



## Food for Thought

### An overview of global research effort in fisheries science

Dag W. Aksnes<sup>1\*</sup> and Howard I. Browman<sup>2</sup>

<sup>1</sup>Research and Education (NIFU), Nordic Institute for Studies in Innovation, Økernveien 9, Oslo N-0653, Norway

<sup>2</sup>Institute of Marine Research, Marine Ecosystem Acoustics Research Group, Austevoll Research Station, Storebø 5392, Norway

\*Corresponding author: e-mail: [dag.w.aksnes@nifu.no](mailto:dag.w.aksnes@nifu.no)

Aksnes, D. W., and Browman, H. I. An overview of global research effort in fisheries science. – ICES Journal of Marine Science, 73: 1004–1011.

Received 22 November 2015; accepted 23 November 2015; advance access publication 24 December 2015.

We used bibliometric indicators to characterize recent (2010–2013) research activity in fisheries science with the objective of garnering insights into how this increased effort has been directed. Specifically, we provide an overview of the primary literature on fisheries research, including which countries are the largest contributors (USA, China, Japan, Australia, Canada, and Norway), and an assessment of the citation impact of the research conducted by different countries. The countries with the highest impact were the UK, Norway, Germany, France, Canada, and Italy. We further assessed the research topics that are most commonly studied and attempt to understand what drives that. During the past three decades, research appears to have shifted from a focus on species-related questions to processes. An analysis of how publication output is distributed at the level of fish species indicates that a small number of species (e.g. Atlantic salmon, rainbow trout, and Atlantic cod) account for a disproportionate volume of the total research effort. Interestingly, publication output is not correlated with the commercial importance of a species. Although fisheries management is purportedly based upon scientific research, our analysis reveals that hardly any research at all is conducted on several of the (commercially) most important species, at least as measured by articles appearing in international scientific journals.

**Keywords:** bibliometrics, cod, fish, rainbow trout, research impact, research trends, salmon, web of science.

#### Introduction

Total global research output has increased significantly during the past 20–30 years (National Science Board, 2014), including in fisheries science and aquaculture (Mather *et al.*, 2008; Natale *et al.*, 2012). This has been driven by, among other things, the need for better science to inform fisheries management, particularly in the context of the ecosystem approach, and to the growing importance and prevalence of aquaculture on an ever-increasing number of species (Link, 2010; Natale *et al.*, 2012; FAO, 2012).

We used bibliometric indicators to characterize recent (2010–2013) research activity in fisheries science with the objective of garnering insights into how this increased effort has been directed. Although a bibliometric analysis of fisheries science was reported by Jarić *et al.* (2012), the analysis reported here expands upon that study by defining fisheries science more broadly, including a much larger number of journals, analysing more species, and reporting on a longer time series. Specifically, we provide an overview of the primary literature on fisheries research, including which countries are the largest contributors, and an assessment of the impact of the research conducted by different countries. We

further assess the research topics that are most commonly studied and attempt to understand what drives that. An analysis of how publication output is distributed at the level of fish species is also presented, including an attempt to correlate publication output with the commercial importance of a species.

#### Methods

##### General approach

The methodological foundation for a bibliometric study such as this is that new knowledge—the principal objective of basic and applied research—is disseminated to the research community mainly through primary publications in scholarly journals; today, predominantly English language journals (see below). Publications can, therefore, be used as indirect measures of knowledge production (van Raan, 2004). This means that indicators of the volume of research on a particular species, for example, can be obtained by using data on scientific publications. Although admittedly imperfect, this approach has been applied in a large number of studies analogous to this one—some examples from fisheries and related

fields are: Neff and Corley (2009), Jarić *et al.* (2012), Jarić and Gessner (2012), Natale *et al.* (2012), and Jarić *et al.* (2015).

The *Web of Science*<sup>®</sup> (WOS) database produced by Thomson Reuters was used as the source of data for assessing research output in fisheries. This is the most commonly used database for bibliometric studies, covering >12 000 scientific, and scholarly journals. Although its coverage is incomplete, this database includes all major scientific journals within the sciences, medicine, and technology and is generally regarded as providing a satisfactory representation of international mainstream scientific research (Moed, 2005). The WOS database has been used as the basis for analogous bibliometric studies in fisheries and related sciences (Neff and Corley, 2009; Nikolic *et al.*, 2011; Jarić *et al.*, 2012, 2015; Jarić and Gessner, 2012; Natale *et al.*, 2012).

Non-English language journals are heavily underrepresented in WOS (van Leeuwen *et al.*, 2001). Therefore, it could be argued that research output from countries that would be expected to produce a significant volume of research in fisheries science (e.g. Russia, Spain, Latin American countries, etc.) will be underrepresented in an analysis based only of data from the WOS. However, recent evidence suggests that the underrepresentation of non-English-speaking countries in the WOS is much less than it has been historically. That appears to have been driven mainly by the addition of a large number of important regional and non-English language journals (e.g. that publish articles with bibliographic information in English but text in another language) to the WOS database, and because of the strong pressure on researchers to publish in English (Wagner and Wong, 2012; López-Navarro *et al.*, 2015). A related issue is disciplinary differences in the WOS's coverage. Biology is very well covered by the WOS (Moed, 2005), and this is also true of fisheries science—all the major journals in this field are in the WOS database. However, a significant volume of fisheries research is produced by national institutes, and they often publish internal reports for their governments in their country's language. The percentage of these reports that eventually make their way into the primary literature, and how that might vary nationally, is very difficult to assess as are its effect on the interpretations of a bibliometric analysis such as the one that we present here. Nonetheless, research results published in the “grey” literature and in non-WOS-indexed journals are not available to a global scientific audience and would, therefore, generally have limited international impact.

