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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'

Introduction

Commemorating 100 years since Hjort's 1914 treatise on fluctuations in the great fisheries of northern Europe: where we have been, where we are, and where we are going

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The year 2014 marks the 100th anniversary of Johan Hjort's seminal treatise, *Fluctuations in the great fisheries of northern Europe, viewed in the light of biological research*. This special issue of the *ICES Journal of Marine Science* commemorates this anniversary. The thirty-two articles that appear herein demonstrate the deep influence that Johan Hjort's work has had, and continues to have, on fisheries and marine science.

Keywords: climate change, density dependence, settlement, Johan Hjort, juveniles, larvae, migration hypothesis, recruitment variability, stock–recruit; critical periods.

Background

The year 2014 marks the 100th anniversary of Johan Hjort's seminal treatise, *Fluctuations in the great fisheries of northern Europe, viewed in the light of biological research* (Hjort, 1914). Since this and many other works by Hjort appeared in the pages of ICES publications, including the precursor of this journal, it seemed natural to commemorate this anniversary in the *ICES Journal of Marine Science*. Therefore, in mid-2012, I distributed a call for contributions to this special issue. My hope was that the entire fisheries science community would be able to produce a special issue with more pages than Hjort's treatise (228), even in this era of the minimum publishable unit and the enormous pressure on scientists to publish anything slightly more than that in a "high impact" journal. Thirty-two of the articles that were submitted in response to the call appear in this special issue—they total considerably more than 228 pages. These articles demonstrate the deep influence that Johan Hjort's work has had, and continues to have, on fisheries and marine science (also see Houde, 2008). In this introduction, I briefly summarize these articles, categorizing them into those that touch upon where we have been, where we are, and where we are going.

Where we have been

One hundred years ago, Johan Hjort distilled a large number of observations, and some of the first time-series of their kind (e.g. the age structure of individuals in a population and their condition), and posited a set of hypotheses that have driven fisheries science ever since (see Hjort, 1914, p. 209, under the heading, "Importance of future investigations as to the-causes of numerical variation"). The historical context in which Hjort accomplished this, and insights into the man and his work environment, is described by Schwach (2014). Hubbard (2014) provides insights into Hjort's activity on the eastern seaboard of North America and how this transformed fisheries science in Canada and established the still strong links between Canadian and Norwegian fisheries science. Holt (2014) provides fascinating insight into the scientific background and the interactions with contemporary researchers who influenced Hjort's thinking about the optimum yield. Aksnes and Browman (2014) present a bibliometric analysis of Hjort's work, concluding that the large number of citations that it has accrued, and the 40–50 citations that it continues to receive every year are exceptional for a 100-year-old scientific article and reflect its place as a seminal, novel, and paradigm-setting study that continues to drive fisheries science to this day.

Where we are

Several articles take up the questions addressed by Hjort (1914), sometimes using new innovations in sampling and analysis, application of mathematical models, adding climate change as a context, or with a slightly new "spin".

Leaf and Friedland (2014) explore the relationship between autumn phytoplankton bloom and recruitment variability of haddock (*Melanogrammus aeglefinus*) on the Georges Bank, concluding that the former has some explanatory power over the latter. Lusseau *et al.* (2014) conclude that recruitment failure in North Sea herring (*Clupea harengus*) is associated with poor feeding success. Robert *et al.* (2014) highlight the limits in our ability to identify the gut content of fish larvae as a possible reason why we have been unable to observe critical periods, as postulated by Hjort (1914, 1926): "As factors, or rather events which might be expected to determine the numerical value of a new year-class, I drew attention to the following two possibilities: 1) That those individuals which at the very moment of their being hatched did not succeed in finding the very special food they wanted would die from hunger. That in other words the origin of a rich year class would require the contemporary hatching of the eggs and the development of the special sort of plants or nauplii which the newly hatched larva needed for its nourishment." (Hjort, 1926, p. 33).

Hjort recognized the importance of the liver as an indicator of condition in cod (*Gadus morhua*) (Hjort, 1914, "Variations in the quality of the cod, p. 176, for example) and Kjesbu (2014) extends the liver index data presented by Hjort (1914) both backward and forward in time and use it to develop a unique 150-year-long condition factor time-series for Northeast Arctic cod. Ottersen *et al.* (2014) review the effects of biotic and abiotic drivers on the early life stage dynamics (from eggs to age 3 juveniles) of Barents Sea cod in the context of the hypotheses developed by Hjort (1914). They conclude that is unlikely that recruitment is, in general, always determined at the same single life stage. In fact, when summarizing the possible drivers of recruitment variability, Hjort said, "I had myself to leave these possibilities and their respective influence, if any, on the formation of the stock undecided, and the final decision in this matter may still be said to be open for discussion." (Hjort, 1926, p. 33).

