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Contribution to the Special Issue: 'Commemorating 100 years since Hjort's 1914 treatise on fluctuations in the great fisheries of northern Europe'

Food for Thought

Johan Hjort's impact on fisheries science: a bibliometric analysis

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We analyse how Johan Hjort's publication, "Fluctuations in the great fisheries of northern Europe, viewed in the light of biological research" (Hjort, 1914), has been cited in the subsequent scientific literature. In the context of this special issue commemorating the 100th anniversary of Hjort's seminal publication, our objective is to provide insights into how his work has penetrated the literature and influenced the development of fishery science. We also tracked Hjort's related article, "Fluctuations in the year classes of important food fishes" (Hjort, 1926). We present the citation life cycles of these articles and analyse various characteristics of the publications that cite them. The importance of Hjort (1914) is reflected in the large number of citations that it has accrued (908), and by the 40 – 50 citations that it continues to receive every year. This is exceptional for a 100-year-old scientific article, in any field. Hjort (1926) initially received as many cites as Hjort (1914), but the latter subsequently became the paradigmatic article. Hjort (1914) has been cited in 162 different journals and by scientists in 53 countries—Hjort's work has had a broad and global impact on fisheries research. The contextual analysis demonstrated that Hjort (1914) is considered a seminal, novel, and paradigm setting study—the core research questions addressed by Hjort (1914) remain unsolved and several of his hypotheses continue to drive fisheries science to this day.

Keywords: 1914, delayed rise no decline, fish biology, highly cited, recruitment.

Introduction

One hundred years ago, Johan Hjort, in his publication "Fluctuations in the great fisheries of northern Europe, viewed in the light of biological research" (Hjort, 1914), posited an interrelated set of hypotheses that have driven fisheries science ever since—the migration/movement, year-class success, parental condition, prey field ("critical periods"), and dispersal hypotheses. Hare (2014, page xx) states, "Arguably, Johan Hjort is the father of fisheries oceanography. His 1914 publication set the stage for a century of work aimed at understanding fluctuations in abundance of fishery species. Hjort knew that fishery yields varied through time, and his purpose was to understand the basis for this variability". The importance of Hjort (1914) is reflected in the large number of citations that it has accrued, and by the unusually large number of citations that it continues to receive every year (detailed below). The latter is, to say the least, exceptional for a 100-year-old scientific article. Therefore, we herein analyse how Hjort (1914) has been cited in the subsequent scientific literature.

In the context of this special issue commemorating the 100th anniversary of Hjort's seminal publication, our objective is to provide insights into how his work has penetrated the literature and influenced the development of fishery science. We also tracked Hjort's related article, "Fluctuations in the year classes of important food fishes" (Hjort, 1926). We present the citation life cycles of these articles and analyse various characteristics of the publications that cite them. Further, using citation context analysis, we investigate and comment on the reasons why Hjort's work continues to be cited. This article is intended to be complimentary to the more biographically oriented articles about Johan Hjort that appear in this special issue (Hubbard, 2014; Schwach, 2014), as well as with Rice and Browman (2014), who track how "recruitment process" research has been subsumed into research on ecosystem-based management and climate change.

Material and methods

The bibliographic database Web of Science (WoS), Thomson Reuters, was used to trace the influence of Hjort's research in the

literature. WoS indexes the majority of the international scientific journals in the fields of fisheries and marine biology. The WoS database is, therefore, well suited to assessing Hjort's impact. However, it is important to note that the standard WoS coverage only extends back to 1945. Thus, the database cannot be used to analyse the research literature in the first three decades after Hjort (1914) was published. It should also be noted that the coverage of the database, in terms of journals indexed, has increased significantly over the course of time—the database presumably covers a larger part of the research literature today than it did in the past (see Aksnes and Hessen, 2009).

Hjort's publications are not indexed as primary literature in the WoS. Therefore, the citations to the articles from the indexed literature were traced using the WoS' citing reference function in which the author names and publication year are used to identify cited references. We searched for citations to "J Hjort, 1914" in journals that are indexed in WoS from 1945 onwards. Therefore, our analysis surely underrepresents the true number of citations and penetration of Hjort (1914). We used the same procedure to search for Hjort (1926), using "J Hjort, 1926". The searches were carried out in January and February 2013.

The retrieved citing publications were then analysed according to bibliographic parameters such as publication year, journal, and nationality of citing authors. In addition, we conducted a citation content analysis in order to explore the reasons why Hjort's publication is still cited in the contemporary literature (see below). In order to make some comparisons with the research output in fishery and marine biology generally, we also used the National Science Indicators (NSI) database which the Nordic Institute for Studies in Innovation, Research and Education (NIFU) has purchased from Thomson Reuters. This database contains aggregated bibliometric data at country and field/subfield levels. The 2012 edition of NSI, with data covering 1981–2011, was used.