### Research effort in fisheries science

The analysis that underlies the overview of global fisheries science presented here is based on aggregated WOS statistics acquired from the Centre for Science and Technology Studies at the University of Leiden for the period 1991–2013. Only regular articles, letters, and reviews were included (i.e. short contributions such as editorials, corrections, book-reviews, and meeting abstracts were not included).

“Fisheries” is a separate category in the WOS. The classification system used involves journal-based field definitions, meaning that all articles in a given journal are assigned to the journal's field. The fisheries category in the WOS is defined as, “Fisheries covers resources concerning numerous aspects of fisheries science, technology and industry, including fish pathology, fish physiology and biochemistry, fish diseases and aquaculture” ([http://ip-science.thomsonreuters.com/mjl/scope/scope\\_scie/](http://ip-science.thomsonreuters.com/mjl/scope/scope_scie/)). Thus, the category includes fisheries science as well as research relating to aquaculture and fish diseases. At the same time, there is a separate WOS category

for “marine and freshwater biology”, in which journals with a broader marine biology focus are generally indexed, although some journals are found in both categories. The WOS category “fisheries” include 69 journals. These are the core journals within the field, but articles within fisheries published outside these core journals (e.g. in general ecology journals) are not included. Thus, the total volume of fisheries publications is underestimated in our analysis. This latter constraint is a general limitation of all journal-based field delimitations applied in bibliometric analyses (Aksnes *et al.*, 2000).

To assess the publication output for individual countries, all articles were classified according to the nationality of all authors affiliated with the article (i.e. the country of their institutional addresses). Many papers are multi-authored, with an international list of authors. In such cases, all countries were fully credited for the article, i.e. with no fractional attribution of credit. The sum of all countries' publication numbers was used as the denominator to calculate any one country's relative contributions to fisheries science. The main indicators of research output at the country level are the number of publications in the WOS “fisheries” category and the relative citation index (see below) of those articles.

The WOS database also includes information on how many times the articles have been referred to or cited in the subsequent scientific literature. The number of citations can be seen as an indirect measure of the scientific impact of the results reported in the article (Moed, 2005). In absolute counts, the countries with the largest number of articles would, of course, also receive the highest number of citations simply because these countries have more papers that can be cited. It is, however, common to use a size-independent measure to assess whether a country's articles have been highly or poorly cited. One such indicator is the relative citation index. This index, which is calculated yearly, shows whether a country's scientific publications have been cited above or below the world average (a score >1.00 means that the country is above the world average). To calculate this indicator, the average citation count of a country's articles in fisheries science is divided by the world average for all articles within fisheries science. Publications co-authored by scientists in more than one country will appear in the calculations of several countries. Since such publications are generally cited more often than articles for which all the authors are from one country, many countries will have a citation index that is higher than the world average.

### Research effort on selected species

We analysed the research output for selected individual fish species (see below). Publication searches were conducted in the WOS database in January 2013 (i.e. publication data for 2013 were not yet available), however, unlike the overall analysis, the species-specific assessment was not limited to journals within the WOS fisheries category; publications in all journals, regardless of field affiliation, were included. There is no straightforward and widely accepted method to identify the volume of research on a particular species. Here, we assumed that if a particular species is mentioned in either the title or the abstract of an article, then that article is focused on that species. Applying this approach, we searched the titles and abstracts of all the publications in the entire WOS database. We used the English and Latin species names, including spelling variants, as search terms. Some species have several different common names: although we used the most common one, this is a potential source of error that would manifest as an underrepresentation in the searches.

The bibliographic details of the publications identified were downloaded and further analysed using software developed for this kind of analysis (Leydesdorff, 1989). This software transforms the bibliographic data of each article into a format permitting quantitative bibliometric analyses.

The number of different species of fish on which research has been conducted is enormous, and therefore we limited the analysis to species with the greatest commercial importance. Although the volume of research on any given species or topic is determined by a large number of factors other than commercial importance, it is reasonable to hypothesize that there is a relationship between the commercial value of a species and the amount of research conducted on it. Commercial importance was decided based upon catch production drawn from the Food and Agriculture Organization of the United Nations' (FAO) statistics. The FAO database contains capture production statistics (in tonnes) by country, fishing area, and species (Garibaldi, 2012). The 2010 statistics, published in 2012, were used (FAO, 2012; Garibaldi, 2012). We focused on the species with the largest capture production. We recognize that capture production in tonnes does not always equate directly with commercial economic value. However, far less data are available on the commercial value of landings, and therefore we used capture production as our proxy for the importance of the fishery. Although farming production was not included, we also analysed three species of major importance in aquaculture: Atlantic Salmon (*Salmo salar*), Rainbow trout (*Oncorhynchus mykiss*), and Nile tilapia (*Oreochromis niloticus*).

