth and variat*, and in the ranking of the journal Ecology there are additionally predate, model and ecology.
Four of those word stems are in the rankings of all applied and pure ecology journals: effect, popul*, forest and speci*. The term forest is describing a kind of ecosystem and the terms popul* and speci* could be seen as measuring units or different forms to divide parts of the ecosystem in. So maybe this similarity between the journals tells us, that applied and pure ecology research often connected to forest and popular units to do research on are populations and species. The term effect might describe what the research is interested in, e.g. finding out about interactions and impacts in some kind of way.
Additionally, the term model is used in the journal Ecology, too, so pure ecology might be also concerned with modelling, but maybe to a lower degree that applied ecology since in Ecology the term model is in rank nine, and in both applied ecology journals on rank three. The term plant, in the Journal of Applied Ecology found on rank eight, is found on rank three in the Journal of Animal Ecology and Journal of Ecology titles, and in the journal Ecology on rank two. Maybe here it is the other way around, and pure ecology is working

more especially on the entity plant than applied ecologists do. The term ecolog* shows up on rank nine in Ecological Applications and in rank ten in Ecology, so just in the journals published in North America. Even if this is North American specific, what that could mean for the research practice stays unclear.
So dynam* and community are the terms that seem to be especially characteristic for pure ecology in this context. The word stem dynam* on rank six and communiti* on rank eight in the Journal of Animal Ecology and the Journal of Ecology and in Ecology vice versa could indicate that pure ecology's research focus is stronger on communities than it is in applied ecology. The term dynam* could indicate that in pure ecology research about processes is of high value. The term variat*, used in the Journal of Animal Ecology and the Journal of Ecology, supports this assumption. The terms size and growth that are also in the ranking of the mentioned journals are attributes that can be measured which also indicated the interest in understanding the research object on a basic level. The term predat*, mentioned in Ecology, is a term that fits to the ones describing on what kind of object research is concentrating the focus on, and in the journal of ecology that might be predators or processes connected to predatory behaviour of organisms.

So the following terms mentioned in both applied ecology journals – manag*, use and habitat – are not in the top ten terms in titles of the pure ecology journals. This is interesting because manag* and use are terms connected to stewardship and utilisation meaning terms that are connected to achieving something. Habitat is also a more concrete term like community for example in that sense that the term habitat is related to a specific species, communities are just there.

The conservation biology journals have nine similar terms in their rankings, which are conserv*, popul*, forest, effect, habitat, speci*, use, manag* and bird. Biological Conservation has also landscap* in the ranking, Conservation biology biodivers*. The term conserve is in both journals in the ranking on the first place, popul*, forest, effect, habitat and speci* between two and six, use and manag* in this order in Biological Conservation on seven and eight, in Conservation Biology on eight and nine and bird is on the last place. So taking the term similarities in content and order as an indicator, the journals seem to publish articles with quite comparable topics.

Seven of these terms – popul*, forest, effect, habitat, speci*, use, and manag* – appear in the ranking of all applied ecology and conservation biology journals. Even though the ranking shows differences – for example manag* and use are located on the positions four and five in the applied ecology journals and between seven and nine in the conservation biology ones – the similarity cannot be denied. Looking just at the words that are on the top ten of the American and the European journals, the similarity is even bigger than to the pure ecology journals because there just four word stems were similar.

The terms conservation biology and applied ecology journals have in common describe different research aspects. The term forest has been described before one type of ecosystem apparently important in research, speci* and popul* as abbreviations for species and population related terms ecosystem parts research can be focused on. Also habitat is such a term, but habitat describes a concrete part of the ecosystem important for a specific species. Use and management have also been described before as terms related to human interests and stewardship.

That the term conservation is showing up at first place in the ranking of conservation biology journals might not be surprising, but it seems interesting that it does not appear in the applied ecology rankings knowing from the book material analysis that it is supposed to be an important part or a goal of applied ecological research. The appearance of the term bird can be also seen as one ecosystem aspect – like forest – that conservation biological research seems to be interested in. Also the appearance of the word stem biodivers* might not surprise taking into account its relevance for conservation and with landscape we have another word describing an ecosystem, but a human influenced one.

3.3.4 Summary

When looking at the top ten lists of words used in titles of articles published in the different journals we saw that the words used in the applied ecology journals and the words used in the conservation biology journals were quite comparable and they all had the terms manag* and use in their lists which did not occur in the pure ecology journals that had more terms useful for describing attributes or focused on dynamics. The applied ecology journals and the pure ecology journals also had terms in common, but maybe also due to the pure ecology

journals using internally more different terms than the applied ecology and the conservation biology journals, there were just four terms occurring in all applied and pure ecology journals. These terms – effect, popul*, speci* and forest – also occur in the conservation biology journals showing that all disciplines seem to be interested in effects, in forests and use the resolution levels of populations and species for their research or are interested in getting information about those. That eight of the ten terms in the applied ecology journals are the same indicates that there might be no big difference between applied ecological research themes in America and Europe.

3.3.5 Development of applied ecology between continents

As a next step, I would like to take a look at the word stem rankings of the articles of the applied ecology journals between 1991 and 1995 as well as 2006 and 2010 to see if some notable changes have taken place.

Tab. 3 The ten most frequently used words in the titles of the mentioned journals between 1991 and 1995 as well as 2006 and 2010 ordered from the most frequently to the less frequently used words. * symbolises that the term is stemmed. Terms without * contain their singular and plural forms.

1991-1995		2006-2010	
Journal of Applied Ecology	Ecological Applications	Journal of Applied Ecology	Ecological Applications
effect	forest	effect	forest
popul*	manag*	manag*	model
model	model	speci*	effect
graze	effect	model	use
veget*	respons*	popul*	ecosystem
control	ecolog*	use	speci*
relat*	plant	landscap*	manag*
plant	ecosystem	habitat	popul*
growth	chang*	invas*	chang*
densiti*	popul*	plant	habitat

Comparing the change in word stems between the single journals from the early 1990s to the late 2000s, we can see that in the Journal of Applied Ecology just four terms – effect, popul*, model and plant – stayed the same, but in Ecological Applications seven terms – forest, manag*, model, effect, ecosystem, chang* and popul* – are equal. So top ten terms changed more in the Journal of Applied Ecology than in Ecological Applications.
Comparing the journals in the five year periods we can see that in 1991 – 1995 four terms were equal in the top ten effect, popul*, model and plant – and in the 2006 – 2010 period seven terms are equal which are effect, manag*, speci*, model, popul*, use and habitat.
So we see that three of the four similar terms in the early 1990s – effect, popul* and model – are still under the seven similar terms in the late 2000s. The forth term plant is on the tenth position in the Journal of Applied Ecology, but it is not in the top 10 of the journal Ecological Applications anymore.
From the four new terms that are similar – manag*, speci*, use and habitat – we know manag* already from the second rank of the top ten of Ecological Applications from the early 1990s, the other terms are new for both journal top ten lists.
The six terms that changed in the Journal of Applied Ecology from the early 1990s to the late 2000s are the same terms than the ones not similar with Ecological Applications: graze, veget*, control, relat*, growth and densiti*.
The word stem relat* – summarising relation related terms – is comparable with the term effect, but relations are more general. Growth and density seem to fit to this because they are terms helping to describe attributes of organisms or groups of organisms, meaning they are also terms to describe general facts. We know this type of terms already especially from the pure ecology journal top ten lists, where growth occurs, too, and also terms like size or dynam* summarising dynamic related terms.
The word stem veget* summarising vegetation related terms points to a part of the ecosystem apparently important in research at that time. The term graze – describing an activity of animals, maybe especially livestock that is naturally related to vegetation and seemed to be of concern in the early 1990s. The term control could be also connected to this, but might be especially seen in connection to the word stem manag*, missing in the Journal of Applied Ecology at that time, but already present in Ecological Applications because management means stewardship and can also be expressed in the control of something.
Next to manag* there are three other terms in the early 1990s top ten of Ecological Applications – forest, ecosystem and chang* that make it to the top ten in the late 2000s, too, but do not show up in the top ten lists of the Journal of Applied Ecology. Forest also

describes an ecosystem that seems to be relevant for research, ecosystem might hint to the level of resolution the researchers are interested to do research on or want to find information about, and chang*, summarising terms related to change, might be also related to effect, since change is based on some kind of effect.