A quantitative bibliometric analysis does not yield any information about the reasons why an article or author's work continues to be cited. In order to provide more insights into that question, we conducted a citation context analysis by analysing the textual passages in which Hjort (1914) is referred to in the citing documents (*sensu* Small, 1982). This is very time-consuming as each article has to be examined manually. Therefore, we made an arbitrary choice to look only at citing articles that in turn have been highly cited. Using this approach, we were able to assess the influence of Hjort's work on other high impact publications within the field. We limited the study to articles with 140 or more citations—a total of 41 articles, of which we were able to obtain 37, were examined for content analysis. Thus, the context analysis should be considered illustrative rather than systematic.

We also input the titles of all of the articles in WoS that had cited Hjort (1914) into the www.wordle.net tool and generated a word cloud that illustrates the frequency of occurrence of the words in those titles. Common words that do not have thematic content, such as *and, of, the*, etc., are excluded.

Results and discussion

In total, 908 unique citations of Hjort (1914) and 187 unique citations of Hjort (1926) were identified (includes citations from 1945 to January 2013). The number of citations has increased with time, with Hjort (1914) currently being cited an impressive 40–50 times per year and Hjort (1926) 5–10 times per year (Figure 1). Very few publications, in any field, attain citation numbers as high as Hjort (1914), and the current citation rate is exceptional for a 100-year-old scientific publication. In fact, from a total of over 120 000 indexed articles in the WoS category "Fisheries", only 7 have accrued a higher total citation count than Hjort (1914).

The typical citation life-cycle pattern of a scientific publication is a parabolic curve of rise and decline. An average article is poorly cited the first year after publication; a citation peak is reached ~3 years after publication, followed by decreasing citedness the subsequent years (Aksnes, 2003). There are, however, differences in citation life cycle across fields; in fisheries research, the rise typically takes longer, although it rarely asymptotes at a level anywhere near as high as Hjort (1914). Moreover, there are also large variations in citation life cycle at the level of the individual article. In a previous analysis of highly cited publications, Aksnes (2003) identified different clusters of temporal citation patterns. One category of highly cited articles, termed "delayed rise, no decline" articles, is characterized by a relatively slow rise in citation frequencies and a stable or increasing citation level thereafter. The citation curve of Hjort (1914) resembles this category of highly cited articles. Such a citation pattern implies that Hjort (1914) reports research–concepts–theories that are of continuing interest (e.g. by paradigm articulation or by developing particularly useful methods). We will take this up below.

Citations to 100-year-old publications are obviously very rare in the natural sciences. The large majority of citations are to recent publications. In 2004, the median age of cited literature in the natural sciences and engineering was about 7 years, while the mean was about 11 years (Lariviere *et al.*, 2008). The mean is significantly higher than the median because some older publications, such as Hjort (1914), are still cited. When interpreting the citation life cycle of Hjort's work, it must be noted that there has been a large increase in the overall volume of research in fisheries and marine biology. For example, the annual number of articles classified within the WoS category "Fisheries" increased from 1400 in 1981 to 4600 in 2011. We do not have corresponding statistics for the preceding period; however, the global production was surely lower at that time. Thus, the volume of articles that could cite Hjort (1914) is much larger today than in the past. However, this does not account for the rise in citations to Hjort (1914), since it has risen from ~5 per year before 1980 to 40–50 per year since

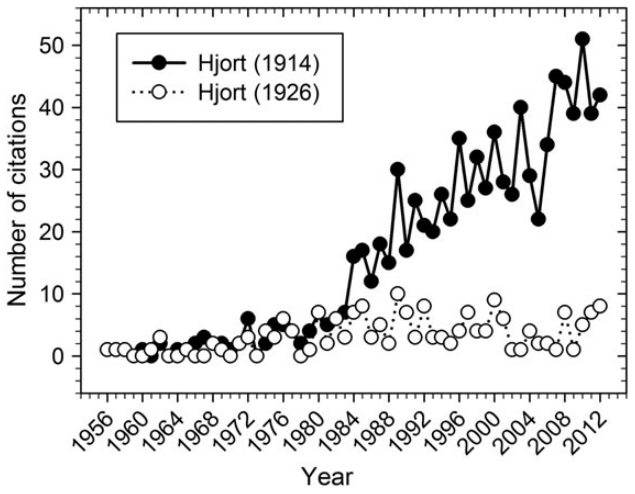

Figure 1. The absolute number of citations to Hjort (1914) and Hjort (1926) per year (1956–2012).

2006, an increase of 8–10 times while the overall growth in fisheries publications during the same period has been by a factor of 3.