### Research effort in fisheries science over time

Although the main focus of the study was to characterize the contemporary publication output in fisheries science, we also assessed changes over time using a snapshot approach. To accomplish this, searches for publications (which followed the same methods as described in Research effort in fisheries science) were conducted over discrete periods within a 20-year span: 1991–1992, 2001–2002, and 2008–2012. We assumed that this approach would be sufficient to identifying overall trends/changes, although any particular brief temporal burst in publication volume (if any) would not have been identified.

The calculation of relative article proportions at the country level, and citation indicators, differs slightly from the analysis described above for fisheries science overall because the data were in different formats. In the analyses of relative proportions, each country was assigned their respective fraction of articles (see e.g. Moed, 2005). For example, if an article had one author address from France and one from Germany, each country received a value of 0.5. Obviously, not every participant makes the same contribution to a study, but at the aggregated level over long time frames and thousands of articles such differences tend to normalize. Thus, the publication measures are taken to reflect the contribution of individual countries to international research. Here, we calculated the citation indicator at the article level and each article is compared with the average article in the respective area of research and year. On this basis, an overall index is calculated (for a further description and assessment of this method, see Waltman and van Eck, 2013). We calculated citation indices for each article separately and this is the basis for the average normalized citation score (Lundberg, 2007).

To detect whether the frequency of the words most commonly appearing in the titles of articles has changed during the past three decades, principal component analysis (PCA) was applied on word counts for all fisheries articles appearing in the years 1993, 2003, and 2013. The word dataset was first distilled by retaining only the words that were listed a minimum of 15 times in all

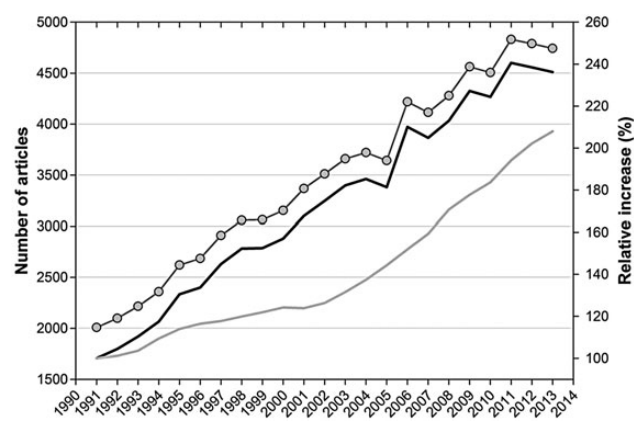
3 years. Words that were present in both singular and plural form, and nouns and adjectives (e.g. “Australia” and “Australian”, or “coast” and “coastal”) were considered as one word.

## Results and discussion

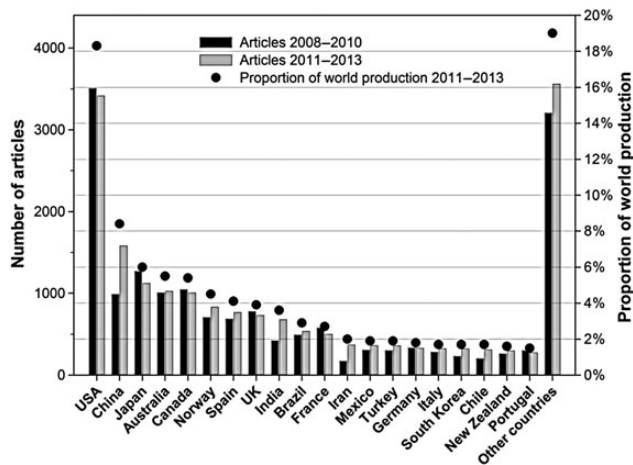
### Research effort in fisheries science

Global production of publications in fisheries research has increased significantly during the past few decades. For example, 4750 articles were published in 2013, compared with 2000 in 1991. In relative terms, the publication volume has risen by 136% during the period; this is higher than the growth in the total global research output (all fields), which was 108% (Figure 1). This reflects an overall increase in global research activity, in which an increasing number of scientists are involved (OECD, 2014). An increased focus on aquaculture species such as Atlantic salmon (*Salmo salar*), Rainbow trout (*Oncorhynchus mykiss*), and Nile tilapia (*Oreochromis niloticus*), coupled with the rapid expansion of aquaculture in general, has contributed significantly to the growth of publication output in fisheries science (see below). The analysis also reveals that the increase has been strongest for countries in the Asian region, both in absolute and relative terms. It should be noted that the coverage of the WOS database—in terms of the number of journals indexed—has grown during the period analysed; that is, the database covers a larger part of the research literature today than it did in the past. At least part of the observed increase is due to this expanded coverage.

The number of publication in fisheries science for two recent 3-year periods—2008–2010 and 2011–2013—were compiled (Figure 2). As in most other research fields, the USA is the largest contributor (National Science Board, 2014), with a proportion of 18.3% of the world total during the most recent period. China has shown a remarkable overall growth in research output during the last decade (Aksnes et al., 2014); this growth is also evident in fisheries science. From 2011 to 2013, China was the second largest fisheries research nation, accounting for 8.4% of the global total, compared with the fifth largest during the previous period (Figure 2). Japan, Australia, and Canada follow, with 5.4–6.0% of the global production. Non-Western countries show the strongest relative growth between these two periods: Iran, India, China, and



**Figure 1.** Absolute number of articles within fisheries science (world total = solid black line through the grey-filled circular points) from 1991 to 2013 and relative increase (%) (1991 is normalized to 100 = solid black line). The relative increase in the number of publications in the entire Web of Science database (all fields) is included as a reference (= solid grey line).

