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Evaluation of biosciences in Norway

Publication and citation analysis – a national profile

Henrik Karlstrøm and Dag W. Aksnes

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Preface

This report presents a bibliometric analysis of research in biosciences in Norway and is a background report for the evaluation of the area. The main intention is to provide a general overview of the national research profile, where both units encompassed by the evaluation and other units are included. Specific analyses of the units included in the evaluations are presented in separate reports. The report is written on the commission of the Research Council of Norway (RCN) by senior researcher Henrik Karlstrøm and research professor Dag W. Aksnes at the Nordic Institute for Studies in Innovation, Research and Education (NIFU).

Oslo, 23.03.23

Espen Solberg

Head of research

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Summary

Norwegian researchers contributed to more than 4300 bioscience publications in 2021, of which approx. 2400 were within biology and 1900 in other biosciences. There has been a considerable growth in the publication output of Norwegian biosciences during the recent 10-year period. Overall, the increase is 33% in terms of number of publications. However, there has been an even stronger growth in the general Norwegian publication output during the period. This means that the relative position of the field in the overall national research landscape is weakened, measured by publication volume.

The University of Oslo and The Norwegian University of Science and Technology are the largest contributors to Norwegian bioscience research publication output. Next follow the University of Bergen and the Norwegian University of Life Sciences. In addition to research carried out by higher education institutions, units in the institute sector as well as hospitals make major contributions to Norwegian bioscience research. Among these, the largest single units by publication numbers are the Norwegian Institute of Marine Research and Oslo University hospital.

In terms of citation rate, Norwegian bioscience research performs reasonably well with a citation index of 119 (2018-2020). This means that the publications are cited 19 % above the world average. This is quite close to the total Norwegian average (all fields combined), which is 120. The publications in some of the subfields (e.g. genetics and fisheries) are particularly highly cited.

There is extensive international research collaboration. In biosciences, 75 % of the publications had co-authors from other countries in 2019-2021. In other words, three out of four publications were internationally co-authored. This is significantly higher than the overall Norwegian average. The USA is the most important collaboration partner, and 20 % of the Norwegian articles within biosciences also had co-authors from this nation.

1 Introduction

This report presents statistics and indicators of the scientific peer-reviewed publication output of Norwegian biosciences. The report is primarily meant to function as a factual background report to the panels and committees involved in the evaluation of the research activities in Norway. Further assessments and considerations regarding the findings are therefore left to the evaluators.

Publication and citation analyses have relevance in the context of science policy and research evaluation. The relevance relies on the assumption that new knowledge – the principal objective of basic and applied research – to a large extent is disseminated to the research community through publications. Publications can thereby be used as indirect measures of knowledge production. Data on how much the publications have been referred to or cited in the subsequent scientific literature can in turn be regarded as an indirect measure of the scientific impact of the research.

The analysis in this paper encompasses data and analyses at the overall national level and of specific disciplines/areas within biosciences. Included are indicators on topics such as:

- Publication volume
- Citation impact indicators
- National and international collaboration measured through co-authorship

A fundamental issue when analysing fields bibliometrically concerns delineation and classification. For the evaluation in question, RCN has provided a thematic panel description. There is, however, no predefined bibliometric category system which corresponds to this specific division of panels. The analyses of disciplines/subfields within the biosciences rely on a predefined classification system developed by the Norwegian Association of Higher Education Institutions (UHR), consisting of 87 different discipline/subfield categories with all areas of science.

The classification method involves journal-based subfield definitions and is further described in the next chapter. To make the analysis more relevant for the different evaluation panels, we have aggregated subfields into broader categories in order to correspond with the panel division of the disciplines encompassed by the

evaluation. However, since the analysis is based on predefined discipline/subfield categories, there are limitations concerning this degree of correspondence.

In the analyses, the category systems described above, will be applied in a constituting way, meaning that the publication output will be delimited using this system, and the various categories distributed under the evaluations where they have relevance.

For analysis of publications from each administrative unit included in the evaluation, we refer to the separate reports for the units. In these reports, all publications of a biology department will be included, regardless of whether the publications are classified as under Biology in the publication databases. In the present report, only publications in the covered categories are included. This means that if a biology department has published in journals classified as earth sciences, these publications are not included.

The report is structured as follows:

- Chapter 2: Presents the data and the methodology applied in the study.
- Chapter 3: Provides an overall bibliometric analysis of the biosciences in Norway.
- Chapter 4: Covers biology, which largely corresponds to the research evaluated by Panel 1 to 3:
    - Panel 1: Land and freshwater based ecosystems, resources and environment.
    - Panel 2: Marine ecosystems, resources and environment.
    - Panel 3: Ecological and evolutionary biological subject).
- Chapter 5: Covers other biosciences, other disciplines/subdisciplines that are relevant for the evaluation and for specific units encompassed by the evaluation. A mixed bag of fields, which has main relevance for Panel 4:
    - Panel 4a: Molecular biology and physiology of animals, plants and microorganisms. Mainly non-human issues.
    - Panel 4b Molecular biology and physiology. Mainly human issues).

However, as is evident the match between chapters and panels is limited. The report contains a large number of tables and figures. Within the scope of this project, we have not been able to give detailed comments on all indicators presented. Rather, we give some examples of how the tables should be read and comment on major patterns. Hence, this is primarily a technical report providing background for the evaluation. As each chapter is intended as a stand-alone contribution which can be read independently of the other chapters, there is extensive use of repeating text.

Please note that the report does not include any extensive international comparisons and benchmarking. Such analyses will be provided in a later report: *A bibliometric analysis of Norwegian sciences. Trends and international comparisons.*

2 Data and methods

2.1 Data sources

2.1.1 The Cristin database

The analysis is primarily based on the publicly accessible Cristin-database, which is a joint system for registration of scientific publications applied by Norwegian higher education institutions, research institutes and hospitals. The Cristin publication data (scientific/scholarly publications) are summarised in the Database for Statistics on Higher Education (DBH) and are used for the calculation of the performance-based budgeting of Norwegian higher education institutions and research institutes (see text box next page).

The Cristin database contains data on a variety of bibliographic parameters, including publication type, publication channel, and publication language. In addition, it includes individual data of the authors, such as their institutional affiliations, age and gender. Accordingly, statistics on many aspects of the publication activity can be provided.

The analysis in this report is limited to the publication categories included in the Norwegian performance-based funding system, namely monographs and contributions to anthologies (book articles) published at publishing houses classified as scientific/scholarly by the Norwegian Association of Higher Education Institutions (UHR), and articles in series and journals classified as scientific/scholarly by UHR. Publications which are outside these channels are not included in our analysis. For example, unpublished PhD-dissertations, "grey literature" such as reports, as well as popular science articles. Hence, the analysis covers the publications primarily directed towards the scientific community, but not other types of research disseminations. This needs to be taken into consideration when interpreting the results.

The performance-based basic funding system – publications

The funding formula for publication activity includes two dimensions. First, articles in journals and series (ISSN-titles), articles in books and books/monographs (ISBN-titles) are given different weights. Moreover, publication outlets are divided into two levels in order to avoid an incentive to productivity only. The outlets given extra weight are those defined to be the leading and most selective international journals, series and publishers (limited to about 20 per cent of the publications). The national academic councils in each discipline or field of research participate annually in determining and revising the highest level under the guidance of the Norwegian Association of Higher Education Institutions (UHR). The table below shows the relative weights given the different types of publications at the two levels.

Table Publication weights

Publication type	Outlets at normal level (level 1)	Outlets at high level (level 2)
Articles in ISSN-titles (journals & series)	1	3
Articles in ISBN-titles (books)	0.7	1
Books (ISBN-titles)	5	8

Note: Co-authored publications are shared among the participating institutions.

The formula only includes scientific publications. The definition is that a scientific publication must:

1. present new insight;
2. be presented in a form that allows the research findings to be verified and/or used in new research activity;
3. be written in a language and have a distribution that makes the publication accessible to most interested researchers;
4. appear in a publication channel (journal, series, book publisher) that has routines for external peer review. (Source: "Vekt på forskning" English translation, UHR 2007).

Co-authored publications are shared, and fractionalised publication points are calculated based on the number of author addresses. Publication points are used in the performance-based funding system for both the higher education sector and the institute sector and hospitals). The formula is identical across sectors.

2.1.2 The Web of Science database

In addition, the analysis is based on the Web of Science (WoS) Core collection database, covering the underlying sub databases: Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, Emerging Sources Citation Index, Conference Proceedings citation indexes, and Book Citation Index. We have applied a local version of WoS maintained by the Norwegian Agency for Shared Services in Education and Research. This is a database covering more than 22,000 specialized and multidisciplinary scientific journals with peer review, in

addition to a selection of scientific books and conference proceedings. Even if the coverage is not complete, the databases will include all major journals within natural sciences, medicine and technology and is generally regarded as constituting a satisfactory representation of the research within these fields (Aksnes & Sivertsen, 2019).

The WoS-database is applied for the calculation of citation indicators and for collecting publication data from units which do not apply the Cristin database such as companies and firms in the business sector. Although these units are not part of the evaluation, and they publish rarely in scientific journals, they have been included to obtain a complete national picture.

2.2 Methods

2.2.1 Field classification system

As described in the introduction, the analyses rely on a predefined discipline/subfield classification system developed by the Norwegian Association of Higher Education Institutions (UHR), consisting of 87 different categories with all areas of science. The classification method involves journal-based subfield definitions, meaning that all articles in a given journal are assigned to the same field. Although such a journal-based field classification is not very accurate (Leydesdorff & Rafols, 2009), it provides a rough picture of the overall profile. For an overview of these categories and list of the journals which are included in each field we refer to the website: https://npi.hkdir.no/fagfeltoversikt

As noted above, subfields have been classified together as to correspond with the panel division of the disciplines encompassed by the evaluation. However, since the analysis is based on predefined categories, there are limitations concerning this degree of correspondence, see Table 2.1.

Tabell 2.1 Overview of the field, chapters and panel structure

Evaluation of biosciences		
Cristin-field	Covered by chapter (this report)	Main relevance for panel
Biology[1]	3, 4	1-3
Biotechnology[1]	3, 5	4
Biomedicine	3, 5	4
Veterinary medicine	3, 5	4
Nutrition	3, 5	4
Environmental technology and industrial ecology[1]	3, 5	4

1) These categories are no longer in use (from 2022) and is therefore not presented on the website.

In the field classification system of the Cristin database, publications in multidisciplinary journals like *Nature* and *PlosOne*, are not field classified but instead assigned specific categories for these journals. This is unfortunate as the publication volume of a particular subject or discipline is underestimated when publications in these journals are not included. As part of the project, we have therefore developed an algorithm allowing these publications to be attributed specific field categories. For this work, we have made use of the reference list of the publications and the field classification of the references in these. Publications in multidisciplinary journals have been reclassified according to the most referenced fields of these publications.

2.2.2 Publication output

The analysis is limited to the ten-year period 2012-2021, with the main emphasis on the recent years. The analysis is limited to the following publication types: full-papers (regular articles, proceedings articles) and review articles published in journals or books and books/monographs. Publications not covered by these categories are not included (for example material such as letters, editorials, corrections, book-reviews, meeting abstracts, etc.).

A main issue in all evaluative use of bibliometric indicators concerns the issue of counting methods. This is related to the fact that most publications have more than one author. Thus, the question arises whether these should be credited individual authors, institutions and countries. Over the years, a large number of indicators have been developed (Gauffriau, 2017). In citation analyses the issue is particularly urgent as citation frequencies generally are extremely skewed (Aksnes et al., 2012). The most common approaches are either "whole counting", where a publication is fully credited all contributors or "fractionalized counting" where credit is divided proportionally. The Norwegian publication indicator is a compromise taking publication characteristics of fields into account and is developed internationally as Modified Fractional Counting (Sivertsen et al., 2019), but where other elements of the Norwegian publication indicator (weighting of journal/publisher level, and international collaboration) are omitted. Modified Fractional Counting was used in the recent version of RCN's S&T Indicator report, and is also used in most of the analyses here, with the exceptions of analyses where adjusting for relative contribution is less relevant (e.g. analyses of international collaboration). The indicator is termed "modified author shares" in the analyses.

2.2.3 Citation indicators

It is commonly assumed that articles are more or less cited in accordance with the impact they have on further research. Based on this assumption, citations are often used as an indicator of scientific impact or influence, and thus as a partial measure of quality. Although citation analyzes are increasingly used in research performance analyses such indicators cannot replace an evaluation carried out by peers. This is due to the various limitations of citations indicators. Moreover, citations do not necessarily reflect societal usefulness or extra-scientific relevance.