Looking at the terms habitat, use and speci* that are new in both journals in the late 2000s we see that use could be seen as related to the term manag* that is just new for the Journal of Applied Ecology in the late 2000s and stand for research interested in stewardship and utilisation in some kind of way. Since in the Journal of Applied Ecology the term control occurred in the early 1990s we cannot say that the general interest of research in humans governing or managing the environment in some kind of way was not there before, but because now both journals have two terms for it – use and manag* – one might assume that the interest in this got stronger over the years.

The term speci* is a term related to the resolution level researchers are interested to find information about or do research on, and habitat can also be seen as such a term, but it is different from a term like biotope or ecosystem in that sense that it is describes the necessary living conditions for a specific species.

The term plant describes a specific research object, but it seems to lose in meaning since it is just found in the Journal of Applied Ecology on the 10^{th} rank now. Also the terms graze and veget* are not found in the Journal of Applied Ecology anymore which could indicate a general loss if interest in research on vegetation in general, but especially in the Journal of Applied Ecology where it seemed more prominent before.

In the top ten of the Journal of Applied Ecology of the late 2000s we also find the word stems landscap* and invas*, not occurring in any of the other three top ten lists. The term invas* – summarising words related to invasive – could hint to invasive species that seem to be of research interest in the Journal of Applied Ecology between 2006 and 2010. Landscape is one of the terms describing an ecosystem just that landscape is a special type because it has the notion of being influenced by humans.

In the journal Ecological Applications, there are no terms in the top ten list of 2006-2010 that have not occurred in the journal itself between 1991 and 1995 before or that also occur in the Journal of Applied Ecology in the late 2000s.

So we talked about all terms by now, but closing I would like to highlight the three terms occurring in all the four lists: effect, popul* and model. These terms describe research interests on different levels. Effect describes that researchers are interested in the influence of one factor on another, so it is comparable to the term relation, but it is somehow more

focused on the “what if” question, in the impact of one influencing factor on for example an organism or an ecosystem. The term popul* hints to the form of resolution nature can be fragmented in that is interesting for the researchers and it seems that in the early 1990 and the late 2000s populations were of special interest for researchers. Researchers seemed to be also interested in models during the time periods, so we can assume that developing and/or evaluating models was an important part of the research in both time periods.

3.3.6 Summary

Comparing just the terms used in the titles of the applied ecology journals in the early 1990s and the late 2000s we see that the terms of the journals differed more in the early years and that the research published has adapted to each other over the years. One term – manag* – that occurred in Ecological Applications already in the early years, occurs in the Journal of Applied Ecology, too, in the late 2000s. However, since the word control – formerly used by the journal – might have just meant the same and it is just one term that could be called adopted, it is not enough to judge if one journal influenced the other more over the years. Still, it can be noted that the words in the top ten lists of Ecological Applications show more continuity between the time periods than the word lists of the Journal of Applied Ecology indicating that applied ecology research of North America and Europe became more similar over the years.

4. Discussion

4.1 Discussion of material and methods

To start the discussion chapter, I would like to comment on the methods and the material I used to summarise what parts were reasonable and what parts would need adjustment when such a study would be conducted again. If appropriate, I would like to give suggestions which methods and material could be used to deepen the knowledge about applied ecology as a science.

4.1.1 Discussion of material and methods in general

4.1.2 Methods

The decision to use already existing material seems reasonable also in the hindsight because it seems useful to first extract useful information already available before producing new material e.g. via interviews. But in some parts the material choice could be modified and new material might help to understand the problem even deeper. Following, I will go more into this.

4.1.3 Material

During the analysis steps I oriented myself on the principles of Mayring (2010). Basically this means documenting where my data comes from, what kind of data it is and what I have done with it. For qualitative analysis it encompasses also the categorisation of information based on category definitions, anchor examples for what information belongs to which category and documentation which information ends up where. In this kind of analyses dealing with a lot of detailed information, the structured procedure and especially the

categorisations in the qualitative analysis parts helped to gain an overview and to make the information tangible, but simultaneously intersubjectively comprehensible.

The combination of quantitative and qualitative content analysis to extract information from the given material seemed to make sense in this case because the qualitative analysis parts allowed detailed insights into the text material and the quantitative analysis steps helped to undermine and supplement results found. Additionally, it made it possible to analyse a higher amount of material, but without the information gained by qualitative analysis steps the interpretation of the results might have suffered. So qualitative and quantitative content analysis seemed to complement each other well in this analysis, but some improvements and suggestions for future analysis will be explained below for the different analysis steps.

4.1.4 Discussion of material and methods specific

4.1.5 Discussion of material and methods for the analysis of the development of applied ecology

4.1.6 Discussion of specific development analysis

4.1.7 Material

By excluding certain text material from the analysis because it did not seem to contribute significantly to a deeper understanding of the context I might have missed some information. The probability of me having missed information is also given because I decided not to check books about related disciplines like pure ecology or conservation biology for information because I assumed that when it is even hard to find information in the literature especially written about the discipline, searching for information in literature about other disciplines might not be useful thinking from an efficiency related point of view.
However, the material seemed useful to get a general overview about important aspects of the development of the discipline. Now – after this analysis – the picture of what applied ecology is and what it is not is clearer and additional material types might be useful to increase the knowledge about the development of applied ecology even further. For example material

that is not written especially about applied ecology could be useful now because the researcher can judge on the basis of the applied ecology definition what applied ecology is and what not, meaning he or she could also go through documents related to ecological science and judge if the research conducted is applied ecology even though it is not stated. This is what Egerton (1985) did on the basis of bibliographies from forestry science, agriculture and so on. Improving such a concept by doing the analysis on a clear definition which information the researcher is exactly interested in, could be a valuable future research undertaking.

Additionally, there is a general flaw in using text material that gives information about applied ecology. Since I reused material from authors talking about applied ecology and few explain exactly what they mean by that, I gather information about how applied ecology developed, but what the authors think applied ecology is can vary between them. Still, with the objective to structure the available information and to detect patterns, the material seems to offer an appropriate first approach to find out how applied ecology developed over time.

4.1.8 Methods

Conducting a qualitative content analysis with deductively generated categories and the option to build more categories inductively during the analysis process, seems still like a reasonable approach. In this part of the analysis the categories were more helpful to structure information than to be informative themselves. So basing them broadly on my research questions helped to focus on my main questions while reading the material, but I still had the option to add more categories if it would have been necessary. This seems necessary at this early stage of the analysis if one wants to avoid the skipping of information – especially since information about the development of applied ecology was rare either way.

Even though the categories have more a structuring value in this analysis part, they enhance the intersubjective comprehensibility because together with the link numbers, the short comments attached to them and the processed text material they make it possible to retrace where information in the text is exactly coming from more easily. To increase the intersubjective comprehensibility even more, I could have also put the link number that every categorised statement has behind the authors' names when I cited them. I decided against that because without having the analysis tables and all the processed text material

directly available it might confuse the reader more than it helps and with the analysis tables and the processed text material the information can still be found easily.

So the method seems still as a good way to me to extract information out of text material in a qualitative way.