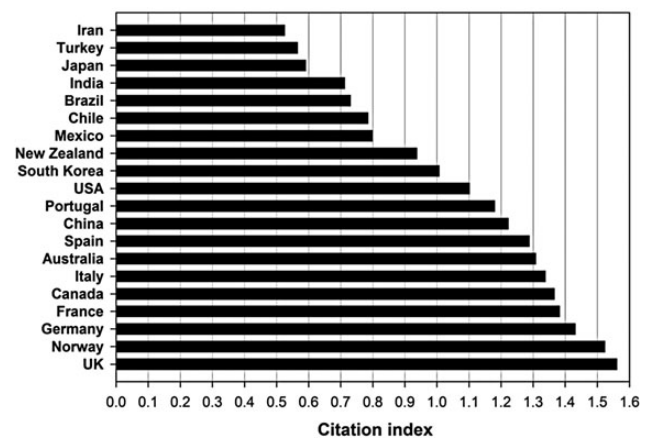


**Figure 2.** The absolute number of articles in fisheries science, and the proportion of world production, for the 20 countries with the highest publication volume (during the period 2011–2013) for 2008–2010 and 2011–2013. The proportion of the world production was calculated using the total publication output of all countries as the denominator.

Chile have all increased their publication output by >50%. On the other hand, publication output declined for seven countries (most notably, Japan and France). In terms of the total publication output (all fields), the relative growth during the two periods has also been strongest for non-Western countries (e.g. China, 53%, Iran, 68%, Malaysia, 95%, Saudi-Arabia, 186%). However, the confounding reality of the expansion in database coverage—which was partly composed of journals from non-Western countries—must also be kept in mind. For example, the *Indian Journal of Fisheries* was added to the WOS database in 2009 and the *Iranian Journal of Fisheries Sciences* in 2007—as a result of this, and other additions, the relative numbers of articles coming from these countries that appear in the WOS database has increased substantially.

The number of citations (i.e. how many times a paper has been referred to or cited in the subsequent scientific literature) is a common indicator of the scientific impact of the research reported in an article. It is generally accepted that frequently cited papers have been more useful or important than publications that are hardly cited at all. The same reasoning can be used for aggregated levels of articles: the more citations that they accrue, the greater their influence. Citation rates vary significantly between countries, with the largest research nations in terms of publication output not necessarily being the most highly cited (Figure 3). Generally, Western countries perform much better than countries from other parts of the world (National Science Board, 2014). The extent to which a country is engaged in international collaboration influences its citation rates. Generally, publications that are coauthored by scientists from many countries are cited more often than articles for which all the authors are from the same country (Jarić *et al.*, 2012).

Two countries stand out with citation indices that are >50% above the world average—the UK and Norway (Figure 3)—indicating that the fisheries research conducted by these nations has a disproportionate impact. Then follows Germany, France, and Canada with citation indices  $\sim 1.4$ . The largest nation in terms of research output, the USA, has an index of 1.10. Publications from Iran, Turkey, and Japan typically have lower scientific impact when measured by citations (citation indices of 0.52–0.59). The latter is likely



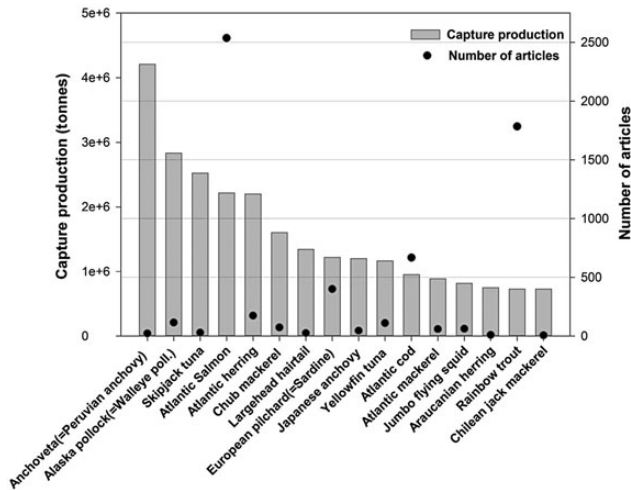
**Figure 3.** The relative citation index in fisheries science for selected countries (those with the largest output in terms of number of articles). The analysis is based on publication output for the period 2008–2012 and accumulated citations to these publications through 2013. A relative citation index >1.00 means that a country's publications have been cited above the world average, and vice versa.

related to the relatively low global profile of research from these countries, particularly when published in regional journals that often have only abstracts in English. For example, the journals *Nippon Suisan Gakkaishi* (*Bulletin of the Japanese Society of Scientific Fisheries*), *Turkish Journal of Fisheries and Aquatic Science*, and *Iranian Journal of Fisheries Sciences* are among the least cited journals in the WOS category. The articles appearing in *Nippon Suisan Gakkaishi* are sometimes published in Japanese (more so in former times than now) and, therefore, are not easily accessible to the worldwide scientific community. Similar negative “language effects” for citation rates have been reported for journals published in German and French (van Raan *et al.*, 2011).