The Web of Science database also includes information on how many times the articles have been referred to or cited in the subsequent scientific literature indexed in WoS. These data have been used to calculate citation indicators. In absolute counts, the units with the largest number of articles would of course also receive the highest number of citations – these units have more papers that can be cited. It is, however, common to use a size-independent measure to assess whether a unit's articles have been highly or poorly cited.

It is the individual articles and their citation counts that represent the basis for the citation indicators. In the citation indicators we have used accumulated citation counts (up to and including 2021) and calculated an overall (total) indicator for the whole period. This means that for the articles published in 2017, citations are counted over a 5-year period, while for the articles published in 2019, citations are counted over a 3-year period (or more precisely a 2–3-year period: the year of publication, 2020 and 2021). Articles from the most recent year (2021) are not included in the citation analysis as these have not been available in the literature for a sufficiently long time to be cited. We have used accumulated citation counts and calculated an overall (total) indicator for the whole period.

The average citation rate varies a lot between the different scientific disciplines. As a response, various reference standards and normalisation procedures have been developed. The most common is the average citation rates of field in which the particular papers have been published.

One such indicator is the relative citation index *MNCS* showing whether a scientific publication has been cited above or below the world average (=100). Here, each article is compared with the average paper in the respective field[1] and year by publication type[2]. It is also weighted by the author contributions of the authors

[1] Subject field as defined by WoS, see overview: https://support.clarivate.com/ScientificandAcademicResearch/s/article/Web-of-Science-List-of-Subject-Classifications-for-All-Databases?language=en_US. In the classification system, some journals are assigned to more than one subfield. In order to handle this problem we used the average citation rates of the respective subfields as basis for the calculations for the multiple assigned journals. The indicator was then calculated as the ratio between the average citation rate of the articles and the average subfield citation rate.

[2] See overview here: https://images.webofknowledge.com/images/help/WOS/hs_document_type.html

on the publication, so that publications where a Norwegian author is one of many has a smaller effect on the average than those with solely Norwegian authorship.

In addition to the MNCS indicator we have analysed the articles that are among the 10 per cent most cited in their fields: More specifically the number and the proportion of a unit's publications that, compared with other publications in the same field and in the same year and by the same publication type, belong to the top 10% most frequently cited. The main objective is to analyse whether there are differences between the two sets of articles along various bibliometric variables.

2.2.4 Collaboration indicators

The fact that researchers co-author a scientific paper reflects collaboration, and co-authorship may be used as an indicator of such collaboration. By definition a publication is co-authored if it has more than one author, internationally co-authored if it has authors from more than one country. Compared to other methodologies, bibliometrics provides unique and systematic insight into the extent and structure of scientific collaboration. A main advantage is that the size of the sample that can be analysed with this technique can be very large and render results that are more reliable than those from case studies. Also, the technique captures non-formalised types of collaboration that can be difficult to identify with other methodologies. In this report, indicators of both international and institutional collaboration have been included.

3 Norwegian biosciences – overall analysis

This chapter gives a general overview of publication within the biosciences in Norway in the period 2012-2021, with combined figures based on the fields analysed separately in Chapter 4 and 5. The delineation of the field is based on the classification system of the Norwegian Association of Higher Education Institutions (UHR) and National Academic Council for Biosciences, see: https://npi.hkdir.no/fagfeltoversikt/fagfelt?id=1150.

The analysis covers all publications with Norwegian contributors within these fields, not only publications from the units included in the evaluation. Overall, the evaluated units account for 47.3 % of all biosciences publishing in Norway. Thus, more than half of the publications within the field as it is delineated here are produced by units which are not part of the present evaluation. These are units which have decided not to participate in the evaluation or will participate in the next evaluation (medicine and health). In addition, publications are also produced by researchers affiliated with other units than the core departments and institutes in biosciences.

3.1 Publication output

3.1.1 General trend

Figure 3.1 shows the development of publication output for the biosciences in the last decade. It shows an increase in the number of publications from 3 224 in 2012 to 4 283 in 2021 (33%). The slower growth in modified author shares (+21% during the period) is an indication of increasingly collaborative authoring in the biosciences in the period. The growth in number of publications has mainly occurred during the recent three-year period (2019-2021).

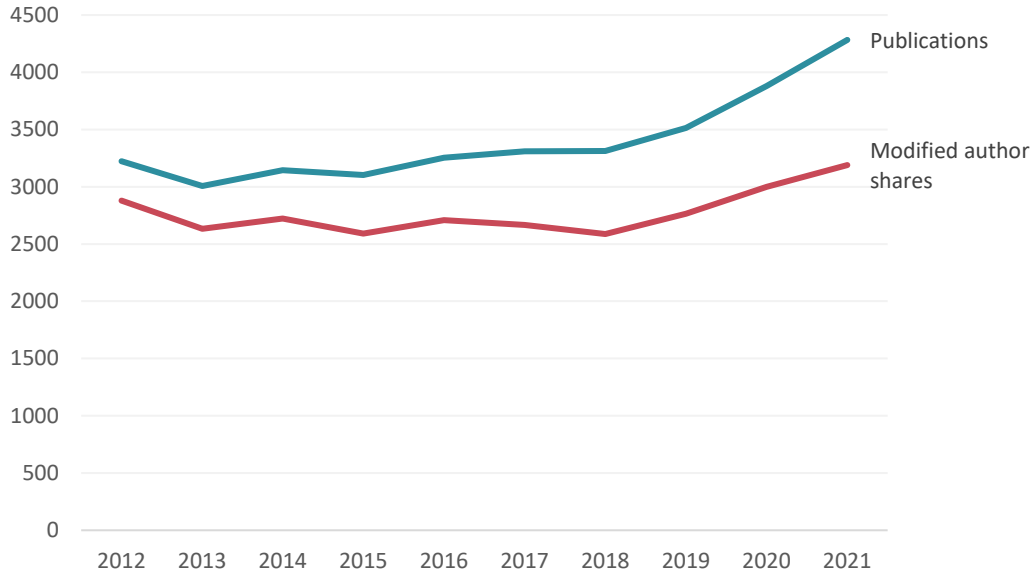

Figure 3.1. Publishing volume and sum of modified author shares for Norwegian biosciences research, 2012-2021.

The last decade has seen a large increase in the number of scientific publications with Norwegian affiliated authors in all fields. Figure 3.2 shows the growth in scientific publishing in the biosciences against the general growth of all Norwegian publishing. As can be seen, while there has been a considerable growth in biosciences publishing, it has not kept pace with the general growth in Norwegian research output over the entire period, during which the increase is 33% and 47%, respectively. Thus, the relative position of the field in the overall national research landscape is weakened, measured by publication volume. The recent three years, the trend is more positive, however.

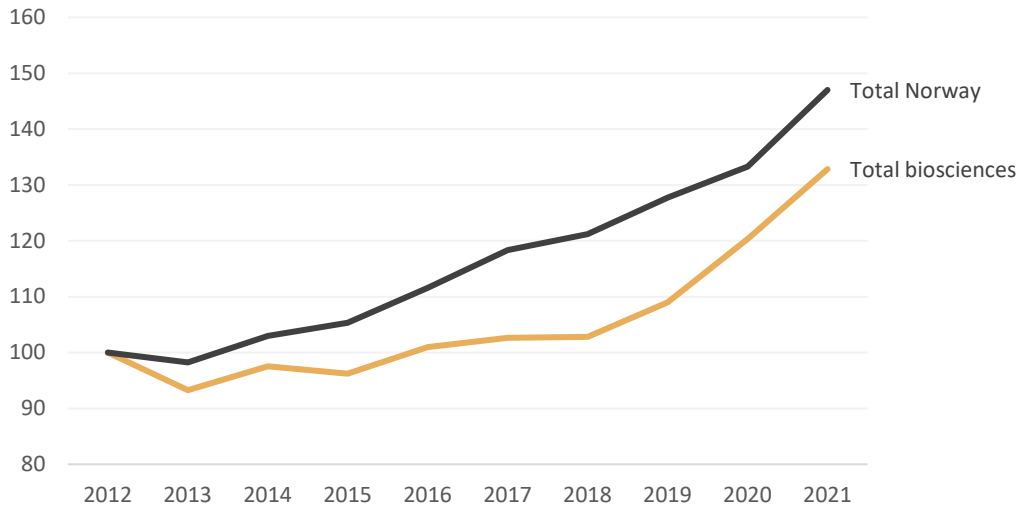

Figure 3.2. Relative growth in number of publications, biosciences and total Norwegian publishing, 2012-2021. 2012=100.

3.1.2 Most publishing institutions

Table 3.1 shows the top five contributors to scientific publishing in the biosciences in Norway by sector in 2021. Having 59 % of the total author contributions, the university and college sector is the biggest contributor to biosciences publishing in Norway. The two largest institutions by publishing volume are Norway's largest research institutions, but the third largest single contributor is the Norwegian University of Life Sciences, which in other fields is much smaller than for example the University of Bergen. Independent research institutes account for a quarter (24.5 %) of author contributions in the biosciences, university hospitals and other health institutions contribute with 16.4 % and various industry and public sector entities make up the remaining 0.2 % of biosciences publications.

Table 3.1. Most publishing institutions in biosciences by sector and institution/institute, 2021

Sector	Institution/institute	Publications	Modified author shares	Share of total publications
Health	Hospitals/health institutions	1081	423.7	16.4 %
Research institutes	Norwegian Institute of Marine Research	292	171.5	4.4 %
	Norwegian Institute of Bioeconomy Research	242	124.3	3.6 %
	Norwegian Institute for Nature Research	241	112.7	3.6 %
	NOFIMA	147	100.0	2.2 %
	Norwegian Institute of Public Health	136	52.7	2.1 %
	Other research institutes	567	280.9	8.5 %
	University of Oslo	906	420.2	13.7 %

Universities and colleges	Norwegian University of Science and Technology	712	357.6	10.7 %
	Norwegian University of Life Sciences	563	317.8	8.5 %
	University of Bergen	633	311.8	9.5 %
	UiT - The Arctic University of Norway	457	226.7	6.9 %
	Other universities and colleges	642	290.0	9.7 %

3.1.3 Publishing venues

The publications are distributed across a large number of different journals. However, the frequency distribution is skewed, and some journals account for a substantial amount of the publication output. Figure 3.3 shows the most common journals for publishing biosciences research in Norway in 2021. In total, these 15 journals account for 26 % of biosciences publishing. 28 % of all biosciences publications were published in journals that are placed on level 2 in the Norwegian journal classification system.

Among these 15 journals, Nature Publishing Group is the most common publisher, followed by Frontiers and MDPI, two pure Open Access publishers.

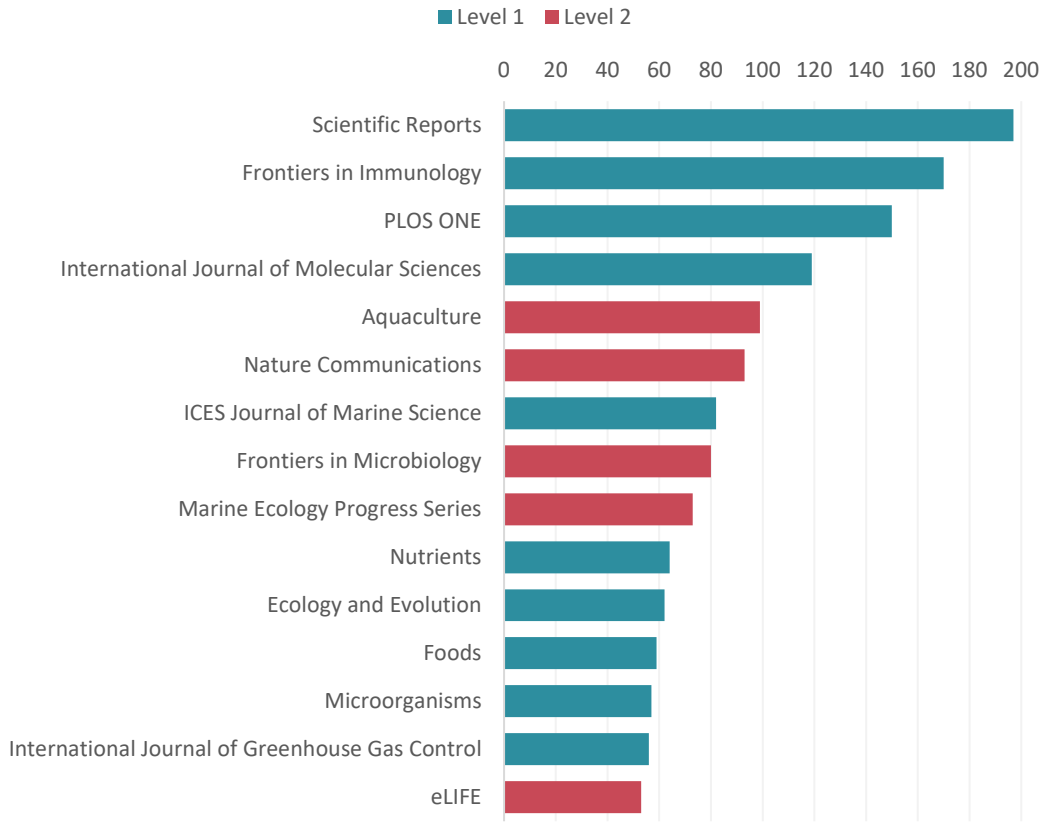

Figure 3.3. Most common publishing venues of biosciences, 2021.