Bergstad *et al.* (2014) report that strong recruitment years in a deepwater species, the roundnose grenadier (*Coryphaenoides rupestris*), are rare and that this must be carefully considered when exploiting long-lived fish with slow growth, high age at first maturity, and low fecundity (deep sea fish with life histories of this nature were not the focus of Hjort's work).

Several articles take up settlement by juveniles, another topic raised by Hjort (Hjort, 1914, p. 100, "Distribution of the youngest bottom stages"), although he did not address issues such as habitat structure/availability or density dependence. Bastrikin *et al.* (2014) report that the settlement dynamics of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and whiting (*Merlangius merlangus*) differs in timing, duration and in the size of individuals at the time of the pelagic-demersal transition. Caddy (2014) takes on the issue of habitat structure and availability, and its relationship with predation pressure and carrying capacity for demersal fish, using a novel fractal-based approach to quantify habitat complexity. Archambault *et al.* (2014) take up density-dependent processes during recruitment of 39 flatfish stocks. In general, settlement dynamics, carrying capacity of the bottom and concomitant density-dependence, has received less attention than they merit.

Hilborn *et al.* (2014) revisit the question of whether fish stocks that have been reduced to <20% of their maximum size exhibit signs of depensation (aka Allee effects). There was little evidence to support strong depensation, although they could not rule out the possibility of depensation at very low stock sizes. They also suggest that severely depleted stocks should rebuild is fishing pressure are reduced, but only if the environment has not changed. Hutchings (2014) also takes up the population dynamics of marine fish at low abundance, concluding that some severely depleted fish populations show signs of an Allee effect, or a transition from strong to weak compensatory dynamics. Like Hilborn *et al.* (2014), Hutchings (2014) notes that a population's sensitivity to environmental change increases the longer it remains at low abundance. Botsford *et al.* (2014) describe "cohort resonance" as a "characteristic behavior of age structured populations which does involve changes in adult abundance but can have a substantial effect on fluctuations in fished populations". It remains to be seen whether this fascinating phenomenon will be found in a wide range of stocks. Hixon *et al.* (2014) emphasize the importance of big old fat fecund female fish (BOFFFFs)—something that Hjort (1914) only alluded to peripherally when taking up maternal effects. The reproductive characteristics of BOFFFFs and the progeny that they produce indicate that they improve individual reproductive success in variable environments; this argues strongly for efforts to conserve them in the population.

It is fair to say that, for at least the past decade, global climate change has been a stronger motivator-focus of research in fisheries and marine science than has variability in recruitment *per se* (see Rice and Browman, 2014). Able *et al.* (2014) analyse a time-series of data on recruitment in the southernmost stock of winter flounder (*Pseudopleuronectes americanus*) and conclude that years in which spring temperatures were warm always experienced poor recruitment. They also took up the possible co-variability of temperature and predator abundance and the effect that this might have on mortality in winter flounder larvae. Zwolinski and Demer (2014) report that, during the last three decades, the periods of stock increase and decrease recruitment in the California Current Pacific sardine (*Sardinops sagax*) stock followed consecutive years with positive and negative Pacific Decadal Oscillation index values, respectively. Punt *et al.* (2014) assess whether incorporating environmental variability into management strategy evaluations improves the performance of those strategies. They conclude that including environmental factors only improves the ability to achieve management goals if their mechanism of action is understood. Importantly, although the context into which these studies are placed is climate change, the processes and mechanisms that they take up are the same as would have been the case if the context had been recruitment variability. Hjort (1914, 1926) also took up climate-related drivers of recruitment variability, for example, annual differences in freshwater run-off, sea surface temperature, and oceanic currents, and he was also well aware of climate-related changes in the distribution and range of stocks (e.g. Hjort, 1948, p. 164).