4.1.9 Discussion of general development analysis

4.1.10 Material

Using articles as the basic material for this analysis step still seems like a good choice. But to be precise I did just use the articles available in Web of Science (www.webofknowledge.com, last checked 01.10.2014) and my frequency count is based on the search function of this data base, too. So this means that because I used the topic search when e.g. the abstract of an article was not loaded in the data base system – which can happen especially in older articles – the probability that an article will be counted decreases. Following, my result that the use of applied ecology increases over time might be artificially intensified because old articles are not completely or not at all loaded in the data base.
But since this problem should occur for all continents in the same way, it should not influence the results from the continent comparison. What could influence these results is the problem that probably especially in earlier years the publication in English language was not common in non-English-speaking countries. Still, the amount of material found outside of Europe and North America is so small that it is probably not just a problem of the material gathering process. Apart from that, I compared the data from different continents also by calculating the percentage out of the articles found in one continent in one specific year and the total amount of articles found in one continent. This analysis step helped to decrease the problem of data loss because of the language barrier and made the development in the different continents comparable.
Still, the gathered material was quite few which is for sure a result in itself, but also makes it questionable if it can be used to illustrate the development of the importance of applied ecology research over time. Using not just articles, but also other types of papers and books as material would have increased the material, but on the other hand that might have diminished the informative value of the analysis because the different material types could

have distorted the results. But maybe the little material is just expressing the youth of applied ecology research, so researchers are just into the process of using the term.

4.1.11 Methods

Doing a frequency analysis which is in this case a form of quantitative content analysis (Mayring 2010) seemed useful to get an overview about the development of applied ecology over time based on a bigger data set than it is feasible with qualitative content analysis. Especially because the material search for qualitative content analysis material showed that there is just not that much information out there – which is also a reason for this thesis – it seemed to make sense to complement the already existing knowledge with an additional analysis.
I used the publishing countries of the journals to group them to the different continents. Also other measures can be used for this, e.g. the first author of the article like Barot, Lata & Lacroix (2011) did it when they tried to get an overview about countries publishing ecological engineering articles. This seems to be reasonable, too, but with my method at least the people responsible for the publication of research in a continent judged the knowledge as important, so I assume that this way of grouping the research to continents is not worse than the method of Barot, Lata & Lacroix (2011).

After the first graph showed that the importance of applied ecology research seemed to be a lot higher in Europe and North America than on the other continents, I decided to sum up the other continents. Therefore, I lost information, but I increased the readability if the graph showing the data presented as a percentage.
Presenting the data in five year periods seems to make sense because in a time interval of 101 years sudden fluctuations are not the main interest. Xia (2009) who is interested in the development of forest fragmentation research also decided to structure her data in five year periods even though for a different purpose. But what is important to see in my case is the general development over time and the five year period structure supports this.

To get more detailed results out of the data I could have e.g. followed Xia's (2009) approach that was interested in the development of forest fragmentation research. To compare time intervals she did analyses of variance (ANOVA's) and used the p-value of these tests to

judge if one five year period is significantly different from the following five year period (Xia 2009). But since I was more interested in the general trend, I followed the approach of Barot, Lata & Lacroix (2011) who had the same interest and plotted their data for better visualisation and comparison.

4.1.12 Discussion of analysis of definitions and characteristics of applied ecology

4.1.13 Discussion of definition analysis

4.1.14 Material

To get a first impression of the components of definitions of applied ecology, my material choice seems reasonable. Still, there were few definitions to be found, but through the wide search for definitions that seems to be more a general pattern than caused by my choice to use texts from books and papers to search for it.

4.1.15 Methods

Not using a sophisticated category system here, but just comparing and summarising the two categories was a useful approach for working with this low amount of material.
Looking for definitions in the books first before diving deeper into the analysis of the whole text material gave me a good overview about important topics and helped me to structure my further analysis.

4.1.16 Discussion of characteristics analysis

4.1.17 Material

Here, I worked with material from books because I assumed it would give the most overarching picture of important characteristics of the science and I would have the biggest chance of finding answers to a lot of my questions in the same material type. Indeed, the books dealing with applied ecology do not all follow the same structure, they do not all answer the same basic questions and every author has his or her own agenda which poses challenges especially when trying to compare statements given and see if authors agree on

certain topics. However, the broad overview I gained through my analysis seems to prove that the general idea was working out.

The material I found and used is from the 1970s up to the 2010s, but because of the small amount of the material I did not dare to try and thoroughly interpret it concerning the development of applied ecology over time. So because I analysed all the material together that might impact especially the topics of applied ecology I found. Some of them might be more up to date than others. But still, because I did not try to judge which is the most important topic at this point, but I was looking for the general picture and the internal structure of applied ecology, I think the material gave a good overview.

Now – after this analysis is done – some main characteristics of applied ecology are disclosed, some discrepancies in the authors' opinions revealed and the category system developed can be recycled to simplify and guide the analysis of further material like articles. Maybe the use of more material would make it also possible to judge if there are different characteristics of applied ecology in different countries because here I concentrated on accumulating information rather than separating the information available into continent subsections.
Additionally, new material could be gathered by conducting interviews with applied ecologists about how they perceive their area of expertise or developing questionnaires based on the information gained from text material.

4.1.18 Methods

Gaining detailed information out of the text material given seems to be best possible with qualitative content analysis and combining deductive and inductive category formulation helped to structure the data in a meaningful way. After working with the material for the different analyses steps and knowing its content, I believe this analysis form was the right strategy to not miss information of central explanatory value.

Because I had read the material I used for this analysis before, I knew that there would be useful information in there, but extracting it in an intersubjectively comprehensible way would be challenging due to the amount of the questions I wanted to answer and the amount of different information provided by the authors. Therefore, it seems like a reasonable

decision that I went through the material several times, once to mark all the important information, give the sentences containing information a link number and group them in preliminary categories, and again to review and adjust the category system and the allocation of the information.
This open way of searching for information also made it for example possible to detect the sometimes unclear relationship of applied ecology to management. This is a major advantage of this method because it can detect results that are complex and might make more detailed explanations necessary. For example when the texts give information about the relation of ecology and management it is often not clear if the authors see management as an institution or as a process, if they have the same understanding of the term management in case they mean the process and if they think applied ecology is responsible for management tasks or if it is more about facilitating management. Summarising and structuring this information freely without being forced to git them in a specific form seems to improve the depth of the analysis.

So the categories helped to structure the given information and together with the tables, link numbers and processed material they help to increase intersubjective comprehensibility.

4.1.19 Discussion of analysis of applied ecology in comparison with other disciplines and between continents

4.1.20 Material

After using books as the material of my last analysis I decided that now I gained enough basic information about applied ecology to go back to article material again and analyse it in a quantitative manner.
In the hindsight I still believe that the journals chosen belonged to the most representative ones of the disciplines they publish research about. As a pure ecology journal representing Europe the journal Oikos would have also been an option due to its mission statement, but the five year impact factor is with 3.979 (http://admin-apps.webofknowledge.com/JCR/JCR/, last checked 03.11.2014) lower than the ones of the other journals. Additionally, because the emphasis was put on finding at least one pure and one applied ecology journal with the same publisher in North America and Europe and Oikos does not share a publisher with the other journals, I decided not to use it.

4.1.21 Methods

The use of quantitative content analysis at this late stage of the analysis seemed reasonable because already gained information could now be used as background knowledge for conducting further analysis. The advantage of being able to analyse a lot of data at once should be also used at this point to substantiate given results and also to provide additional information.

Using the article number published in one year divided by the total article number published in a journal in the time frame to compare the different journals made it possible to see the general development of articles published over time, without getting confused by differences in total amounts of articles published in the journals which are of minor relevance here.

Using the titles and not for example whole abstracts for the top ten frequency lists kept the focus on the key words the article authors want to stress. Another possibility of getting the most used words here would have been the creation of a percentage out of the number one specific word is used and the total amount of words used in the titles of a specific journal. Then a decision would have to be made which percentage of the total amount of terms one term has to get to appear on the sought after world list. However, that would have resulted in different word numbers per journal which – again – would have complicated interpretation. Since I was just interested in getting a straightforward impression of the journal material, the method chosen seems sufficient.
For comparing the development of applied ecology in North America and Europe the comparison of the early 1990s and the late 2000s seems sufficient to get a first impression, but this impression could be confirmed by also including the late 1990s and the early 2000s in the analysis. The five year periods themselves seem like a reasonable compromise between being too detailed and too simplistic.