During the first three decades of the time-series, Hjort (1914) and Hjort (1926) had similar citation rates (Figure 1). However, unlike Hjort (1914), the annual citation rate of Hjort (1926) did not rise significantly thereafter. Although we can only speculate, the differential citations to these two articles could be related to their somewhat different content and/or to the sociology of the citers (e.g. authors choose to cite the article that has been receiving more cites and, over time, that article becomes the only one that is cited and becomes the paradigmatic one).

In terms of the journals in which most citations to Hjort (1914) come from—not surprisingly, the list is strongly dominated by fishery and marine biology titles (Table 1); there are only a few citations from journals in other fields. The publication has been cited in 162 different journals, but the majority of these journals (104) have only cited the publication one or two times. *Marine Ecology Progress Series* (*MEPS*) is at the top of the list with 108 articles citing Hjort (from its foundation in 1979 to 2012). During this period, more than 12 000 articles have been published in *MEPS* and, therefore, almost 1% of the articles have cited Hjort (1914). After *MEPS*, follows the *Canadian Journal of Fisheries and Aquatic Sciences* (83 articles) and then the *ICES Journal of Marine Sciences* (52 articles).

Hjort (1914) has been cited by scientists in 53 countries—Hjort's work has had a broad and global impact on fisheries research. Approximately one-third of the authors citing Hjort (1914) are from the United States (Figure 2). Canada and Norway follow with 13 and 10% of the citations, respectively. The distribution of nationalities of citing authors corresponds loosely to the pattern of global scientific contributors within the fields of fishery and marine biology. For example, within the WoS category "Fisheries", the United States accounted for 23% of the global publication output during the period 1981–2011 (using the sum of all country's publication output as the denominator). The corresponding figures for Canada and Norway are 9 and 4%, respectively. Thus, researchers from the United States, Canada, and Norway tend to cite Hjort (1914) more often than those from other countries, relatively speaking. Hjort being a Norwegian scientist, this is not surprising for Norway and Hjort's connection to Canada and the fisheries on the east coast of North America was also strong (see Hubbard, 2014).

We used the wordle word cloud tool to visualize the most frequently appearing words in the tiles of articles that cite Hjort (1914; Figure 3). The size of a word in the word cloud is proportional to the number of times that it appears in the titles of the citing articles. The most frequently appearing words by far are *larval* and *larvae* with 178 and 171 appearances, respectively. Then follows *growth*, *fish*, and *recruitment* with frequencies in the range of 122–134 times. These word frequencies indicate that the topical themes of the citing articles are closely aligned with those taken up in Hjort (1914).

The citation context analysis, although limited to 37 highly cited articles, demonstrates clearly that Hjort (1914) is most often cited in the introduction of the articles. There are also many references to Hjort (1914) in the discussion of the articles. Typically, the introduction of a scientific article is structured as a progression from the general to the particular and often starts with references to the more general or basic works within a field. Consistent with this, references to Hjort (1914) are often found at the beginning of the text. Moreover, the citations are relatively uniform and the work

Table 1. List of the journals that cite Hjort (1914) most often (1956–2012).

Journal	# of articles	Journal	# of articles
Marine Ecology Progress Series	108	*Nippon Suisan Gakkaishi*	7
Canadian Journal of Fisheries and Aquatic Sciences	83	*Aquaculture*	7
ICES Journal of Marine Science	52	*Limnology and Oceanography*	7
Fisheries Oceanography	43	*Ecological Modelling*	7
Transactions of the American Fisheries Society	39	*Netherlands Journal of Sea Research*	7
Marine Biology	37	*Journal of the Marine Biological Association of the United Kingdom*	6
Fishery Bulletin	35	*Proceedings of the Royal Society B: Biological Sciences*	6
Journal of Fish Biology	32	*Nature*	6
Fisheries Research	19	*Fish and Fisheries*	6
Journal of Experimental Marine Biology and Ecology	18	*Plos One*	5
Journal of Sea Research	17	*California Cooperative Oceanic Fisheries Investigations Reports*	5
Bulletin of Marine Science	17	*Proceedings of the National Academy of Sciences of the United States of America*	5
Scientia Marina	14	*Marine and Freshwater Research*	5
Journal of Plankton Research	13	*Reviews in Fish Biology and Fisheries*	5
Ecology	13	*Advances in Marine Biology*	5
Environmental Biology of Fishes	12	*Fishery Bulletin of the National Oceanic and Atmospheric Administration*	4
Journal of the Fisheries Research Board of Canada	10	*Estuarine Coastal and Shelf Science*	4
Progress in Oceanography	9	*Biological Bulletin*	4
Journal of Marine Systems	9	*Archive of Fishery and Marine Research*	4
Deep-Sea Research Part II: Topical Studies in Oceanography	9	*American Naturalist*	4
Marine and Coastal Fisheries	8	*Trends in Ecology and Evolution*	4
Journal of Great Lakes Research	8	*Annual Review of Ecology and Systematics*	4
Ecological Applications	8	*North American Journal of Fisheries Management*	4
Fisheries Science	7	Other journals	167

tends to be cited for its hypotheses about advective loss, critical periods, and starvation (see Hare, 2014).