3.1.4 Field distribution

There is not a complete overlap between the Norwegian journal classification system and that of Web of Science. Figure 3.4 shows how Norwegian biosciences publications are distributed among research fields as classified by Web of Science. This gives an impression of the field profile of Norwegian biosciences, as defined in the project. The most important WoS fields that fall under the biosciences umbrella is Ecology, followed by Biochemistry and molecular biology and Marine and freshwater biology.

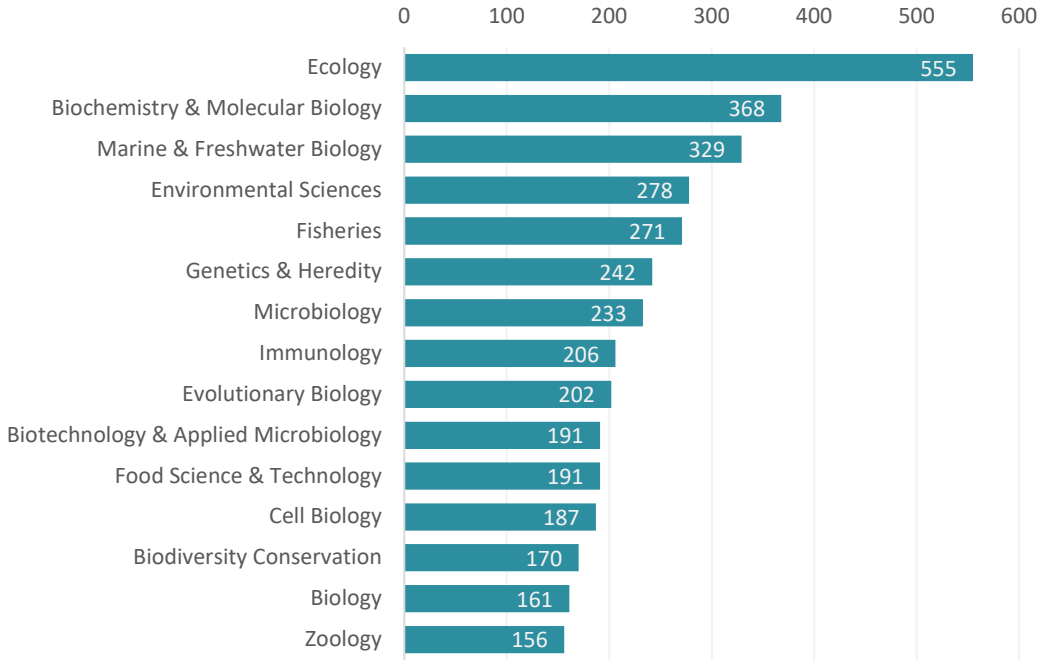

Figure 3.4. Web of Science subfield distribution of publications within biosciences journals in the Norwegian journal classification system, 2021.

3.2 Citation indicators

There are many different indicators of the citation impact of a publication, but two of the most common are 1) Mean normalized citation score (MNCS), where the citation count of a publication is compared to the average number of citations received by publications within the same field and from the same year, and 2) citation percentile, which is a publication's percentile position in a list of all publications from a given field and publication year ordered by citation count.

Figure 3.5 shows the average MNCS for all biosciences publishing in Norway 2012-2020, weighted by the modified author contributions of the Norwegian authors on each publication, on the left axis. On the right axis, marked with black

dots, is the share of modified author shares that fall within the 10th percentile in the citation percentile calculation.

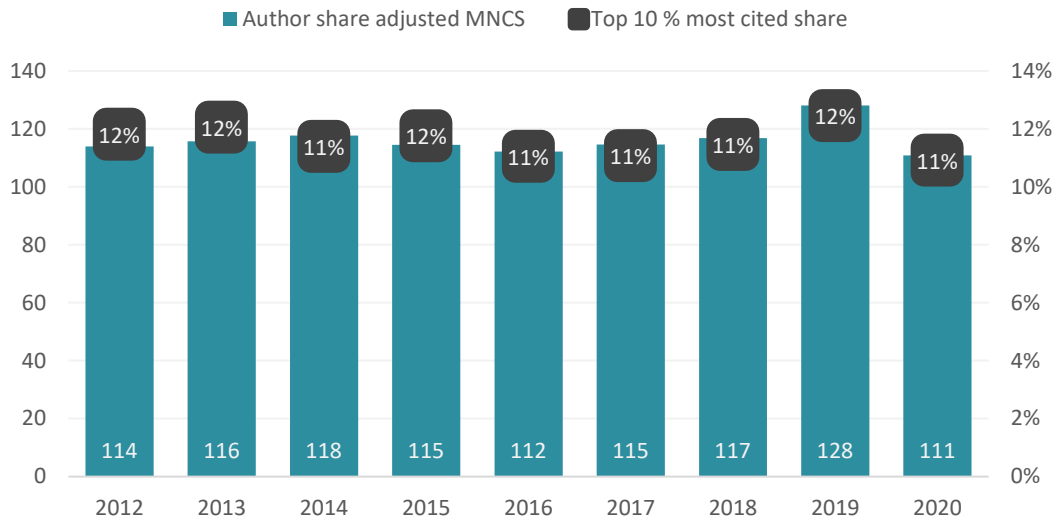

Figure 3.5. MNCS of biosciences publications (left axis, 100 = global mean citation score for publications from same field and year) and share of publications among the 10 % most highly cited publication from same field and year (right axis), 2012-2021.

In general, Norwegian biosciences research is above the global average for all years, with the average MNCS for all years being 116 and the share of author contributions that fall within the top 10 % most cited publications being 11.6 %. The MNCS for the most recent three-year period is 119. In terms of citation impact Norwegian bioscience research performs above the global average, and around the national average. The world average is, however, not a very ambitious reference standard, and most Western countries have citation indexes above this average.

Figure 3.6 shows the MNCS for the period 2018-2020 for selected disciplines encompassed by the two present evaluations. In the natural sciences, the articles in geosciences have the highest citation impact score, 127. At the opposite end of the scale, we find chemistry and materials science with a citation index of 87.

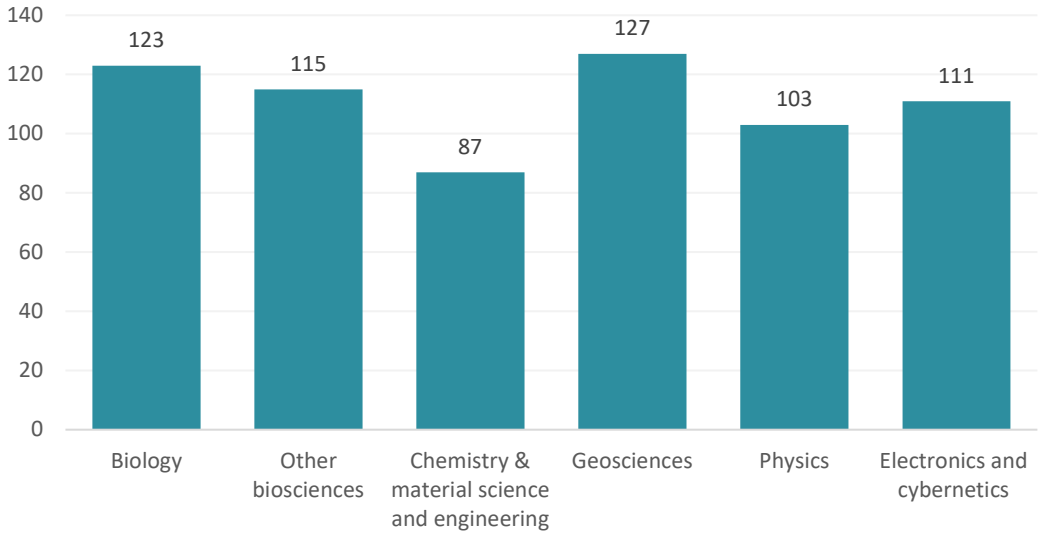

Figure 3.6. MNCS of disciplines encompassed by the two present evaluations, 2018—2020 figures.

Figure 3.7 shows the similar indicator for the publications that fall under the biosciences category, but using the more fine-tuned WoS-classification system (cf. Figure 3.4). Genetics, agriculture and fisheries research have some of the most impactful Norwegian research publications in general, while at the other end, we find subjects such as mycology, horticulture and biophysics with citation impact well below the world average (not shown in the figure).

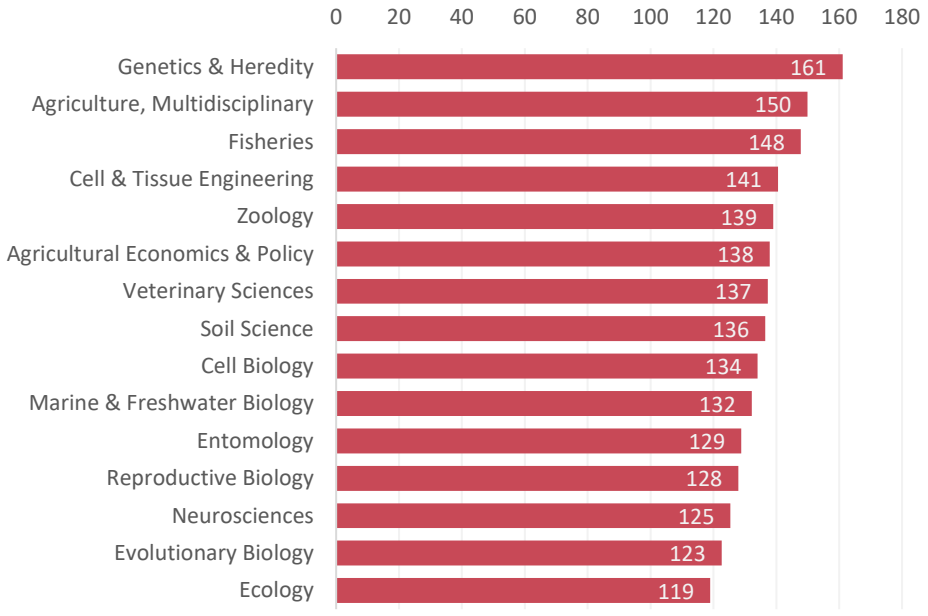

Figure 3.7 MNCS for the 15 Web of Science subfields with highest score (of Norwegian biosciences publications), 2018-2020.

3.3 International collaboration

Which countries are the most important collaborative partners for Norway in the field? To answer this, the distribution of co-authorship by country has been analysed. Table 3.2 shows the frequencies of co-authorship for the nations that comprise Norway's main collaboration partners from 2019 to 2021. The USA is the most important collaboration nation. In total, 20% of the "Norwegian" articles had co-authors from the USA. Almost of equal size is the UK, with a proportion of 19%. Next follow Germany, Sweden, and Denmark with proportions of 15, 13, 11%, respectively.

Of all the "Norwegian" publications within the field, 75% had co-authors from other countries as well. In comparison, this is also the corresponding national average for the natural sciences, all fields combined. Thus, the extent of international collaboration is wide. Apparently, the large majority of the Norwegian research is carried out in collaboration with scientists from other countries.

Table 3.2. International collaboration by country.* Number and proportion of collaborative publications with Norway, 2019-2021.