4.2 Discussion of results

4.2.1 Development of applied ecology

The text material analysis showed that during the 1960 up to the 1990 the focus on productivity and utilisation of resources seemed to be a main concern of practical applied ecological research even conservation related thoughts were already part of the self-concept of the discipline. But just in the 1990s concern about the environment and focus on conservation related research grew stronger increasing the focus on making research useful and available to management. During the 2000s this focus was even more strengthened, but also the focus on the influence of society using nature was emphasized and sustainable use as well as a more holistic concept of the science was propagated.

This period from the 1990s to the late 2000s is also the time in which the usage of the word applied ecology in scientific articles started to increase. Even though this development started in Europe already in the late 1970s and dropped again in the late 1980s just to increase again, there might be a relation of applied ecology focussing more on conservation related topics and the growing establishment of the term applied ecology in research. This could be interesting because it could mean that the term applied ecology could be maybe less associated with topics related to productivity and utilisation, but more for topics related to conservation and the concept of sustainability.

Between 1991 and 2010 the articles published in applied ecology journals increased, too, which could be an indicator that the science as such expanded and therefore also the term was used more. But because also the publication of articles in pure ecology and conservation biology journals increased it seems more probable that these biology and ecology related sciences rose for comparable reasons. This still might influence the word use, but the probability seems low.

According to Meine, Soulé & Noss (2006) conservation biology did not just grow from the 1990s on – as we saw in this study – but it was developed as recently as the mid 1980s. So the emergence of conservation biology in the mid 1980s, the rise of conservation related topics in ecology in the 1990s and the rise in the usage of the term applied ecology from the late 1980s on could maybe be connected and caused by the same driving factors. Proving this hypothesis demands further research.

The change in the terms used in applied ecology journals from the 1990s to the 2000s can be seen as a support of the above statements concerning the topic development, even though the time interval might not fit completely. Because in the early 1990s the word stem manag* was just in the top 10 list of the journal Ecological Applications and not in the Journal of Applied Ecology, but it showed up in both word lists of the late 2000s. A follow-up study could check what happened in the meantime, but since the term usage shows up in the total top ten lists of both journals of 1991 until 2010 it is probable that the usage of management related terms rose between the late 1990s and the early 2000s. It is interesting that the term usage also shows up in the top ten lists from 1991 to 2010 and the top ten list focussing just on the late 2000s. This indicates that the topic of using and utilising something – probably natural resources – grew stronger again even though the text material analysis showed that the importance declined during the 1990s. But probably this result can be seen in connection to the rise of the topic of sustainability and the responsibility society has for how the environment is treated and utilised. It seems to support that the holistic approach grew stronger during the 2000s, trying to take all aspects – also human needs – into account in the debate about environmental problems.

What exactly causes the developments of the applied ecology topics over time is indicated by my analysis of applied ecology problems. One of the results of this analysis is that humans define problems. So because applied ecology wants to orientate itself on real-world problems, when the problems of society change, applied ecology science should change accordingly. The change from topics concerned with productivity issues to more conservation related topics and the whish for harmony between nature and people could reflect the general change in Europe and North America from a materialistic to a post-materialistic society. But this has to be proved by further studies.

4.2.2 Applied ecology different continents

It is also interesting that the top ten terms used in the Journal of Applied Ecology and Ecological Applications got more similar from the early 1990s to the late 2000s increasing from four common terms to seven. This can be taken as an indicator for applied ecological research in North America and Europe growing more similar over the years. But even though Egerton (1985) mentions that there are differences between the execution of applied

ecology research between the continents and that the time of the formal organisation of the discipline in the continents differed, none of the other authors even mentions a difference between the continents or broaches the topic in any kind of sense. This could mean that the other authors do not care about continent differences, but this could also mean that the differences are not appreciable. Probably it is a mixture of both, but the second theory could be supported by applied ecology being a young science – e.g. being confronted with globalisation through big parts of its existence – and the two most important applied ecology journals are published in English, so everybody that understands the language and fulfils the standards of the journals can publish in them. Since applied ecology is concerned with finding solutions of environmental problems like global warming it would also seem counterproductive not having scientific exchange over borders and that should lead to an alignment of the scientific cultures. But this theory should be further tested, maybe in comparison with an older science being confronted with more local problems.

That North America and Europe seem to be the continents where most of the applied ecology research is conducted could be connected to the history of ecology. Ecology – founded by the German Haeckel at the end of the 19th century – was a discipline with strong European traditions, but with a growing following in North America (Kingsland 2005). Because ecology has been developed in Europe and North America, it is through its history connected to these continents, it might be that this is reflected in applied ecology still today. But other factors like the language barrier might also be the cause of other continents not showing up under the publishers of titles with the term applied ecology in it. Research about the differences between the development in industrialised and development countries could also be insightful.

Milner-Gulland *et al.* (2012) explain that the Journal of Applied Ecology wants to pay more attention to science originating in developing countries. One of those countries scientific exchange shall be promoted with is China (even though this is a newly industrialized country) (Milner-Gulland 2009). Milner-Gulland (2009) further describes the “pressing need for robust applied science worldwilde” (Milner-Gulland 2009, p. 510). All these statements point into the direction that there is really a problem of especially less developed countries participating in the Western research community and being in exchange with it. This partly supports my data showing that North America and Europe are the most important continents when it comes to applied ecology research. But maybe my data is not necessarily just

showing importance, but also separation of the Western research community to other parts of the world. The existence of the Chinese Journals of Applied Ecology (http://www.cjae.net/EN/volumn/home.shtml, last checked 05.11.2014) is an example for applied ecology research also being published in non-Western countries, even though the language barrier does not make it possible to check if its applied ecology definition would fit to the applied ecology characteristics for example illustrated in this thesis.
To ensure the strong similarity of North American and European research further studies seem appropriate, maybe taking the development of conservation biology and pure ecology into account plus other possible influencing factors like policy changes and developments in the society. It might be also illuminating to monitor the development of the disciplines when the research exchange between the continents should increase like Milner-Gulland *et al.* (2012) want it to.

4.2.3 Relation of ecology and applied ecology

The relation of applied ecology to ecology – its science of origin – is also interesting, especially because authors do not seem clear about how this relation is actually shaped. The ambiguity whether applied ecology is a sub-discipline of ecology, whether theoretical or pure ecology can be called its sister discipline or if it applied ecology is more like a separate discipline outsources from ecology shows there does not seem to be a consistent definition of what applied ecology is and maybe also what pure or theoretical ecology as such is does not seem to be clear for a lot of the authors of the books material used in the analysis. The different way of the authors' using the different terms seems confusing for the reader and counterproductive to communicate what the term applied ecology actually stands for. But the question is if the problem lies more on the side of having different opinions of what applied ecology, pure ecology and ecology are or if it is more different authors using different names for the same thing. The material is not extensive enough to clarify this problem finally, but we can use the information gained about the development of applied ecology as a hint. Since authors at least do not disagree that applied ecology originated out of ecology because the original ecological research did not focus on solving real-world problems, we can understand that some authors just use the terms applied ecology and ecology because ecology was the old term already established and applied ecology was the name for the real-world problem oriented part of ecology. It could have been that the term pure ecology was more frequently

used to name what was originally called ecology because applied ecology was still part of ecology and that way both terms could be summarised under the general term ecology. This would fit especially to the logic of Douglas (1974), but also none of the other authors gives information contradicting this theory. Still, the information acquired just give a hint in this direction and further research has to be conducted – especially also in direction to the general history of ecology – to confirm it.