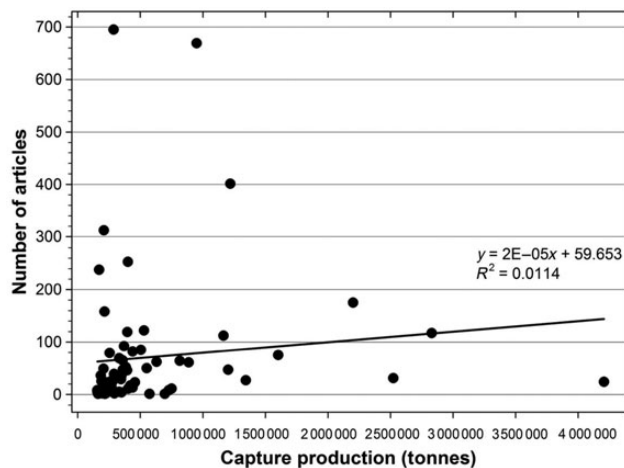
### Research effort on selected species

We focused on the species (fish, crustaceans, molluscs, etc.) with the largest capture production in 2010, according to FAO data, and also included Atlantic salmon and Rainbow trout (Figure 4, and see Supplementary Table S1 for a more complete overview). Anchoveta (Peruvian anchovy, *Engraulis ringens*) has by far the highest capture production (>4 million tonnes). Interestingly, there appears to be relatively little research on this species (Figure 4), which is used mainly for the production of fishmeal: only 24 articles on the species were identified during the period 2010–2012. Next follows Alaska Pollock (*Theragra chalcogramma*), Skipjack tuna (*Katsuwonus pelamis*), and Atlantic herring (*Clupea harengus*), with capture production between 2 and 3 million tonnes. Of these species, Atlantic herring has the highest number of articles: 175 during the 3-year period. Only 31 articles concern Skipjack tuna. The aquaculture production of Atlantic salmon and Rainbow trout amounts to 2.2 and 0.7 million tonnes, respectively. The research efforts on these species, measured in number of articles (2540 and 1780, respectively), far exceed those of other species. At least part of this pattern may relate to the relative ease of studying a species widely available in culture vs. the relative difficulty of studying species that are not cultured in the laboratory. In addition, more research funds may be available for studying these species.

The rank order in terms of scientific article production is very different from the one based upon capture production (Figure 4, Supplementary Table S1): the highest number of articles by far are

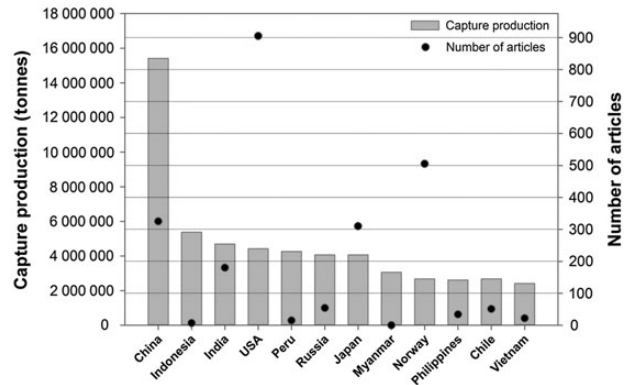


**Figure 4.** Capture production by species and the number of articles during the period 2010–2012. The species presented are those with capture production of 700 000 tonnes or more in 2010, excluding aquaculture. Nonetheless, Atlantic salmon (*Salmo salar*) and Rainbow trout (*Oncorhynchus mykiss*) are also presented because of the very large number of articles on these farmed species.



**Figure 5.** Relationship between the number of articles published during 2010–2012 and capture production in 2010. Each point corresponds to the data for a single species (Cf. data in Supplementary Table S1).

on Atlantic salmon and Rainbow trout, as well as another species with significant aquaculture production, Nile tilapia (*Oreochromis niloticus*, 695 articles, not show in Figure 4). These findings are consistent with Jarić *et al.* (2012), who reported that the most frequently studied group of species was the Salmonidae. Next follow Atlantic cod (*Gadus morhua*, 669 articles), European pilchard (*Sardina pilchardus*, 401 articles), and Giant tiger prawn (*Penaeus monodon*, also an aquaculture species, 312 articles). Surprisingly, for many of the commercially important species, there is hardly any research at all, at least as measured by articles in scientific journals (11 species with <5 articles each). As a result, there is no correlation ( $R^2 = 0.01$ ) between capture production and number of articles (Figure 5). Jarić *et al.* (2012) argued that the most commercially important species were the most studied. However, the basis for such a general conclusion is



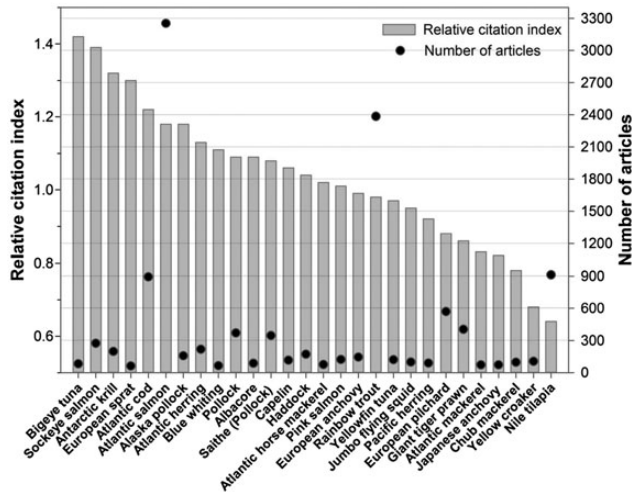
**Figure 6.** Capture production in 2010 of fish, crustaceans, molluscs, etc. (excluding aquaculture), by country and the number of articles during the period 2010–2012. The countries displayed are those with capture production of 2 million tonnes or more in 2010. The number of articles refers to articles about the species included in Supplementary data, Table S1 (those with capture production of 150 000 tonnes or more in 2010).

unclear and is not supported by the observation that there is significant research on several commercially important species (particularly intensively farmed ones) but not on others.