Country	No coll pub	Prop all pub	Country	No coll pub	Prop all pub
USA	2448	20 %	Australia	818	7 %
UK	2307	19 %	Switzerland	716	6 %
Germany	1819	15 %	China	687	6 %
Sweden	1614	13 %	Belgium	618	5 %
Denmark	1297	11 %	Austria	504	4 %
France	1213	10 %	Poland	482	4 %
Netherlands	1150	9 %	Russia	453	4 %
Spain	1130	9 %	Portugal	390	3 %
Italy	981	8 %	Czech Republic	374	3 %
Canada	938	8 %			
Finland	926	8 %	Total	9138	75 %

*) The overview is limited to the 20 largest countries in terms of number of collaborative articles.

The proportion of international collaboration differs somewhat across disciplines. This is shown in Figure 3.8, where also other natural science disciplines encompassed by the evaluation are included. In all fields, Norwegian research has a strong international orientation with extensive collaboration with researchers in other countries.

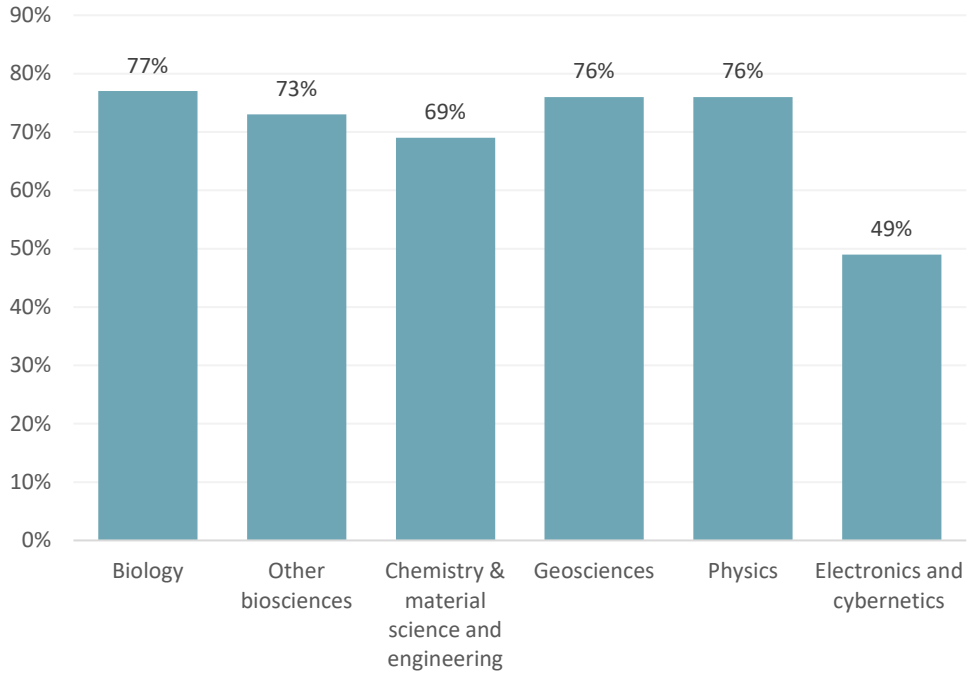

Figure 3.8. Proportion of international collaboration of disciplines encompassed by the two present evaluations, 2019—2021 figures.

3.4 National collaboration

Figure 3.9 provides a graphic illustration of the Norwegian national research collaboration. In the figure, the size of the circles represents the total number of articles and the width of the lines the number of collaborative articles between different institutions/institutes. The distance between the circles gives an indication of the relative intensity of the collaboration, so that units with relatively many joint publications are grouped together (clusters). Only the largest contributors in terms of number of publications are shown separately, the others are grouped together.

There are two main clusters, one dominated by institutions where non-human biosciences dominate (red) and one where human biosciences dominate (green). It should be noted that this is within the specific field delimitation applied in the study, where clinical medicine is excluded and also part of biomedicine.

We observe particularly close links between the medical faculties and the affiliated university hospitals, where a large part of the publications have co-authors from both the university and the university hospital. This partly reflects the use of "shared" positions, for example in that a senior physician at the university hospital is adjunct professor (II) at the university. If both institutions are listed as author addresses, this will be registered as external national collaboration in the analysis.

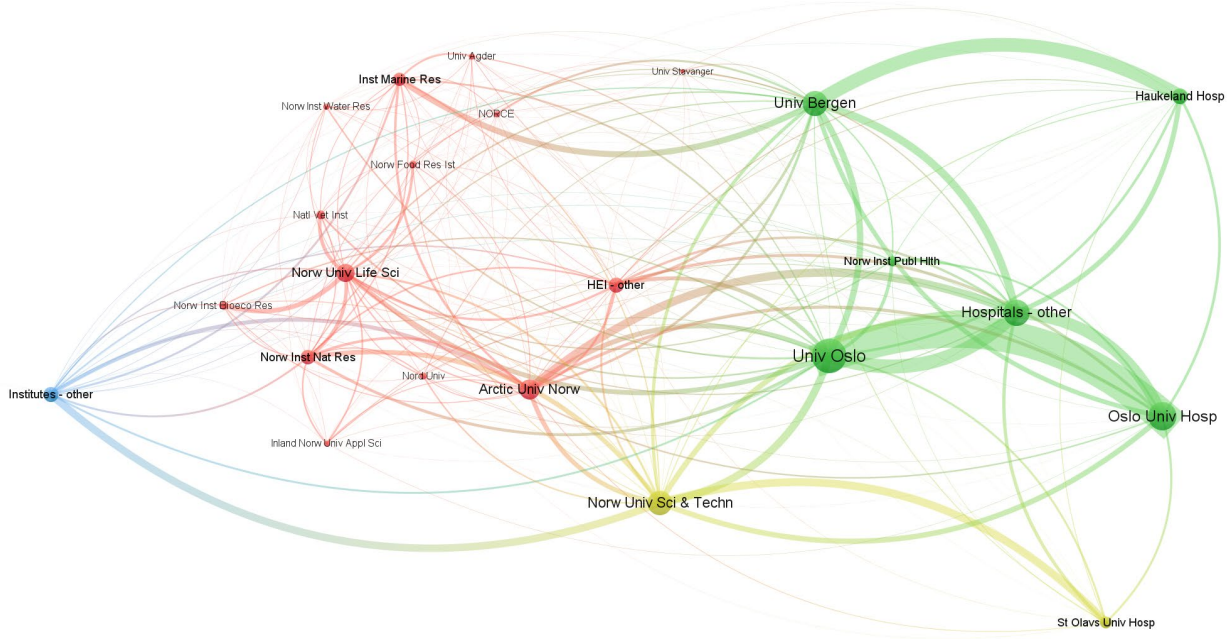

Figure 3.9. Illustration of research collaboration between Norwegian institutions based on co-authorship data 2019-2021

3.5 Scientific publishing – number of researchers

This subchapter presents a short analysis of the number of authors contributing to the scientific publications. Included in the figures are authors affiliated with Norwegian institutions and institutes. This gives an overview of the size of the population which are active researchers and publish scientifically; how this varies across fields and develops over time. Thus, it provides a complementary view to the analysis of research personnel presented in a separate report to the evaluation. In order to provide a comparative view, we have also shown results for disciplines which are covered by the other evaluation.

It should be noted that the publication productivity at the level of individuals is highly skewed. A small proportion of researchers are extremely productive, while many have few publications. This pattern is common in all research fields. Moreover, some of the contributors may not have a research position (e.g. technicians, physicians, and students), and some of them may be researchers mainly publishing in other fields. In the analysis all individuals are included, but these facts should be taken into consideration when interpreting the results.

Figure 3.10 shows how the number has developed during the recent 10-year period. In 2021 the number of publication active individuals is 3,610 in biology in

2021 and even higher in other biosciences: 4,170. Some individuals will appear in both categories so the numbers should not be added.

There is a notable increase in number of individuals contributing to scientific publishing in all disciplines. In both biology and other biosciences this number has increased by more than 1,000 persons during the 10-year period.

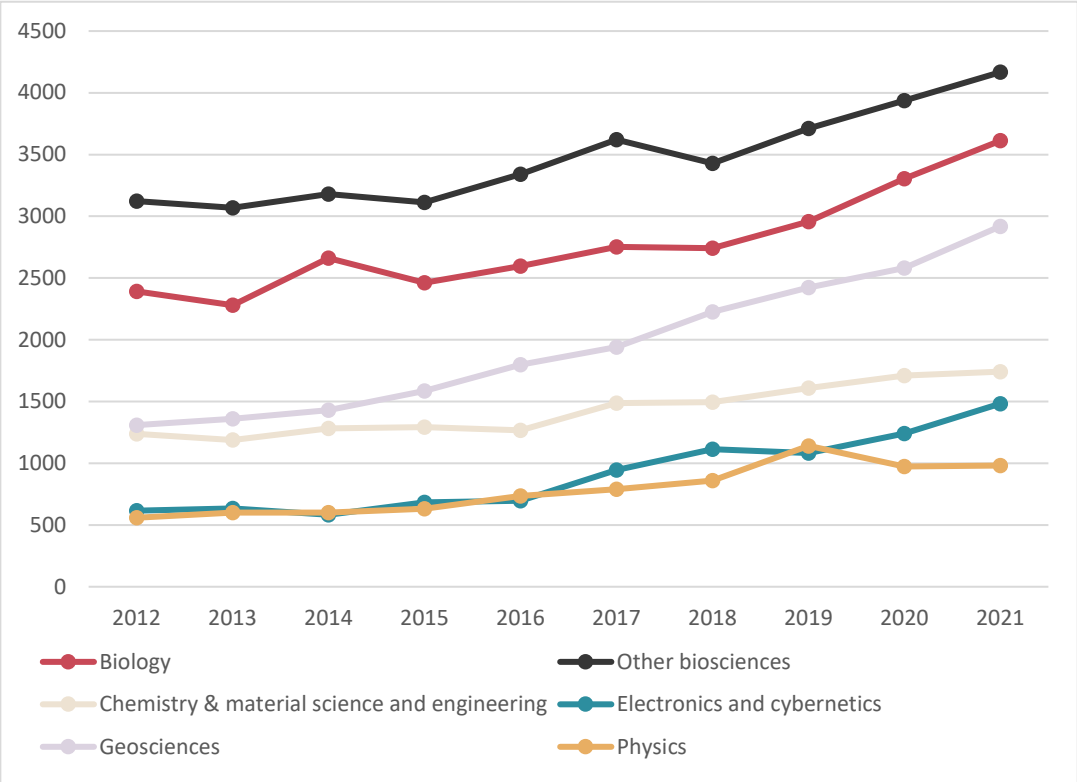

Figure 3.10. Number of individuals contributing to scientific publications by discipline and year, 2012-2021.

In relative terms, the number of individuals has increased by 51% in biology and 33% in other biosciences during the 10-year period. This is shown in Figure 3.11. Compared with the other disciplines shown in the figure, the growth rate is still moderate. Electronics and cybernetics and geosciences have a much stronger growth and have more than doubled during the period. The figure also shows calculations for the period 2017-2021. Generally, the increase in this period has been more limited in all disciplines.

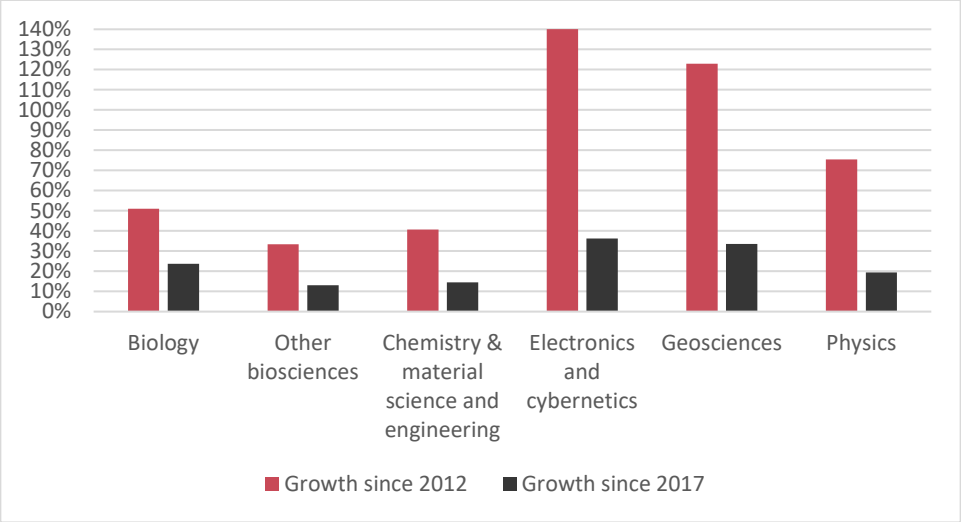

Figure 3.11. Relative growth in the number of individuals contributing to scientific publications by discipline, 2012-2021 and 2017-2021.