A different aspect of the problem of confusing terms is in this context unintentionally demonstrated by Nievergelt (1999) who wrote an article about pure or theoretical – he uses the terms in the same context – and applied ecology. The problem occurring is just that the German version of the paper talks literally translated about fundamental research in pure and applied ecology, but the English version of the abstract leaves out the 'fundamental research' part which adds an aspect to what applied ecology can be according to the authors, but got lost in translation. This might add a different angle of how confusing term use and different understandings of terms can occur.

That applied ecology and ecology or pure ecology – however you want to call it – are still connected today is also illustrated by the top ten lists of terms used in the article titles of applied and pure ecology journals. That more than half of the terms are comparable between the journals despite them being published on different continents and publishing different science types illustrates that applied and pure ecology are dealing with comparable topics, especially concerning the ecosystem parts investigated. Both disciplines are also interested in effects in some kind of way, but applied ecology is additionally interested in research related to management and usage probably of natural resources.

This difference might underline the difference between the research process applied ecology and basic ecology – how Olson (1998) calls it – focuses on. Olson (1998) describes that basic ecology focuses more on the question when doing research whereas applied ecology focuses more on finding answers to environmental problems. He thinks that basic ecology tends to pose questions itself, but applied ecology tends to work with questions raised by managers and people involved in decision-making processes (Olson 1998). According to this logic, the stronger focus on management and usage related topics in ecology and more general terms used in research processes in the pure ecology journals seems plausible.

Also Thomas & Blanford concern themselves with pure or basic ecology – as they choose to call it – and applied ecology stating like Olson that they "tend to emphasize different aspects of the research process; the former placing emphasis on the question, the latter on finding answers" (Thomas & Blanford 1999, p. 71). They propose applied ecology and pure ecology should orientate themselves on medicine where the value of solving real problems is not as much questioned as in ecology. This is because Thomas & Blanford (1999) also criticise that through increasingly focussing on impact factors and citation indices to measure research output, applied ecology – which main interest through its focus on problem solving might not necessarily lie on publishing – seems to be rated less than pure science. The impact factor-related problem is also recognised by Memmott *et al.* (2010) who would like to see applied ecology research having a "wider and long-lasting impact" (Memmott *et al.* 2010, p. 4).

4.2.4 Relation of applied ecology and management

The relatedness of applied ecology to management is another unclear topic. No author disagrees that there is a connection between management and applied ecology and that applied ecology somehow seems to need management in certain cases for the solution of problems. Management is described by all authors broaching the topic as the implementing body of applied ecological science. Management is the instance or the tool of putting the knowledge applied ecology gained into practice. But in how far applied ecology is responsible for this problem solving step, if it is always a necessary part of the problem solution, what this management the authors talk about actually is – an institution or an occupation – stays unclear. It is especially interesting that the authors talk in detail about the different problems of ecology – in such detail that it was hard to find fitting categories for the information given – that they also describe quite a lot of goals of applied ecology, that almost all authors agree on applied ecology wanting to solve problems, explain also in quite some detail – even though in an unstructured manner – what tasks related to actual research applied ecology has to contribute to this goal of problem solving, but when it comes to actually explaining what should happen with the gained knowledge all authors stay vague. None of the authors gives any kind of action plan what is supposed to happen with the knowledge despite of that management should do something with it. The development of best practice suggestions and the publishing of books etc. is mentioned, but still, compared

to the partly excessive lists of problems and research occupations the information given seems moderate. This might be an important hint to the probably biggest problem applied ecology has: Not just to want to solve problems, but actually doing it. Applied ecology – having developed out of a science more or less just concentrated on its own not necessarily real-world relevant problems – is confronted with the challenge of wanting to have real-world impact. But maybe it just misses the knowledge or the tools to achieve this important step. Maybe this is also the reason for the authors not being clear about how management is related to applied ecology. Maybe the understanding of the concept of management is insufficient to use it for the profit of applied ecology. But maybe problems of implementing knowledge is also related to communication problems since applied ecology – at least after the results of this analysis – does not really seem to have a concept of getting the knowledge across to people that could make use of it.

Maybe it would help to ask researcher what they do to get their knowledge across and investigate studies where it actually worked to implement suggestions made by the researchers to see what can be learned from that.

Actually, there are studies concerned with the impact research has on the real world. Milner-Gulland *et al.* 2012 collected some of those studies showing that applied research can have impact on policy, but in many cases researchers did not plan on implementing the knowledge gained and managers are not reading scientific papers, so Milner-Gulland *et al.* (2012) also conclude that there is a gap between the ones possessing knowledge and the ones involved in decision making that might have a use of it. They propose that practitioners being involved in the article writing process could be a part of solving this problem (Milner-Gulland *et al.* 2012). Also Hulme (2011) wants to enhance the possibilities of practitioners publishing in the Journal of Applied Ecology so that they have a possibility to communicate to the researchers what their problems are. Memmott *et al.* (2010) go into the same direction wanting to strengthen the focus on papers with "direct relevance to ecological management and policy while maintaining a strong link to basic ecological concepts and theories" (Memmott *et al.* 2010, p. 1) and also points to facilitating communication between academics and practitioners.

But there is also one study (Ormerod *et al.* 2002) stating applied ecology researcher do almost all give recommendations in their papers and in almost 60% there was also evidence that the research was implemented in practice. But this study also states that sometimes curiosity and no clear real-world problem is leading decisions what kind of research is conducted and it has to be stated that the underlying data for this study was based on

statement of the authors writing the papers (Ormerod *et al.* 2002) who might be potentially biased relating to the usefulness of their own studies.

So despite of this study, my results and the results of the authors before seem to indicate clearly that there is a problem of getting applied ecological knowledge implemented in practice. This also helps us to sort out the question in how far management and applied ecology are related. If applied ecology is seen as a research respectively an academic discipline then there is a gap between it. But Memmott et al. (2010) use the term applied ecology in a way that it clearly includes academics and practitioners, e.g. "…facilitate the channels of communication between applied ecologists, from academic to practitioner and *vice versa*" (Memmott *et al.* 2010, p. 3). This line of thought fits to the concept of Douglas (1974) that views everybody as a potential ecologist. So the confusion of how applied ecology is connected with management could also – like in the case of applied ecology and ecology or pure ecology – mainly related to a different understanding of the underlying meaning of certain terms rather than a completely different understanding of the underlying concepts themselves. Applied ecology not possessing a general theory (Beeby 1993) and ecology in general being still in a rudimentary state (Caldwell 1966) could be related to those terminology problems being in existence.

4.2.5 Problem-fixing in applied ecology

Maybe the mentioned implementation problem runs deeper than just laying in the challenge of transporting information from the researcher to the receiver.
The problem could be related to the way applied ecology tries to fix environmental problems. After Heberlein (2012) there are three kind of environmental fixes: The technological fix, the cognitive fix and the structural fix. In his book he shows that in most of the cases only the structural fix – changing human behaviour by changing the structure of the situation – leads to long-term solution of the environmental problem given. The question is now in which kind of environmental fixes applied ecology engages. Since applied ecology does not really seem to have a clear idea how it wants to fix problems, it is also not possible to say definitely which kind of way it prefers to go, but since applied ecology is involved in the development of techniques and tools – also technology based ones – from which it hopes that they can contribute to the problems solution, it might be reasonably assumed that this is

one problem fix applied ecology would go for. Communicating research results seems important in general if you want to propose a technological, cognitive or structural fix, but together with applied ecologists publishing text material for people to inform themselves it hints to applied ecology trying to achieve a cognitive fix, meaning educating the public. This approach shown in my results is reconfirmed by additional sources like Caldwell (1966) thinking the mass distribution of booklets could "increase public understanding and cooperation in the solution of a large number of environmental problems" (Caldwell 1966, p. 526). Freckleton *et al.* (2005) talk about communicating research to an audience as big as possible, too. Furthermore, my results showed that the development of plans can be part of applied ecology and a plan could include or lead to some kind of structural fix. So it seems that some of the knowledge provided by applied ecology might lead to a working problem solution, but a lot of the knowledge accumulated might be not as helpful as desired.