Fisheries management is purportedly based upon scientific research. Our findings cast doubt about the extent to which this is generally the case. However, the management of exploited stocks is still based primarily on stock assessments. Since much of the research conducted in support of such assessments is not published in the primary literature, it is not included in the preceding analysis.

To provide more insight into the distribution of research effort in fisheries science between nations, we analysed (by country) the profiles of a selection of species that are important either in terms of volume of capture production (again, excluding aquaculture) or number of articles (Supplementary Table S2). As expected, the country profiles reflect, to a large degree, the geographical distribution of the species. For example, the major contributor to research on Atlantic cod (*Gadus morhua*) is Norway, USA to research on Alaska Pollock (*Theragra chalcogramma*), USA and Japan to the research on Sockeye salmon (*Oncorhynchus nerka*), and Thailand and India to research on Giant tiger prawn (*Penaeus monodon*). The national profiles also reflect that there is little research on species that are mainly fished by less developed countries although these may be important for the global food supply. Most of the global fishery research effort is carried out by developed countries and concerns species fished by those countries. Further, there is little covariation between the volume of capture production at the national level and scientific research in terms of published articles (Figure 6). China has by far the largest capture production, with >15 million tonnes landed (although there are concerns about the reliability if these statistics, Watson and Pauly, 2001; Pauly *et al.*, 2014) but only a moderate scientific production of 325 articles during 2010–2012. However, several of the highest producing fishery countries have hardly any research at all, at least as reflected in journal articles, for example, Indonesia, Peru, Myanmar, and Viet Nam (Figure 6). Of course, these are developing countries with small research systems both generally and in terms of fishery research. Nevertheless, it is clear that there may be research activity in these countries that are not captured by the bibliometric indicators that

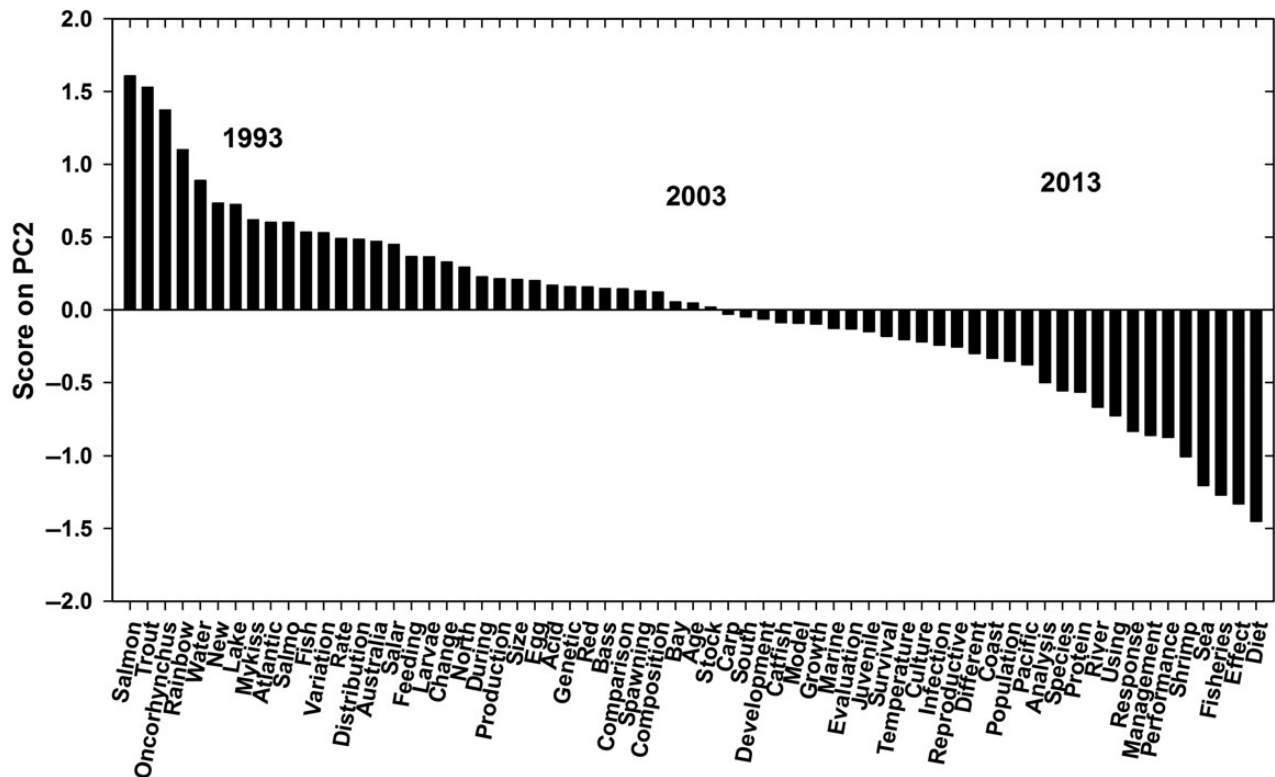
we report. For example, Peru has a large marine research institute that regularly publishes reports concerning fisheries science, but most of this material appears to be published in Spanish and/or as grey literature, neither of which are captured by our analysis.