Figure 3.12 shows how the researchers are distributed across the two sectors represented in the evaluation: the HE- sector and the institute sector (contributions from other sectors are not included). As expected, a large majority of the individuals are affiliated with the HE-sector. This holds for both biology and other biosciences, as well as the other disciplines shown in the figure. However, the institute sector also plays a significant role, particularly in biology and geosciences.

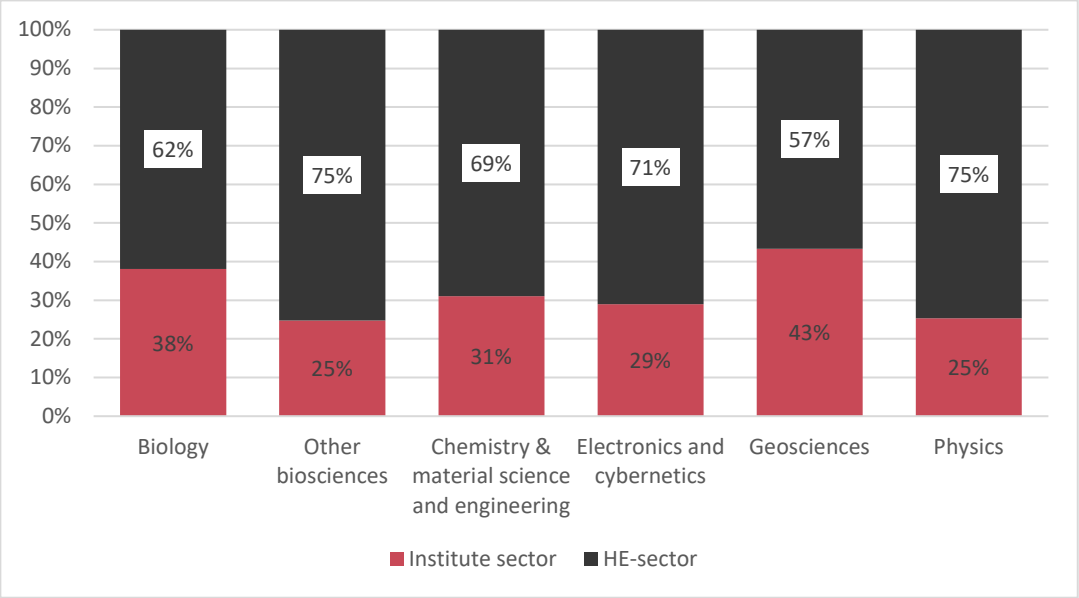

Figure 3.12. Proportion of individuals contributing to scientific publications per sector and discipline, 2021.

4 Biology

This chapter gives a general overview of publication within biology in Norway in the period 2012-2021. The delineation of the field is based on the classification system of the Norwegian Association of Higher Education Institutions (UHR). The biology category covers journals within disciplines such as botany, zoology, ecology, fisheries research and marine biology, microbiology, aquaculture, forestry and agriculture.

The analysis covers all publications with Norwegian contributors within these fields, not only publications from the units included in the evaluation. Overall, the evaluated units account for 63.1 % of all biology publishing in Norway. Thus, one third of the publications within the field as it is delineated here are produced by units which are not part of the present evaluation. These are units which have decided not to participate in the evaluation or will participate in the next evaluation (medicine and health). In addition, publications are also produced by researchers affiliated with other units than the core departments and institutes in biology.

4.1 Publication output

4.1.1 General trend

Figure 4.1 shows the development of publication output for biology in the last decade. The number of publications has increased from 1 728 in 2012 to 2 362 in 2021, which corresponds to a relative growth of 37%. Measured by fractionalised counts (modified author shares), the growth is less strong (+12%), an indication of increasingly collaborative authoring in the biology during the period. Most of the growth appearing the recent three years, while the publication volume was relatively stable during the years 2012-2018.

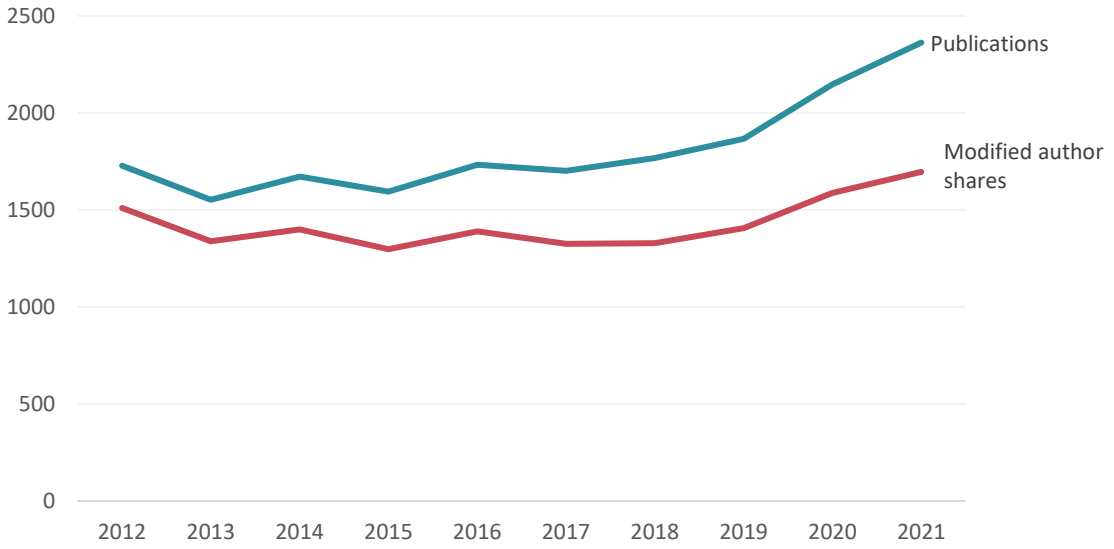

Figure 4.1. Publishing volume and sum of modified author shares for Norwegian biology research, 2012-2021.

The last decade has seen a large general increase in the number of scientific publications with Norwegian affiliated authors. Figure 4.2 shows the growth in scientific publishing in biology against the total growth of all Norwegian publishing (all fields combined). In general, changes in publishing volume in biology largely tracks the changes in Norwegian research publishing over the period, albeit at a slightly lower rate. During the ten-year period the total Norwegian publication output increased by 47%, compared to 37% for biology.

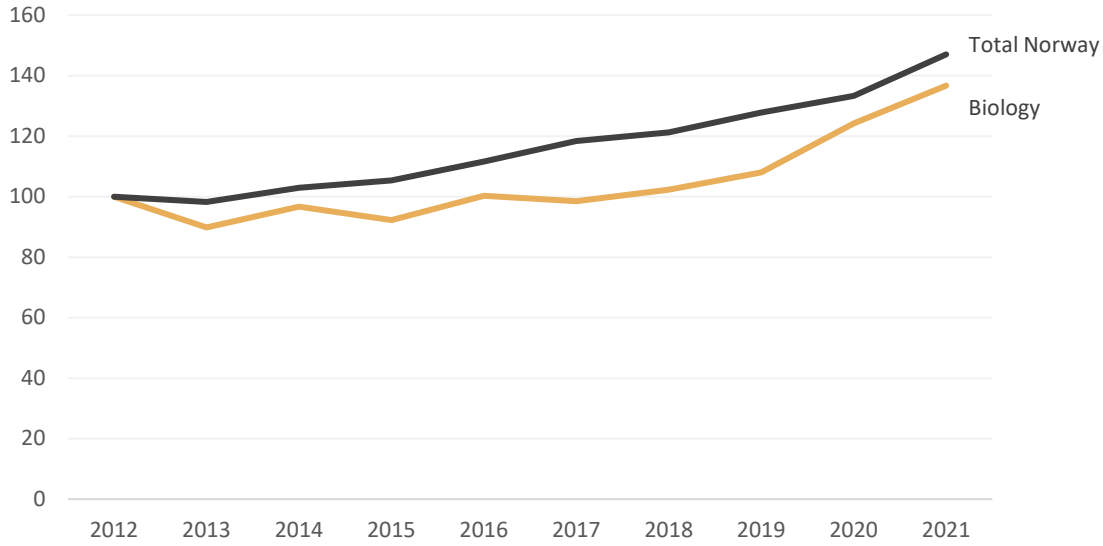

Figure 4.2. Relative growth in number of publications, biology and total Norwegian publishing, 2012-2021. 2012=100.

4.1.2 Most publishing institutions

Table 4.1 shows the top five contributors to scientific publishing biology in Norway by sector in 2021. Having 61.8 % of the total author contributions, the university and college sector is the biggest contributor to biology research in Norway. The largest single contributor in terms of author contributions is the Norwegian University of Life Sciences, even if the University of Oslo is affiliated with more publications. Independent research institutes account for a third (31.7 %) of author contributions in the biology, university hospitals and other health institutions contribute with 5.9 % and various industry and public sector entities make up the remaining 0.6 % of biology publishing. Compared to biosciences publishing in general, independent research institutes publish a larger share of biology publishing and health institutions a smaller.

Table 4.1. Most publishing institutions in biology by sector and institution/institute, 2021

Sector	Institution/institute	Publications	Modified author shares	Share of total
Health	Hospitals/ health institutions	202	80.5	6 %
Research institutes	Norwegian Institute of Marine Research	243	143.0	7 %
	Norwegian Institute of Bioeconomy Research	209	107.4	6 %
	Norwegian Institute for Nature Research	221	101.7	6 %
	NOFIMA	78	55.4	2 %
	Norwegian Veterinary Institute	61	31.7	2 %
	Other	281	132.9	8 %
Universities and colleges	Norwegian University of Life Sciences	369	202.6	11 %
	University of Oslo	402	192.6	12 %
	Norwegian University of Science and Technology	379	182.2	11 %
	University of Bergen	338	169.3	10 %
	UiT - The Arctic University of Norway	276	133.5	8 %
	Other	365	162.9	11 %

4.1.3 Publishing venues

Figure 4.3 shows the most common journals for publishing biology research in Norway in 2021. In total, these 15 journals account for 24.4 % of biology publishing. 30.5 % of all biology publications were published in journals that are placed on level 2 in the Norwegian journal classification system. The top three journals are all in marine biology, with two of them being considered to be of particularly high standard.

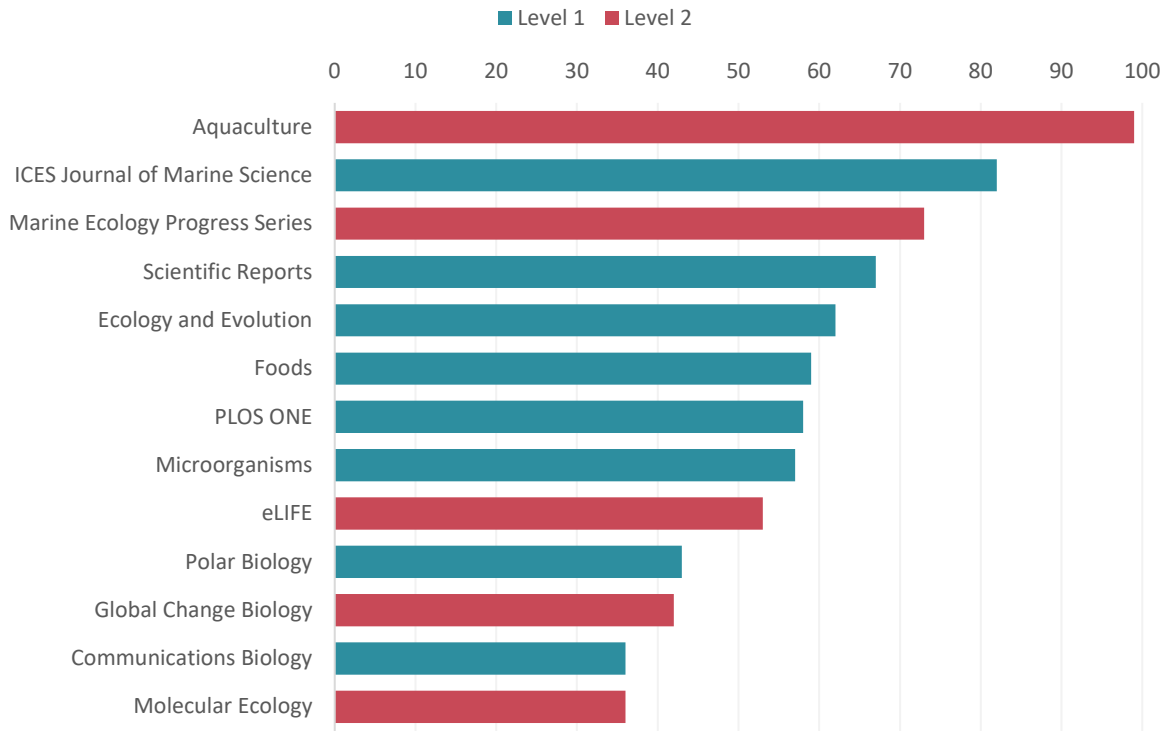

Figure 4.3. Most common publishing venues of biology, 2021

4.1.4 Field distribution

There is not a complete overlap between the Norwegian journal classification system and that of Web of Science. Figure 4.4 shows how Norwegian biology publications are distributed among research fields as classified by Web of Science. This gives an impression of the field profile of Norwegian biology, as defined in the project. The largest WoS fields that fall under the biology umbrella is Ecology, followed by Marine and freshwater biology and Fisheries.