Since the themes taken up by Hjort (1914) deal with the factors that underlie variability in the productivity of ecosystems, and how that influences the population dynamics of high-fecundity organisms with low cumulative survival to reproductive age, I tried to attract contributions from outside the marine fish community. My success in that was limited, although there are articles herein on the drivers of population fluctuations in insects (locust) and invertebrates (octopus) (Cheke *et al.*, 2014; Sonderblohm *et al.*, 2014), which are entirely consistent with analogous studies on fish. Janssen (2014) and Pritt *et al.* (2014) assess whether the main mechanisms that influence recruitment variability in the sea apply in large lakes—the instances where they do, and where they do not, are instructive (also see Houde, 1994). Persson *et al.* (2014) also use freshwater vs. marine case studies to conclude that an ecological perspective that includes size- and food-dependent processes and, therefore, mechanistic linkages between trophic levels at multiple scales are needed to support a truly ecosystem-based management of fisheries. Bakun (2014) provides insights into the mechanisms of recruitment variability in the anchovies (genus *Engraulis*) and sardines (genera *Sardinpos* and *Sardina*) that exhibit different life history strategies in the face of changing conditions (on both short and long time-scales) (also see Zwolinski and Demer, 2014). All of these articles apply the compare-and-contrast approach, which can be a powerful lens to focus our thinking. Furthermore, broadening our perspective beyond fish and beyond the sea, and applying a compare-and-contrast approach to other systems, is a direction in which we should surely go, so these articles could also have been placed in the next section.

Where we are going

The remaining articles in this special issue give us a sense of where we might be going, and how we might get there. Rice and Browman (2014) track how "recruitment" research has developed since the 1920s and conclude that, in recent years, it has been subsumed into research on ecosystem-based management and climate change. They caution that this comes at a cost that should be recognized, and carefully considered.

Dickey-Collas *et al.* (2014) take up the challenge of categorizing approaches to modelling in fisheries science, recommending that trade-offs and limitations in modelling must be carefully considered in assessing their utility for decision-making in management. Subbey *et al.* (2014) present a review of stock recruitment forecasting focusing on challenges to predicting recruitment. They highlight the apparent failure of models to forecast recruitment even when environmental covariates are included, but offer insights into a way forward in their concluding remarks. Gaichas *et al.* (2014) apply a risk assessment approach to evaluate climate vulnerability for demersal and pelagic fish and benthic invertebrates in the Gulf of Maine and Mid-Atlantic bight. They use these case studies to demonstrate how a risk assessment approach can guide prioritization of short-term regional climate risk management action. Risk/uncertainty assessments are tools that are now being more widely applied in fisheries science.

Hare (2014) presents an overview of different approaches to thinking about and studying recruitment variability, concluding that we should focus on Hjort's approach: multi-hypothesis, integrative, and interdisciplinary. As Hjort said, ". . . it seems to me for several reasons desirable not to attack this important problem from any preconceived standpoint. On the contrary, the simultaneous investigation of meteorology, hydrography and biology seems the only way to a deeper understanding of the conditions in which the destiny of the spawned ova is being decided." (Hjort, 1926, p. 35).

In fisheries oceanography, traditional approaches to biological, physical, and chemical sampling occurs at spatio-temporal scales that typically far exceed those on which productivity-determining processes occur (e.g. predator–prey interactions; feeding). Godø *et al.* (2014) describe developments in acoustic technology that have the potential to provide quantitative knowledge and understanding of species distribution, abundance, and productivity-determining processes at the spatio-temporal scales on which they occur. If these technologies realize this potential we will be able to go far beyond where we have been and where we are now in terms of our descriptions and understanding of the processes that drive recruitment variability.

It has been a great privilege and honour to have motivated and overseen this special issue commemorating Hjort's most influential work. I can think of no better way to close than with his own words:

> It will be evident from the foregoing, that a study of the conditions which determine the numerical value of the year classes can only attain its object when based upon a very extensive plan. As a matter of fact, the object can *never be fully attained;* new questions will constantly arise, as *the knowledge obtained creates the demand for new,* and it will always be possible to increase and intensify our comprehension of the vital conditions affecting the organisms in question. A study of the fluctuations in the population of the sea, both fish and smaller organisms, and thus of the whole organic life existent in the ocean, is therefore the soundest possible basis for marine research, whether with theoretical or practical ends in view. There is moreover, scarcely any other question which is so well calculated to focus the attention of men engaged upon different branches of science. . . (Hjort, 1914, p. 209).

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On 30 March, 2012, Christopher Taggart sent me an e-mail asking whether the Norwegian Institute of Marine Research—my employer and the institute at which Johan Hjort worked—would be doing anything to commemorate the 100th anniversary of Hjort's 1914 treatise. His e-mail served as the impetus for this special issue. I am grateful to Ian Sherman and Oxford University Press for generously making this special issue freely available. HB's editing work for the *ICES Journal of Marine Science* is supported by Project # 83741, "Scientific publishing and editing", from the Norwegian Institute of Marine Research.

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