**Figure 7.** The relative citation index by species based on publications during 2008–2011 and accumulated citations to these publications through 2012. Only species with >60 articles during this period are presented. A relative citation index > 1.00 means that a country's publications have been cited above the world average, and vice versa.

Research on some species tends to be much more cited than that on other species (Figure 7). For example, the citation indices are high for publications about Sockeye salmon (1.39) and Atlantic cod (1.22), while those on Nile tilapia, Giant tiger prawn, and European pilchard are significantly lower (0.64–0.88). Although the reasons for this are difficult to assess, the former species are of relevance to developed nations with a long history of research in fisheries and aquaculture while the latter are mainly of relevance to developing countries (see below). Further, as discussed above, there are significant national variations in citation indices that confound the by-species interpretations. Specifically, the Western European and North American countries generally have citation indices that are significantly higher than the world average, while those from other countries are below average (Figure 3). The citation indices for articles on individual species (Figure 7) at least partly reflect this. It should be noted that the number of articles underlying this analysis is small for some of the species and, in such cases, the citation index is vulnerable to the presence or absence of a small number of highly cited articles.

Several issues should be considered when interpreting these data. For example, the commercial value of the capture production varies significantly across species and is not strongly related to tonnage captured. Commercial value might be a more relevant driver for research effort than capture production measured in tonnes. Nonetheless, the list includes many high-value species on which there has been very little research. The large research focus on aquaculture species may reflect their high commercial value and increasing importance in human food consumption (see FAO, 2012, p. 26).



**Figure 8.** Usage frequency of words appearing in fisheries articles published in 1993, 2003, and 2013. The usage frequency is represented by the factorial scores (row scores on the second principal component, PC2) of each word calculated by PCA. The correlation between the years (column scores) and PC2 was 0.71, 0.001, and -0.71 for 1993, 2003, and 2013, respectively. Therefore, 1993 was characterized by words with positive scores while 2013 was characterized by words with negative scores. Words with lower scores appeared mainly during the intermediate period (2003).

There are surely many other reasons why some species are heavily researched while others are not. A large knowledge base is already available for species such as Atlantic cod for which there is a very long historical tradition of research, while less is known about species for which there has been little research in the past. As a result, species such as Atlantic cod have become model organisms for studying various more general biological and ecological questions. In addition, there is large annual variability in the landings of some of the species, for example, Anchoveta, while stocks of other species have collapsed. It is possible that a significant research effort is applied to species that formerly had very large landings but which were overfished and then collapsed. Under that scenario, there is suddenly a lot of research on them, but little or no landings. The reverse is also possible—when landings fall to low levels, research support disappears.

### Research effort in fisheries science over time

The relative increase in research output on individual species is highly variable (Supplementary Table S3). Among the species with the largest research volume in terms of publication output, Nile tilapia stands out with a particularly strong growth. In 1991–1992, 64 articles could be identified for this species compared with 449 in 2011–2012. This growth probably reflects the increasing importance of this species in aquaculture. Atlantic cod also shows a large increase, from 121 articles in 1991–1992 to 455 articles in 2011–2012. This is likely due to the collapse of the cod fishery in Canada in the early 1990s. The growth in output has been weaker for the next ranked species on the list, European pilchard, Giant tiger prawn, and Saithe (Pollock, *Pollachius virens*).

As science evolves, activity on some research questions expands while that on others contracts. Neff and Corley (2009) proposed that the frequency of words appearing in articles could provide insights into the development of a scientific field and changes in research priorities. The frequency of words most commonly appearing in the titles of articles about fisheries has changed during the past three decades (Figure 8). The highest word counts were 259 in 1993 (“fish”), 379 in 2003 (“growth”), and 532 in 2013 (“fish”). After PCA, all 3 years had similar negative scores on the first principal component (PC), while they were more scattered along the second PC. Correlations between year and PC2 were 0.71, 0.001, and  $-0.71$  for 1993, 2003, and 2013, respectively. Words with positive scores on PC1 (i.e. that had a low word count = 149 words) were removed from Figure 8 to ease visualization of the words that contributed most to the analysis. The general trend from 1993 to 2013 is that there was a decrease in the use of species names and an increase in words descriptive of more general processes and concepts (Figure 8). Interestingly, the number of times that the word “first” (as in, “... for the first time” ...) appeared was 2 in 1993, 29 in 2003, and 79 in 2013. Since it is doubtful that the number of “firsts” (entirely new discoveries) has actually increased by a factor of 40 in 20 years, we propose that this increase reflects the intense pressure on researchers to promote the importance of their work.