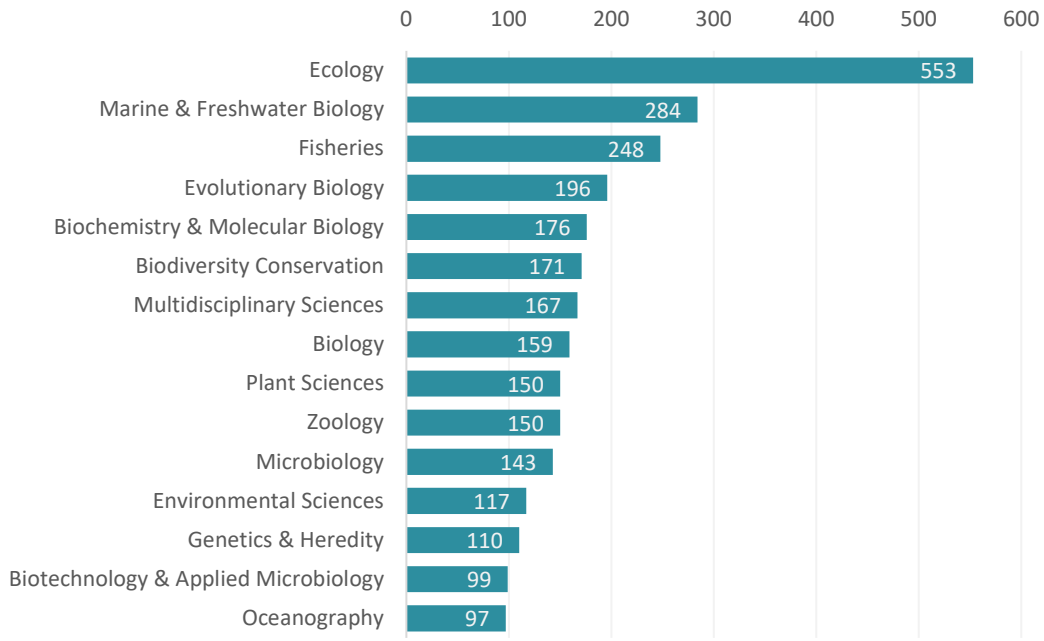

Figure 4.4. Web of Science subfield distribution of publications within biology journals in the Norwegian journal classification system, 2021.

4.2 Citation indicators

Figure 4.5 shows the average MNCS for all biology publishing in Norway 2012-2021, weighted by the modified author contributions of the Norwegian authors on each publication, on the left axis. On the right axis, marked with black dots, is the share of modified author shares that fall within the 10th percentile in the citation percentile calculation.

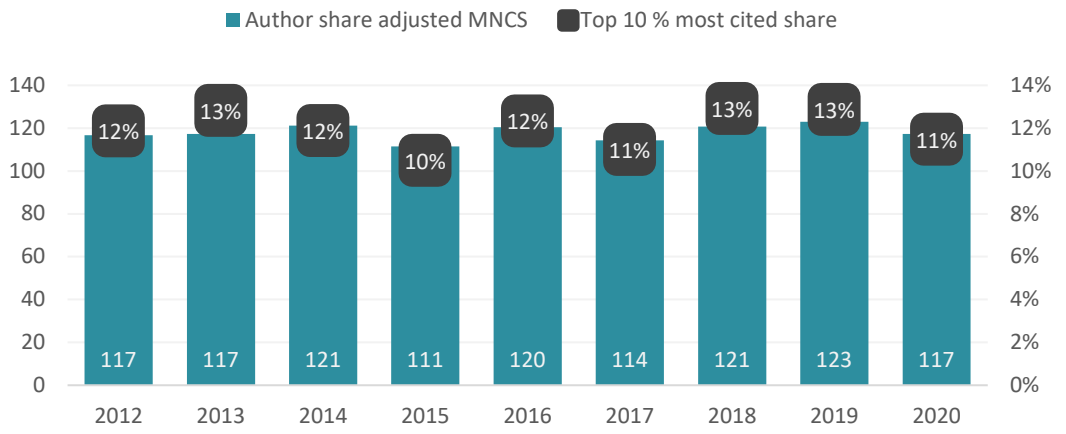

Figure 4.5. MNCS of biology publications (left axis, 100 = global mean citation score for publications from same field and year) and share publications among the 10 % most highly cited publication from same field and year (right axis)

In general, Norwegian biology research has been cited above the global average in recent years. Over the whole period, the share of author contributions that fall within the top 10 % most cited publications is 11.9 %, but this figure has fluctuated a bit, with no clear directional trend. The average MNCS over the whole period is 118, and above 120 the last three years under consideration. The world average (100) is, however, not a very ambitious reference standard, and most Western countries have citation indexes significantly above this average. Still, in terms of citation impact Norwegian biology research performs reasonably well.

Figure 4.6 shows the similar indicator for the publications that fall under the biology category, but using the more fine-tuned WoS-classification system (cf. Figure 4.4). Various agricultural research, fisheries research and zoology is particularly highly cited. Among the least cited subfields we find mycology and horticulture, which have MNCS of 87.9 and 72.7, respectively (not shown in the figure).

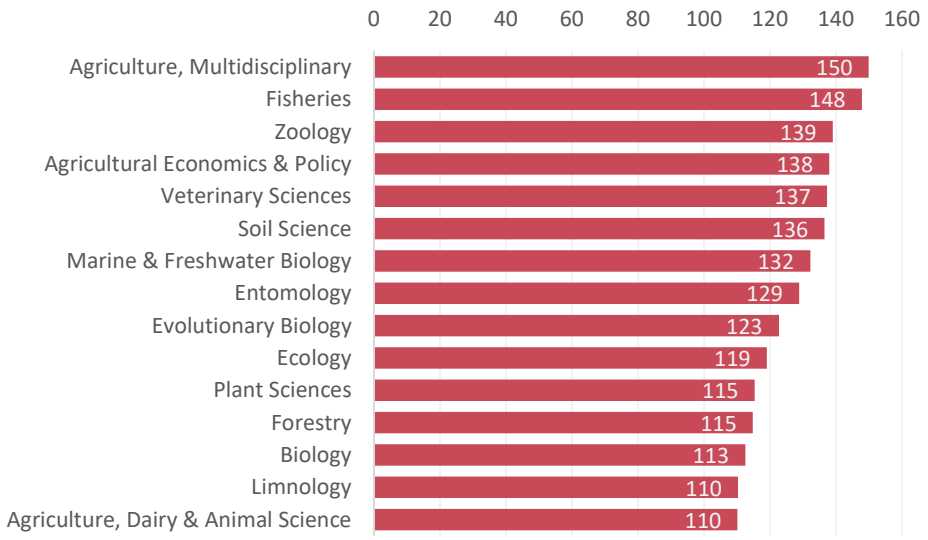

Figure 4.6. MNCS for the 15 Web of Science subfields with highest score (of Norwegian biology publications), 2018-2020.

Table 4.2 shows which countries can be said to have publications with the highest average citation impact for the period 2018-2020, adjusted for the size of their author contributions to these publications. Only countries with at least 2 000 author shares have been included. The Netherlands ranks on top. Norway is the 7th most impactful country in biology of a total consisting of the 67 largest countries.

Table 4.2. Author share adjusted MNCS of most impactful countries in biology, including Norway, 2018-2020.

Position	Country	Modified author shares	MNCS
1	Netherlands	15613	139
2	Singapore	2909	138
3	Switzerland	13404	133
4	UK	52593	132
5	Sweden	11145	126
6	Denmark	10267	124
7	**Norway**	**9503**	123
8	Australia	48904	123
9	Austria	8099	122
10	Italy	52632	122

4.3 International collaboration

Which countries are the most important collaborative partners for Norway in biology? To answer this, the distribution of co-authorship by country has been analysed. Table 4.3 shows the frequencies of co-authorship for the nations that comprise Norway's main collaboration partners from 2019 to 2021. The USA is the most important collaboration nation. In total, 20% of the "Norwegian" articles had co-authors from the USA. Almost of equal size is the UK, with a proportion of 18%. Next follow Germany, Sweden, and Denmark with proportions of 14, 13, 11%, respectively.

Of all the "Norwegian" publications within the field, 77% had co-authors from other countries as well. In comparison, this is slightly above the corresponding national average for the natural sciences, all fields combined which is 75%.

Table 4.3. International collaboration by country.* Number and proportion of collaborative publications with Norway, 2019-2021.

Country	No coll pub	Prop all pub	Country	No coll pub	Prop all pub
USA	1303	20 %	Italy	424	6 %
UK	1208	18 %	Switzerland	361	5 %
Germany	943	14 %	China	356	5 %
Sweden	859	13 %	Russia	310	5 %
Denmark	710	11 %	Belgium	294	4 %
France	637	10 %	Poland	284	4 %
Spain	609	9 %	Austria	268	4 %
Canada	591	9 %	Czech Republic	252	4 %
Finland	568	9 %	Portugal	247	4 %
Netherlands	509	8 %			
Australia	467	7 %	Total	5077	77 %

*) The overview is limited to the 20 largest countries in terms of number of collaborative articles.

4.4 National collaboration

Figure 4.6 provides a graphic illustration of the Norwegian national research collaboration. In the figure, the size of the circles represents the total number of articles and the width of the lines the number of collaborative articles between different institutions/institutes. The distance between the circles gives an indication of the relative intensity of the collaboration, so that units with relatively many joint publications are grouped together (clusters). Only the largest contributors in terms of number of publications are shown separately, the others are grouped together.

For example, we observe strong collaborative links between Norwegian Institute for Nature Research (NINA) and Norwegian University for Science and Technology (NTNU); Institute of Marine Research and University of Bergen; Norwegian University of Life Sciences (UMB) and Norwegian Institute of bioeconomy Research.