Still, applied ecology seems to keep out of the decision which fixes to choose and to concentrate on providing the ecological part of the information necessary to come up with fixes. This is underlined by my result showing the involvement of applied ecology research in making models, and developing other analytical tools to make for example predictions without stating in which exact context this knowledge is going to be used.

But if the decision is made to work with structural fixes, the fixes introduced must be in line with the dominant attitudes and values of the people confronted with these changes (Heberlein 2012). That is why the current changes in applied ecology in direction of taking the society and its responsibility towards the environment more into account could be the right step in being more effective in problems solution in the future. Because in the 2000s applied ecology started to focus more on sustainability and the role of humans in environmental conservation – even though the wish of living in harmony with nature was already uttered by Douglas (1974) in the 1970s – applied ecology might be more effective in problem solving in the future. That applied ecology is an interdisciplinary science not just connected to other natural sciences but also to social and political research seems like a good asset of overcoming the problem of developing useful information and getting information across to the 'user' because the exchange with other science forms seems – according to Heberleins (2012) statement that understanding human values and attitudes is required for solving environmental problems – necessary and might therefore help in achieving the ultimate goal of problem solving.

4.2.6 Applied ecology as a mission-driven discipline

Since applied ecology seemed to be concerned a lot with conservation related issues and also connected to other natural sciences, the comparison between conservation biology and applied ecology in addition to the comparison between pure ecology and applied ecology seemed like a proper method of not just finding out about the similarities and differences of the disciplines, but also in which direction applied ecology tends. Is applied ecology still strongly connected to its discipline of origin pure ecology? Or is it more related to the clearly mission-driven discipline conservation biology (Meine, Soulé & Noss 2006)? I found that both statements are true because the terms used in the titles of the journals articles that ranked highest were comparable with both disciplines. This helps to illustrate the core of applied ecology. The discipline is still concerned with the same topics than pure ecology is, but it is also a mission-driven discipline like conservation biology. And this mission – inferring from the problems and the goals of applied ecology – extends over just conservation or ecology related topics, but includes economic and social issued as well. Its mission is not just conservation, but the creation of harmony between humans through creating harmony between humans and nature.

That the interaction of humans and nature is a central concern of applied ecology also according to de Pablo & de Agar (2005). Caldwell (1966) adds that ecology suffers from the division of social and biological sciences and sees the same problem in separating economics and ecology. He thinks that "both disciplines are potentially as broad as the values and problems involved in the care and management of the human environment" (Caldwell 1966, p. 526) and believes by working together they could develop problem solutions and implement them in public environmental policy. This is quite an old source compared to the ones I used in my results when I tried to assess the relation of applied ecology to other disciplines, so that might be the reason why in my results the borders between the different sciences do not seem to be so strict anymore.
The problem that humans should take their responsibility concerning the environment arising from these human – nature interactions more seriously has been already mentioned in the results chapter and is affirmed by Caldwell (1966) who criticises the lack of the public realising this responsibility.

The different society organisation that might be necessary to achieve this state of harmony is mentioned by Travis (1977) who describes that the no- or low-growth is the way to go in times of environmental and life change on the planet and he sees “planning as applied ecology” (Travis 1977, p. 6) which he uses as a different term for “creative conservation planning” (Travis 1977, p. 6) as a necessary asset for this new society order.

4.2.7 Understanding of applied ecology

The usage of the term applied ecology in scientific articles shows how unimportant the term seems to be in research papers. And if the term is not used often, it would be interesting to look in the reasons for that. It might be an indicator for applied ecology being not as important as it would like to be and it might also be an expression of the problem that there does not seems to be a clear acknowledged definition out there of what applied ecology actually means.

But through my analysis it got clear that the authors write about common characteristics of applied ecology and even though they do not always state exactly the same characteristics and write unclear about the relation of applied ecology to ecology and management, they seem to agree that applied ecology can have different kinds of problems related to ecology, economics and social aspects, they agree on humans being a threat to the environment and on certain environmental aspects being a threat to humans, they agree on wanting to solve real-world problems, on the general steps to do applied ecological research to gain knowledge about problems and develop solutions, and they all do not seem to know exactly how to implement the solutions practically – or at least they do not tell the reader.

Thus, the authors agree on big parts of what applied ecology is and what it is supposed to do. Especially the descriptions of the tasks of applied ecology and the different forms of solutions they propose can be seen as a start of a theoretical description of applied ecology, or at least a start of summarising common structures concerning what research does and what its aims are.

Therefore, it is surprising that few authors actually define applied ecology in their texts. But maybe they assume to mention that applied ecology applies ecological research is already a

sufficient definition. That would also explain why they do not go into detail on how this application is actually supposed to happen.

This could be related to applied ecology's roots in pure ecological research. Additionally, Douglas (1974) states that ecologists work in practice on pure and applied ecological topics because a division of both fields in practice would be artificial. However, when researchers have a strong pure ecology background and less other capabilities like management and social science skills, it might hinder them of seeing possibilities to get results implemented. This was also discussed on the seminar on challenges of applied ecology in Evenstad, Norway on 14th October. Mc Pherson & De Stefano (2003) state that managers and scientists should work together to improve their effectivity. This could be one possible way of overcoming the problem. But since researchers and managers tend to not pay attention to one another (Milner-Gulland *et al.* 2012) it might not be an easy one.

But it might not just hinder the implementation of solutions, it might also hinder the development of solutions that work. When the authors were talking about problem solutions, analytical and technology-based solutions were big topics. Experiments and other practical tests of methods were mentioned, but not that often. Most authors saw models and other predictive tools as the solution they can offer to solve real-world problems. However, since these tools just explain a given situation and predict a future situation (Slobodkin 1988), that might not be enough to solve the problem which has also been discussed on the mentioned conference in Evenstad on the 14th October.

My analysis showed that authors writing about applied ecology do not seem to have a clear understanding of in how far it is responsible for implementing solutions and how to do it. Additionally, the type of solutions they are proposing might be semi-useful in practice.

4.2.8 Future of applied ecology

By detecting the parts of applied ecology the authors can agree upon, a common basis of understanding for discussions of the future of applied ecology research is identified. By detecting the parts of applied ecology where the understanding of applied ecology differs between authors, a topic to discuss about is found, too.

That applied ecology has problems with implementing its research results might not be news, but that it could be caused by a different and in parts indistinct understanding of the science itself has been clarified. Keeping in mind that not everybody means the same when stating that one wants to apply research and find solutions can help to focus discussions and avoid that people unconsciously talk at cross. This will help not just in discussions between applied ecology researchers, but also between applied ecology researcher and managers, practitioners and the public in general.

The information about the development of applied ecology helps to consolidate this knowledge because it shows where applied ecology is coming from, which helps to understand the scientific tradition of the discipline, that its major topics changed over time, which helps to understand that the science is not static and changes in time with the problems it wants to solve, and that it is likely to develop further in the future.

Further research could try to clarify further especially how applied ecologists see their discipline connected to management and how they would tackle problems with the help of applied ecological research. Maybe a study identifying what kind of problem solutions actually work in practice would help, too. This knowledge could be an important additional asset in the necessary discussion of how far applied ecology wants to be involved in the solution implementation process.

5. Conclusion

Applied ecology is an interdisciplinary science with strong relations to pure ecology and conservation biology. The research form is especially conducted in North America and Europe. Since the 1960s applied ecology developed from a discipline focussed over productivity and utilisation related topics over conservation related topics to a stronger focus on social aspects today. The research in North America and Europe aligned with each other more and more over the last 20 years.