This overview of worldwide research effort in fisheries science was intended to assess how the field has changed during the past 20 years, and to identify current trends and priorities. In some cases, the outcome was counterintuitive (e.g. seemingly low level of effort on economically important species), demonstrating how a bibliometric analysis such as this one can inform the scientific community, funding agencies, and policy-makers.

### Supplementary data

Supplementary material is available at the ICES/JMS online version of the manuscript.

### Acknowledgements

We thank Emory Anderson, Geir Ottersen, and Kostas Stergiou for comments on earlier drafts of the manuscript and Caroline Durif for help with the figures and the word frequency analysis.

### Funding

HIB's contribution to this article was supported by Project no. 83741 (“Scientific Publishing and Editing”) from the Institute of Marine Research, Norway.

### References

- Aksnes, D. W., Olsen, T. B., and Seglen, P. O. 2000. Validation of bibliometric indicators in the field of microbiology. A Norwegian case study. *Scientometrics*, 49: 7–22.
- Aksnes, D. W., van Leeuwen, T. N., and Sivertsen, G. 2014. The effect of booming countries on changes in the relative specialization index (RSI) on country level. *Scientometrics*, 101: 1391–1401.
- FAO. 2012. The State of World Fisheries and Aquaculture. FAO Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, Rome. 223 pp.
- Garibaldi, L. 2012. The FAO global capture production database: a six-decade effort to catch the trend. *Marine Policy*, 36: 760–768.
- Jarić, I., and Gessner, J. 2012. Analysis of publications on sturgeon research between 1996 and 2010. *Scientometrics*, 90: 715–735.
- Jarić, I., Knežević-Jarić, J., and Gessner, J. 2015. Global effort allocation in marine mammal research indicates geographical, taxonomic and extinction risk-related biases. *Mammal Review*, 45: 54–62.
- Jarić, I., Knežević-Jarić, J., and Lenhardt, M. 2012. Trends in fisheries science from 2000 to 2009: a bibliometric study. *Reviews in Fisheries Science*, 20: 70–79.
- Leydesdorff, L. 1989. Words and co-words as indicators of intellectual organizations. *Research Policy*, 18: 209–223.
- Link, J. S. 2010. *Ecosystem-Based Fisheries Management: Confronting Tradeoffs*. Cambridge University Press, Cambridge, UK.
- López-Navarro, I., Moreno, A. I., Quintanilla, M. Á., and Rey-Rocha, J. 2015. Why do I publish research articles in English instead of my own language? Differences in Spanish researchers' motivations across scientific domains. *Scientometrics*, 103: 939–976.
- Lundberg, J. 2007. Lifting the crown – citation z-score. *Journal of Informetrics*, 1: 145–154.
- Mather, M. E., Parrish, D. L., and Dettmers, J. M. 2008. Mapping the changing landscape of fish-related journals: setting a course for successful communication of scientific information. *Fisheries*, 33: 444–453.
- Moed, H. F. 2005. *Citation Analysis in Research Evaluation*. Springer, Dordrecht.
- Natale, F., Fiore, G., and Hofherr, J. 2012. Mapping the research on aquaculture. A bibliometric analysis of aquaculture literature. *Scientometrics*, 90: 983–999.
- National Science Board. 2014. *Science and Engineering Indicators 2014*. National Science Foundation, Arlington, VA.
- Neff, M. W., and Corley, E. A. 2009. 35 years and 160,000 articles: a bibliometric exploration of the evolution of ecology. *Scientometrics*, 80: 657–682.
- Nikolic, N., Baglinière, J.-L., Rigaud, C., Gardes, C., Masquillier, M. L., and Taverny, C. 2011. Bibliometric analysis of diadromous fish research from 1970s to 2010: a case study of seven species. *Scientometrics*, 88: 920–947.
- OECD. 2014. *Main Science and Technology Indicators. Volume 2013/2*. OECD Publishing, Paris.
- Pauly, D., Belhabib, D., Blomeyer, R., Chueng, W. W. W. L., Cisneros-Montemayor, A. M., Copeland, D., Harper, S., et al.

2014. China's distant-water fisheries in the 21st century. *Fish and Fisheries*, 15: 474–488.
- van Leeuwen, T. N., Moed, H. F., Tijssen, R. J. W., Visser, M. S., and van Raan, A. F. J. 2001. Language biases in the coverage of the science citation index and its consequences for international comparisons of national research performance. *Scientometrics*, 51: 335–346.
- van Raan, A. F. J. 2004. Measuring science. *Capita selecta of current main issues. In Handbook of Quantitative Science and Technology Research. The Use of Publication and Patent Statistics in Studies of S&T Systems*, pp. 19–50. Ed. by H. F. Moed, W. Glänzel, and U. Schmoch Kluwer, Dordrecht.
- van Raan, A. F. J., van Leeuwen, T. N., and Visser, M. S. 2011. Severe language effect in university rankings: particularly Germany and France are wronged in citation-based rankings. *Scientometrics*, 88: 495–498.
- Wagner, C. S., and Wong, S. K. 2012. Unseen science? Representation of BRICs in global science. *Scientometrics*, 90: 1001–1013.
- Waltman, L., and van Eck, N. J. 2013. Source normalized indicators of citation impact: an overview of different approaches and an empirical comparison. *Scientometrics*, 96: 699–716.
- Watson, R., and Pauly, D. 2001. Systematic distortions in world fisheries catch trends. *Nature*, 414: 534–536.