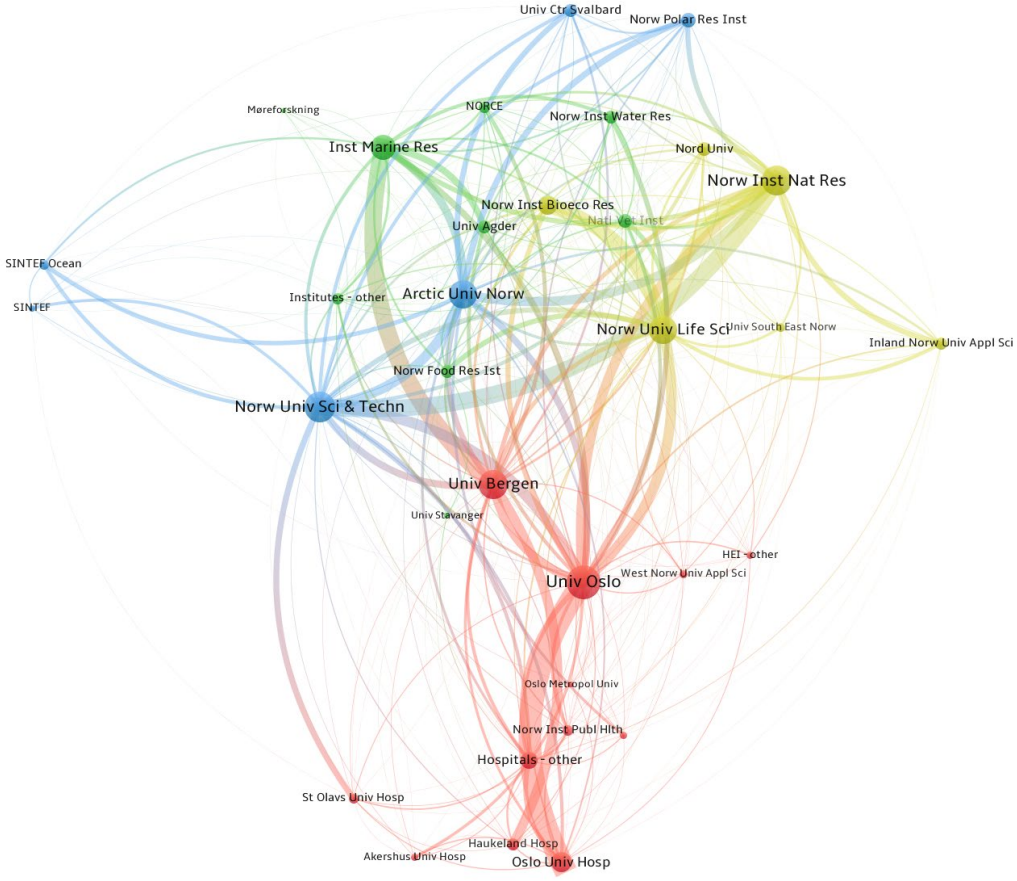

Figure 4.7. Illustration of research collaboration between Norwegian institutions based on co-authorship data 2019-2021

5 Other biosciences

This chapter gives a general overview of publication within other biosciences in Norway in the period 2012-2021. As noted in Chapter 2, a mixed bag of fields is included in this category: biotechnology, biomedicine, veterinary medicine, nutrition and environmental technology and industrial ecology.

The analysis covers all publications with Norwegian contributors within these fields, not only publications from the units included in the evaluation. Overall, the evaluated units account for 29.2 % of all publications within other biosciences in Norway. Thus, the large majority of the publications within the field as it is delineated here are produced by units which are not part of the present evaluation. These are units which have decided not to participate in the evaluation or will participate in the next evaluation (medicine and health). In addition, publications are also produced by researchers affiliated with other units than the core departments and institutes in other biosciences.

5.1 Publication output

5.1.1 General trend

Figure 5.1 shows the development of publication output for other biosciences in the last decade. It shows an increase in the number of publications from 1 497 in 2012 to 1 922 in 2021, this corresponds to a relative growth of 28%. The publication output is also measured by modified author shares. Using this indicator the relative growth is less strong (+9%), an indication of increasingly collaborative authoring in the biosciences in the period.

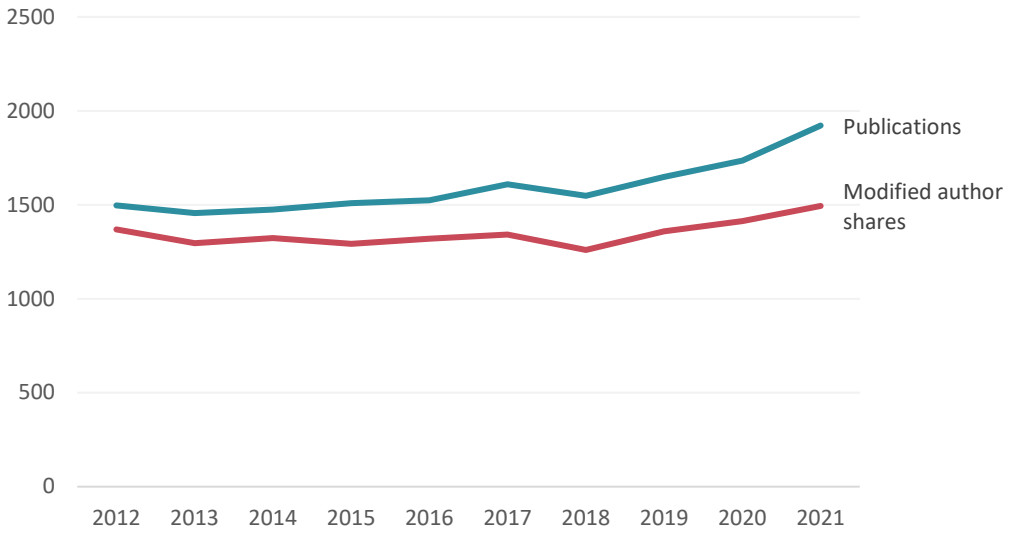

Figure 5.1 Publishing volume and sum of modified author shares for other biosciences research, 2012-2021.

There has also been a general growth in the Norwegian publication output the recent decade. Figure 5.2 shows the growth in scientific publishing in other biosciences compared with the total growth of all Norwegian publishing (all fields combined). Although there has been an increase in the publishing volume in other biosciences, the growth is less strong than for the total Norwegian scientific publishing, the increase for the ten-year period is 28% and 47%, respectively. Thus, the relative position of the field in the overall national research landscape is weakened, measured by publication volume.

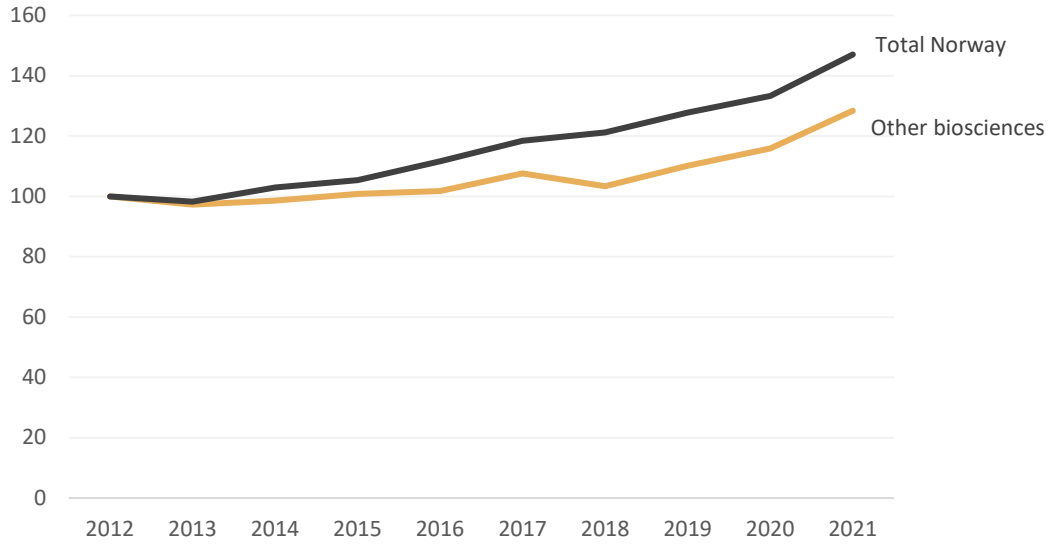

Figure 5.2. Relative growth in number of publications, other biosciences and total Norwegian publishing, 2012-2021. 2012=100.

5.1.2 Most publishing institutions

Table 5.1 shows the top five contributors to scientific publishing in other biosciences in Norway by sector in 2021. Having 55.6 % of the total author contributions, the university and college sector is the biggest contributor to other biosciences research in Norway. The largest single contributor in terms of author contributions is the University of Oslo. Followed by two of the other largest institutions in Norway. Independent research institutions account for a sixth (16.6 %) of author contributions in the other biosciences, only amounting to half their share compared to publishing in biology. University hospitals and other health institutions on the other hand contribute 27.4 %, a five times larger share than for biology. This reflects the predominance of biomedical research done at university hospitals, while indicating a more general biology orientation among other research institutions.

Table 5.1. Most publishing institutions in other biosciences by sector, by sector and institution/institute, 2021

Sector	Institution/institute	Publications	Modified author shares	Share of total
Health	Hospitals/health institutions	879	343.4	27 %
Research institutes	NOFIMA	69	44.6	2 %
	Norwegian Institute of Public Health	99	36.0	3 %
	Norwegian Veterinary Institute	55	31.3	2 %
	Norwegian Institute of Marine Research	49	28.5	2 %
	SINTEF	52	28.1	2 %
	Other research institutes	208	101.5	6 %
Universities and colleges	University of Oslo	504	227.6	16 %
	Norwegian University of Science and Technology	333	175.2	10 %
	University of Bergen	295	142.5	9 %
	Norwegian University of Life Sciences	194	115.2	6 %
	UiT - The Arctic University of Norway	181	93.1	6 %
	Other universities and colleges	277	127.1	9 %

5.1.3 Publishing venues

Figure 5.3 shows the most common journals for publishing other biosciences research in Norway in the 2021. The most frequently used journals are Frontiers in Immunology, Scientific Reports and International Journal of Molecular Sciences.

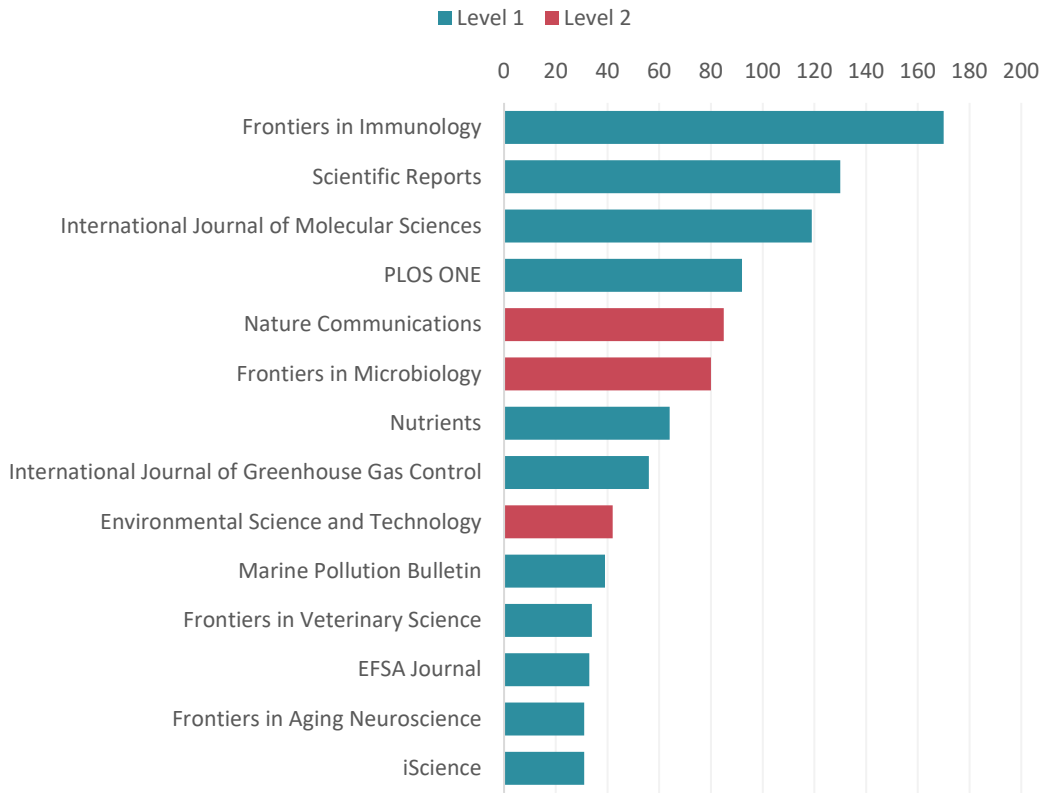

Figure 5.3. Most common publishing venues of other biosciences, 2021

5.1.4 Field distribution

Figure 5.4 shows how Norwegian bioscience publications are distributed among research fields as classified by Web of Science. As noted above, the category of other biosciences consists of a conglomerate of different disciples. The largest WoS fields that fall under the other biosciences umbrella are multidisciplinary sciences (publications in general journals), Biochemistry & Molecular biology, and Immunology.