Garfield (1977) identified 15 reasons why a particular article might be cited. At least two of them seem particularly relevant for Hjort (1914): paying homage to pioneers and identifying original publications in which an idea or concept was discussed. The quotes below exemplify the first type of citation, which normally appear the article's introduction: "The importance of recruitment variability in the dynamics of exploited fish populations has been appreciated since the turn of the century (Hjort 1914)..." (Fogarty *et al.*, 1991); "Pelagic fish stocks have been studied intensively, and, since the classic work of Hjort (1914), environmental factors are recognized as a determinant of recruitment success" (Cury *et al.*, 2000). In these examples, Hjort (1914) is mentioned, although his theories do not necessarily play a central role in the article. The second, more specific type of referencing, "identifying original publications in which an idea or concept was discussed", also appears frequently for Hjort (1914). Such citations also usually occur in the introduction of the article. The following quotes illustrate this type of citation: "Documenting strong year classes in various fish stocks, Hjort (1914) was the first to articulate the idea that variation in larval survival may drive adult population dynamics" (Caley *et al.*, 1996); "Hjort (1914) marked the beginning of a paradigm shift away from the migration theory to the view that fluctuations in adult abundance might be caused by variable recruitment..." (Swearer *et al.*, 2002); "The match–mismatch theory first postulated by Hjort (1914) predicts that larvae hatching from eggs at a time when plankton densities are high will experience more rapid growth and higher survival than larvae produced when food is in short supply..." (Trippel, 1998). In addition to the two types of contextual referencing described above, other examples include articles where Hjort's work is cited in line with other literature as establish findings: "Variability has long been a recognised feature of the recruitments of marine organisms using broadcast reproduction (Hjort 1914, Coe 1953, 1956; Loosanoff, 1964, 1966, others in Underwood 1979)" (Doherty, 1983); "This is reflected by the dominance of single age cohorts for extended periods in both tropical and temperate species (e.g. Hjort 1914; Russ *et al.* 1996)" (Dulvy *et al.*, 2003). The latter type of referencing is less frequent than the other two and occurs in both the introduction and discussion of articles. Overall, the contextual analysis demonstrates that Hjort (1914) is considered a seminal, novel, and paradigm setting study.

Generally, citations to older publications decrease as a result of the phenomenon termed "obliteration by incorporation": authors cease citing basic theoretical knowledge because it quickly becomes adopted as fact and/or the article unequivocally resolves the question that it took up. As a consequence, articles that present very basic and widely important findings may not be highly cited. One example of this is the article by Watson and Crick (1953) on

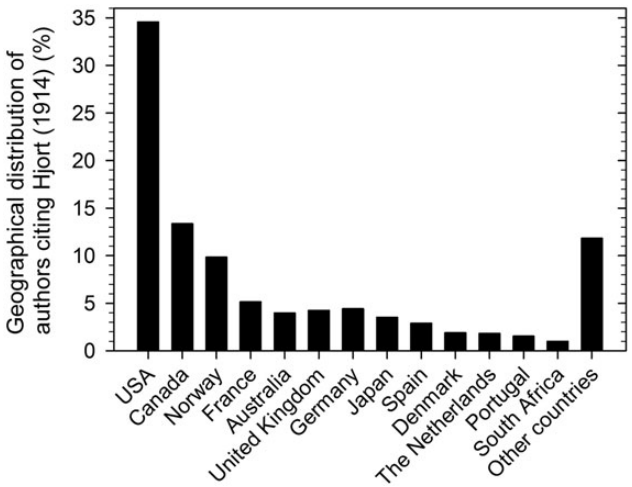

Figure 2. National distribution of authors citing Hjort (1914; 1956–2012). Note that articles with co-authors from more than one country are counted once for each country.

Figure 3. Illustration of the frequency of title words in articles citing Hjort (1914; 1956–2012). The size of the word is proportional to its frequency. Source: wordle.net.

the double helix structure of DNA, which is highly cited but not as frequently as one might expect for such a revolutionary contribution. Their findings were rapidly incorporated into the common body of accepted knowledge and, when this happened, researchers no longer cited it—everyone knew that the DNA molecule was a double helix. Importantly, for Hjort (1914), there is no evidence of this phenomenon; quite the contrary. We contend that this is because the core research questions addressed by Hjort (1914) remain unsolved and several of his hypotheses continue to drive fisheries science to this day (see Godø *et al.*, 2014; Hare, 2014; Hutchings, 2014).

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