Applied ecology developed out of the science of ecology and uses ecological knowledge to find solutions for real-world problems that can be of long- or short term dimension. It is concerned with ecological, economical and social problems that are connected to each other and are defined by humans respectively the society. The overall goal is to achieve harmony between humans and the environment. To do so, applied ecology uses knowledge especially provided by pure ecology, identifies knowledge gaps, if necessary conducts own studies to fill knowledge gaps, tries to find analytical, technology-based or experimental solutions for problems, formulates good practice suggestions and writes about the research outcome. It aims at implementing the results and sees management as one important component to do so.

People engaged in applied ecology seem to disagree about how strong the relation of applied ecology to management is and what applied ecology should do to implement proposed solutions.

Hopefully, this clarification of what applied ecology is, respectively how it is understood by the people working with it, will help to avoid communication problems in the future. The topics in which the understanding of applied ecology is unclear might be kept in mind for future discussions and research to clarify them and work towards a more effective applied ecology science.

This first attempt to summarise, structure and exemplify what applied ecology is and how it is understood can be broadened and modified in the future to come closer to a commonly acknowledged theory or structure underlying applied ecology. The thesis will hopefully

increase the awareness that differences in the perception of applied ecology exist and that they have to be at least acknowledged, if not better clarified, for fruitful discussions and the development of problem solutions.

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7. Appendix 1. Material for qualitative content analysis. X means used, (x) means checked and nothing found, empty space means not checked

material qualitative content analysis			
books	history	definition	characteristics
Ambasht & Ambasht (2002), p. ix-xii	x	(x)	x
Ambasht & Ambasht (2003), p. ix-xi	x	(x)	x
Beeby (1993), p. ix-27	x	(x)	x
De Santo (1978), p. vii-5	x	(x)	x
Douglas (1974), p. 13-32	x	x	x
Hayward (1992), p. vii-viii	x	(x)	x
Hinckley (1976), p. v-13	x	(x)	x
Mavrodiev (1999), p. vii-xv	x	(x)	x
Mc Pherson & De Stefano (2003), p. ix-16	x	(x)	x
Newman (2000), p. vii-6	x	(x)	x
Richter & Weiland (2012), p. 1-12	x	(x)	x
Sakhare & Vasanthkumar (2011), p. ix-x	x	(x)	x
Verdade, Lyra-Jorge & Piña (2014), p. v-vi	x	(x)	x
papers			
de Pablo & de Agar (2005)	x	(x)	
Ormerod (2003)	x	(x)	

Slobodkin (1988)	x	x	
Caldwell (1966)	x	(x)	
Fernow (1903)	x	(x)	
Memmott et al.(2010)	x	(x)	
Thomas & Blanford (1999)	x	(x)	
Freckleton et al. (2005)	x	(x)	
Milner-Gulland et al. (2013)	x	(x)	
Egerton (1985)	x	(x)	

8. Appendix 2. Categories for the analysis of the development of applied ecology

development of applied ecology		
category name	**category definition**	**anchor example**
before formal organisation	Information related to applied ecology before the formal organisation of the science.	"applied ecological problems were investigated long before they were organized fields of applied ecology" (Egerton 1985, p. 104 / link number 104.1)
time of formal organisation	Information related to applied ecology about the time of the formal organisation of the science.	"applied ecology became organized in the United Staes after Congress passed the National Environmental Policy Act in 1969" (Egerton 1985, p. 104 / link number 104.4)
reasons for development	Information about why applied ecology developed.	"ecology, however, had remained mainly rooted in botany and zoology" (Ambasht and Ambasht 2003, p. ix / link number ix.4); "it did not permeat hard sciences, engineering, or industrial technologies leading to widespread environmental degradation, pollution, and frequent episodes leading to mass deaths and diseases" (Ambasht and Ambasht 2003, p. ix / link number ix.5); "in this direction there is an acute need for books on applied ecology" (Ambasht and Ambasht 2003, p. ix / link number ix.7)
general course of development	Information about the development of applied ecology given without a	"ecological concepts and issues of environmental quality are increasingly freatured in the communications media" (Caldwell 1966, p. 524 / link number 524.2);

	clea time specification.	"there is an influential and nationwide receptivity to applied ecology" (Caldwell 1966, p. 524 / link number 524.2 1/2)
time periods of development	Information about the development of applied ecology given with a time specification.	"fifty years ago, applied ecology was widely viewed as the poor relation of the more glamorous fundamental areas of this young science" (Millner-Gulland et al. 2013, p. 1 / link name 1.1)
development related to other disciplines	Information about the development of applied ecology in connection to other disciplines	"restoration ecology offers yet another example where the application of ecology simultaneously provides academic leadership and solutions to real environmental problems" (Ormerod 2003, p. 44 / link number 44.3)

9. Appendix 3. The grouping of the countries to the continents

North America	Europe	Oceania	Central and South America	Asia
Canada, United States of America	Czech Republic, Netherlands, France, Switzerland, Norway, Moldova, Slovakia, Denmark, Bulgaria, Portugal, Hungary, Germany, Italy, Finland, Sweden, Spain, Poland, Russian Federation, England	Australia, New Zealand	Venezuela, Argentina, Chile, Costa Rica	Japan, China, Singapore

10. Appendix 4. Category table for analysis of applied ecology in context with other disciplines

applied ecology and other disciplines		
category name	**category definition**	**anchor example**
applied ecology and ecology	Text gives information about the conenction of applied ecology and different other forms of ecology in a direct or indirect way.	"nor does it affect the distinction that exists between pure ecology and applied ecology" (Douglas 1974, p. 21 / link number 21.3); "while the former is concerned with the acquisition of fundamental information, the latter is devoted chiefly to putting into practice the knowledge obtained from ecological studies" (Douglas 1974, p.21 / link number 21.4)
applied ecology and management	Text gives information about the conenction of applied ecology and management in ist insitutional understanding and ist understanding as a concept in a direct or indirect way.	"applied ecology is designed for versatility" (Hinckley 1976, p. v / link number v.2); "it can be used by instructors with diverse professional interests including population control, resource management, or pollution abadement" (Hinckley 1976, p. v / link number v.3)
applied ecology and other disciplines	Text gives information about the connection of applied ecology to other scientific disciplines in general or specifically related to certain desciplines.	"the student of this intricate field must certainly seek support from an interdisciplinary understanding not commonly reinforced by the fragmented course of study offered in a formal and clasical education system" (De Santo 1978, p. 2 / link number 2.5)

applied ecology and society	Text gives information about the connection of applied ecology to the society meaning any human groups that are not a scientific discipline.	"the need for cooperation between ecologists, other professionals, and all concerned citizens is stressed if we are to solve our problems" (Hinckley 1976, p. 12 / link number 12.6)

11. Appendix 5. Category table developed for the analysis of existing problems of applied ecology

existing problems		
category name	**category definition**	**anchor example**
pollution	Something is added to the environment that does not belong there originally.	"applied ecology is about […] solving pollution problems" (Beeby 1993, p. x / link number x.3)
environmental change	The environment or processes of the environment are changing compared to a previous state.	"the increasing levels of global warming, the depletion of the ozone layer […] have also made everyone aware of the growing environmental concerns" (Sakhare & Vasanthkumar 2011, p. ix / link number ix.2)
destruction	The environment or parts of the environment are destroyed, mostly in a direct manner.	"era in which biodiversity loss and the ecological consequences of environmental degradation are increasingly unacceptable" (Verdade, Lyra-Jorge and Piña 2014, p. v / link number v.5)
exploitation	The environment or parts of the environment are used in an unsustainable manner.	"serious damage caused by thoughtless exploitation of natural resources" (Douglas 1974, p. 29 / link number 29.12)
invasive species	Problem description concerning the dispersal of a species into a territory where it has not been before.	"humans have increased the rate of extinction directly by the destruction of habitats, deforestation, introduction of exotic species that do not have predators and pollution" (Ambasht and Ambasht 2002, p. xi / link number xi.4)