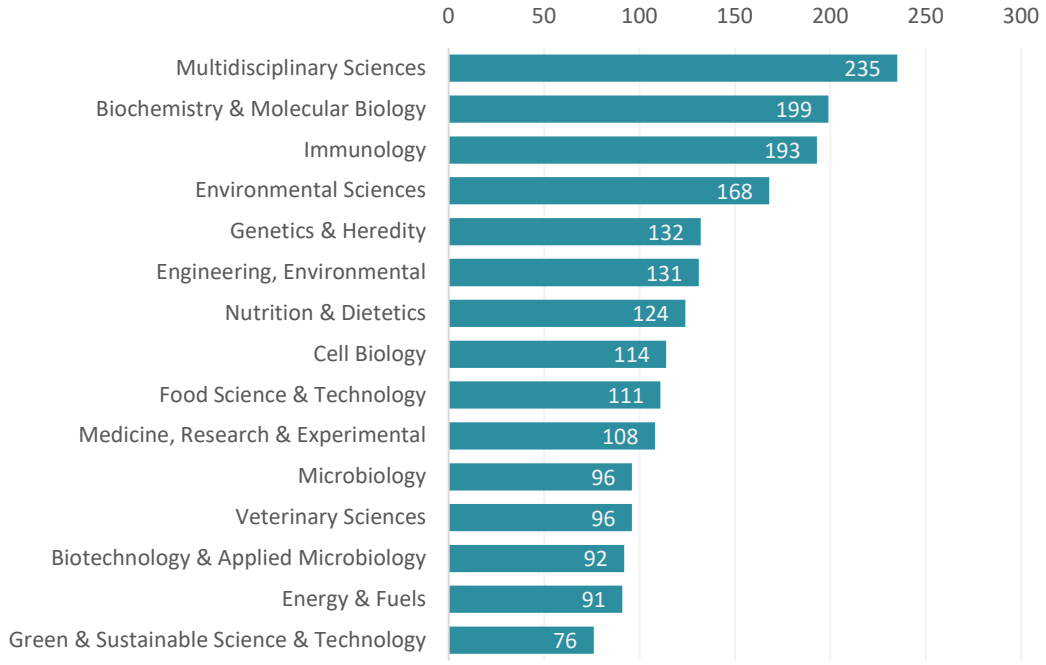

Figure 5.4. Web of Science subfield distribution of publications within other biosciences journals in the Norwegian journal classification system, 2021.

5.2 Citation indicators

Figure 5.5 shows the average MNCS for all bioscience publishing in Norway 2012-2021, weighted by the modified author contributions of the Norwegian authors on each publication, on the left axis. On the right axis, marked with black dots, is the share of modified author shares that fall within the 10th percentile in the citation percentile calculation.

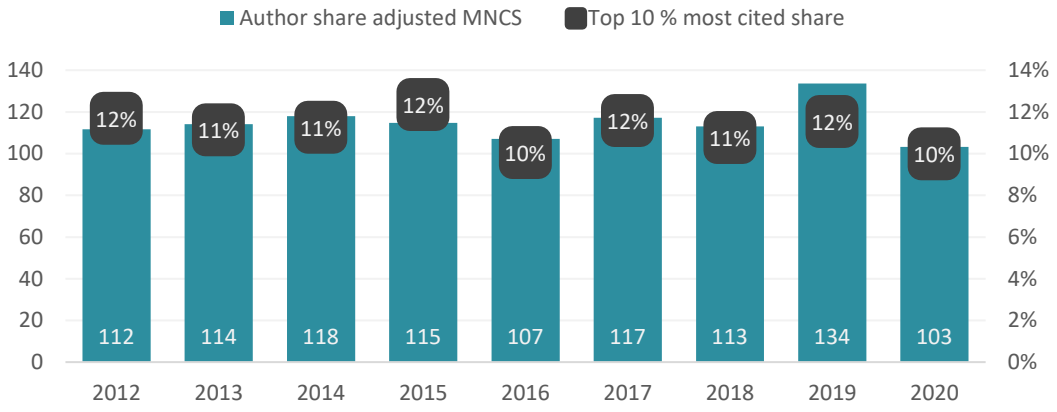

Figure 5.5. MNCS of other biosciences publications (left axis, 100 = global mean citation score for publications from same field and year) and share publications among the 10 % most highly cited publication from same field and year (right axis)

In general, other biosciences research in Norway has been above the global average in recent years. Over the whole period, the share of author contributions that fall within the top 10 % most cited publications is 11.1 %, with most years falling within one percentage point of the global average 10 % share. The average MNCS over the whole period is 114.

Figure 5.6 shows the similar indicator for the publications that fall under the other biosciences category, but using the more fine-tuned WoS-classification system (cf. Figure 5.4). Genetics and cell research has the highest citation impact. The lowest-scoring subfields are developmental biology and biophysics, with an MNCS of 93 and 66, respectively (not shown in the figure).

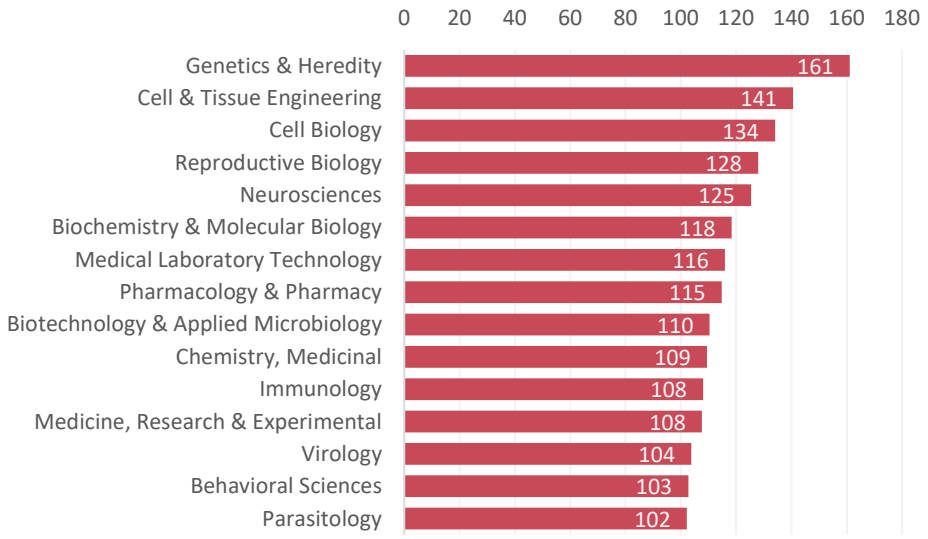

Figure 5.6. MNCS of 15 most impactful Web of Science subfields within Norwegian other biosciences publications, 2018-2021.

Table 5.2 shows which countries can be said to have publications with the highest average citation impact for the period 2018-2020, adjusted for the size of their author contributions to these publications. Only countries with at least 2 000 author shares have been included. The UK ranks on top. Norway is the 13th most impactful country in other biosciences of a total consisting of the 64 largest countries.

Table 5.2. Author share adjusted MNCS of most impactful countries other biosciences, including Norway, 2018-2020

Position	Country	Modified author shares	MNCS
1	UK	126475	148
2	Switzerland	33668	146
3	USA	667981	142
4	Singapore	12056	142
5	Netherlands	50210	137
6	Sweden	27033	126
7	Belgium	25724	125
8	Denmark	23232	123
9	Ireland	9164	122
13	**Norway**	**11167**	**115**

5.3 International collaboration

Which countries are the most important collaborative partners for Norway in other biosciences? To answer this, the distribution of co-authorship by country has been analysed. Table 5.3 shows the frequencies of co-authorship for the nations that comprise Norway's main collaboration partners from 2019 to 2021. The USA is the most important collaboration nation. In total, 21% of the "Norwegian" articles had co-authors from the USA. Almost of equal size is the UK, with a proportion of 20%. Next follow Germany, Sweden, and the Netherlands with proportions of 16, 14, 12%, respectively.

Of all the "Norwegian" publications within the field, 73% had co-authors from other countries as well. This is slightly below the corresponding national average for the natural sciences, all fields combined, which is 75%.

Table 5.3. International collaboration by country.* Number and proportion of collaborative publications with Norway, 2019-2021.

Country	No coll pub	Prop all pub	Country	No coll pub	Prop all pub
USA	1145	21 %	Australia	351	6 %
UK	1099	20 %	Canada	347	6 %
Germany	876	16 %	China	331	6 %
Sweden	755	14 %	Belgium	324	6 %
Netherlands	641	12 %	Austria	236	4 %
Denmark	587	11 %	Poland	198	4 %
France	576	10 %	Japan	180	3 %
Italy	557	10 %	Ireland	153	3 %
Spain	521	9 %	India	144	3 %
Finland	358	6 %			
Switzerland	355	6 %	Total	4061	73 %

*) The overview is limited to the 20 largest countries in terms of number of collaborative articles.

5.4 National collaboration

Figure 5.7 provides a graphic illustration of the Norwegian national research collaboration. In the figure, the size of the circles represents the total number of articles and the width of the lines the number of collaborative articles between different institutions/institutes. The distance between the circles gives an indication of the relative intensity of the collaboration, so that units with relatively many joint publications are grouped together (clusters). Only the largest contributors in terms of number of publications are shown separately, the others are grouped together.

As noted in Chapter 3, we observe particularly close links between the medical faculties and the affiliated university hospitals, where a large part of the publications have co-authors from both the university and the university hospital. This partly reflects the use of "shared" positions, for example in that a senior physician at the university hospital is adjunct professor (II) at the university.

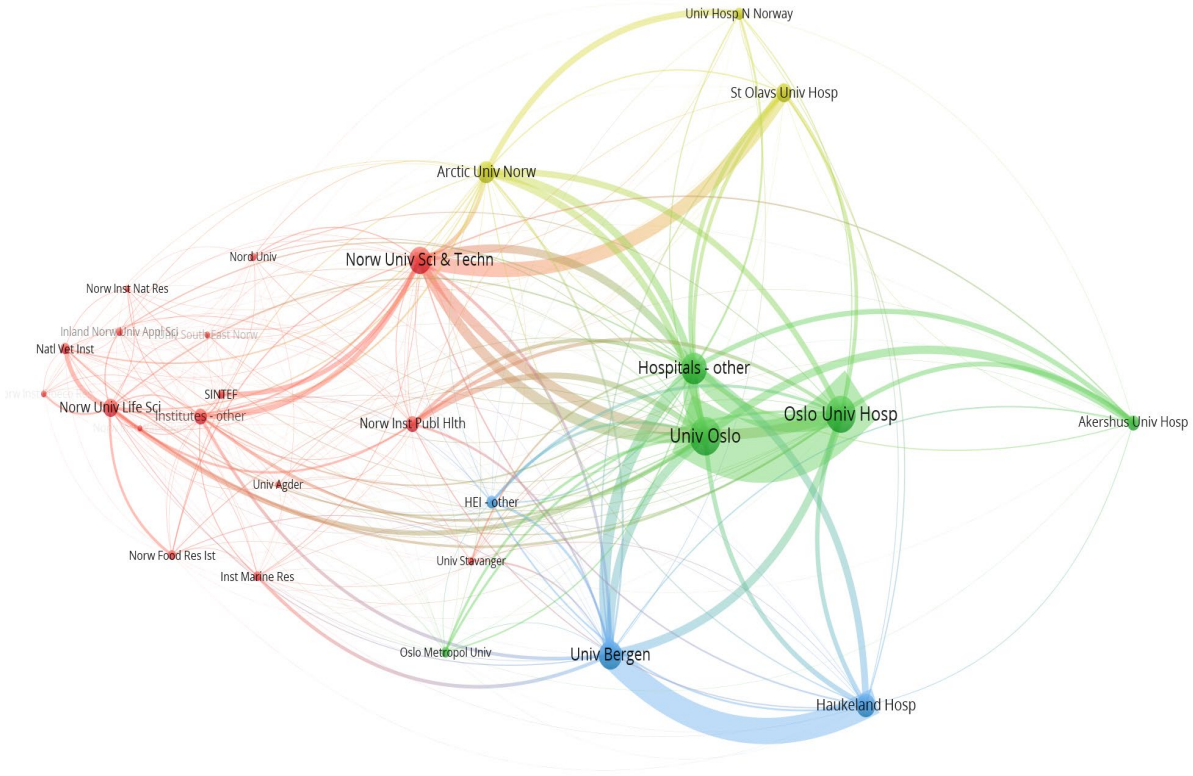

Figure 5.7. Illustration of research collaboration between Norwegian institutions based on co-authorship data 2019-2021

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