pests, weeds and diseases	Organisms taht are identified as negative to humans	"things we do not want - weeds, pests, diseases" (Newman 2000, p. 5 / link number 5.2)
productivity loss	After human measures the environment changes in a way that it is not as useful for humans as it was before.	"where the ill effects are uncontrolled and become cumulative, a decline in productivity of the land often occurs" (Douglas 1974, p. 27 / link number 27.3)
human population growth	The population of humans is increasing and this is seen as a problem.	"problems associated with technological impacts, resource depletion, and changes in human population distribution and abundance" (Hinckley 1976, p. 12 /link number 12.2)
human health and security	The health and security of humans is threatened by processes happening connected to the environment.	"show how the growth of Indian mega-cities has been and is being accompanied by severy environmental problems and health risks, especially related to air and water pollution and poor sanitary conditions" (Richter and Weiland 2012, p. 1 / link number 1.2); "continuing problems of [...] national as well as ecological security" (p. ix / link number ix.1)
ignorance	Humans ignore the knowledge other humans provide.	"many ecological investigations are pursued without appropriate consideration of management implications" (Mc Pherson & De Stefano 2003, p. 1 / link number 1.3)
political system	The political system is a problem because of environmental issues.	"the doctrine of unlimited growth, which incidentally is unknown in nature, so assiduously propagated in certain quarters today, is a complete misconception" (Douglas 1974, p. 24 / link number 2 1/2)

12. Appendix 6. Category table for the analysis of the causes of problems of applied ecology

problem cause		
category name	**category definition**	**anchor example**
pollution	Text describes what causes the particular problems understood under the category topics	"fumes from smelters in the local copper mines were allowed to escape and killed off forest trees for many miles around" (Douglas 1974, p. 29 / link number 29.4)
environmental change		"rapid industrialisation, lure of fast financial gains, and commercialisation activities creating global rises in temperature, and CO2 levels and increased ultraviolet B at ground level" (Ambasht and Ambasht 2002, p. ix / link number ix.1)
destruction		"humans have increased the rate of extinction directly by the destruction of habitats, deforestation, introduction of exotic species that do not have predators and pollution" (Ambasht and Ambasht 2002, p. xi / link number xi. 4)
exploitation		"increasing human population puts further pressure on basic resources, including land and soil, oceans, fresh water and energy sources" (Newman 2000, p.1 / link number 1.3)
invasive species		"the indroduction, without care and forethought, of new species into an environment can often result in the extinction of existing species" (Douglas 1974, p.20 / link number 30.1)
pests, weeds		"monocultures or the growing of pure stands of single species does away with variety and offers unrivalled

and diseases		chances for the outbreak of diseases and plagues" (Douglas 1974, p. 28 / link number 28.10)
productivity loss		"these natural conditions, however, rarely fit in with civilised man's requirements and so he modifies them, causing an upset in the banalce of nature" (Douglas 1974, p. 27 / link number 27.2); "when this is done on a large scale or when the ill effects are uncontrolled and become cumulative, a decline in productivity of the land often occurs" (Douglas 1974, p. 27 / link number 27.3) [caused by men -> link number 27.2]
human population growth		
human health and security		"show how the growth of Indian mega-cities has been and is being accompanied by severy environmental problems and health risks" (Verdade, Lyra-Jorge and Piña 2014, p. 1 / link number 1.2)
ignorance		
political system		

13. Appendix 7. Category table for the analysis of reasons why something is a problem of applied ecology

reason for problem		
category name	**category definition**	**anchor example**
pollution	Text describes the actual reasons for the problems understood under the category topics to be problems in the first place	"radioactive pollutants [...] can be little doubt that the manner in which such substances alter the environment and move in food chains are highly relevant to the welfare, health and future happiness of all living creatures" (Douglas 1974, p. 29 / link number 29.8)
environmental change		"widespread surge in […] global climate changes creating global rise in temperature, and CO2 levels and increased ultraviolet B at ground level" (Ambasht and Ambasht 2002, p. ix / link number ix.1); "these threats to human health" (Ambasht and Ambasht 2002, p. ix / link number ix.2)
destruction		"habitat fragmentation and reduction worldwide at steady rates and scales and populations are reducing in numbers and becoming genetically eroded and therefore compromising its long term persistence, the consequences of this biotic impoverishment to human beings through the loss of biodiversity-based ecosystem services and the consequent decay of entire ecosystems, are being more and more acknowledged by practitioners, decision makers, and society in general" (Verdade, Lyra-Jorge and Piña 2014, p. 4 / link number v.4)
exploitation		

invasive species		
pests, weeds and diseases		
productivity loss		"the consequences of this biotic impoverishment to human beings through the loss of biodiversity-based ecosystem services and the consequent decay of entire ecosystems, are being more and more acknowledged by practitioners, decision makers, and society in general" (Verdade, Lyra-Jorge and Piña 2014, p. 4 / link number v.4)
human population growth		"inreasing human population puts further pressure on basic resources" (Newman 2000, p. 1 / link number 1.3); "it will become more difficult to provide adequate amounts of food and timber" (Newman 2000, p. 1 / link number 1.4)
human health and security		
ignorance		"in many cases, such difficulties could have been foreseen - and indeed were by qualified persons - and prevented by the use of applied ecological methods, had there been better understanding of the dangers in the right quarters, so that proper remedial action was taken in time" (Douglas 1974, p. 31 / link number 31.6)
political system		"the doctrine of unlimited growth" (Douglas 1974, p. 24 / link number 24.2 1/2); Those who advocate this approach to modern problems are in reality scourging the environment and forging a vicious weapon that will eventually turn upon them and

		those they lead and destroy them all" (Douglas 1974, p. 24 / link number 24.2 3/4)

14. Appendix 8. Category table for analysis of goals of applied ecology

goals		
category name	**category definition**	**anchor example**
ecology	Information related to applied ecology having goals connected to ecology like biodiversity and conservation.	"applied ecology is about conserving habitats, endangered species or solving pollution problems" (Beeby 1993, p. x / link number x.3)
economics	Information related to applied ecology having goals connected to economic issues like productivity and utilisation.	"ensure sustained, continuously profitable and maintained production" (Douglas 1974, p. 26 / link number 26.2)
social issues	Information related to applied ecology having goals connected to social issues like human health and safety	"sometimes it can help with resolution of conflicts, for example over alternative uses of land" (Newman 2000, p. vii / link number vii.8)
overall goal	Information related to applied ecology having goals connected to	"such framework that focuses on the application of ecological theories, methods, and knowledge to address human-mediated environmental challenges and develop solutions to create a harmonized interaction between

	achieving harmony between people and people as well as people and humans.	people and nature is the main target of applied ecology" (Verdade, Lyra-Jorge and Piña 2014, p. v, / link number v.2)

15. Appendix 9. Category table for analysis for tasks of applied ecology

tasks		
category name	**category definition**	**anchor example**
collect existing information	Information related to applied ecology collecting and summarising information already existing.	"reviewed modern literature on different definitions, myths and facts, causes of biodiversity losses and methods of biodiversity conservation" (Ambasht and Ambasht 2002, p. xi / link number xi.2)
gain new information	Information related to applied ecology working on gaining information that have not been existing before.	i.5: "joint unified system for collection and processing of data" (Mavrodiev 1999, p. xv / link number xv.5)
develop tools and techniques	Information related to applied ecology working on improving and developing tools and techniques.	"applied ecology […] concerned with lots of midterm corrections of old technologies and reformation of new ones" (Ambasht and Ambasht 2002, p. ix / link number ix.4)
develop good practice suggestions	Information about applied ecology developing good practice suggestions.	"increasingly, applied ecologists include humans as integral to the systems they study and seek to characterize the relationship between human actions and biological responses, to develop plans to remediate the effects of human actions, or to inform decision-making processes that regulate human activities" (Verdade, Lyra-Jorge and Piña 2014, p. v /

		link number v.3)
distribute knowledge	Information about applied ecology distributing knowledge.	"information about the results from investigations and predictions given to every citizen" (Mavrodiev 1999, p. xv / link number vx. 5)