‘Linking Herring’: do we really understand plasticity?

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“*When you study herring, there are no wrong answers*.” A. J. Geffen (2006)

The symposium was organized to link our understanding of herring biology, population dynamics and exploitation in the context of ecosystem complexity. It is beyond argument that herring play a pivotal role in shaping the structure and dynamics of many boreal continental-shelf ecosystems. Thus, in moving to an ecosystem approach to fisheries management, the time seemed right for ICES to hold another herring symposium. Since the last ICES symposia on herring in the 1960s (ICES Herring Symposium, 1961; Biology of Early Stages and Recruitment Mechanisms of Herring, 1968), many of the former paradigms have been rejected and substantial progress has been made by striking out along new avenues. In addressing this particular topic, we could also follow on from the decadal herring symposia series held in North America and thus cover new research from both the ICES and PICES community.

The symposium took place from the 26th to the 29th August 2008, at the National University of Ireland, Galway, Ireland. The conference was co-sponsored by Marine Institute (Ireland), Institute of Marine Research (Norway), ICES, the Irish Tourist Board, PICES and Wageningen IMARES (The Netherlands) and supported by GLOBEC. In total there were 80 presentations, 64 oral and 16 posters. These studied the Atlantic (NE and NW), Pacific (NE and NW), Baltic and Arctic herrings. Delegates, numbering 100 in total, attended from Ireland, UK, Norway, Denmark, Italy, France, the Netherlands, Germany, Canada, USA, Russia, Latvia, Iceland and Poland. The local organisation was lead by Maurice Clarke (Marine Institute) and Patricia Walsh (National University of Ireland, Galway).

Coming together in Galway in the summer of 2008, it became clear that herring still stirs strong and often divergent opinions. We surmise that this engagement reflects both the plasticity of the species and the diversity of people’s experiences of working with local stocks. Many of the notions that have evolved over the last 400 years have been abandoned. As clearly illustrated by our key note speaker Mike Sinclair: as we learn more about herring, our general understanding of fisheries and the marine environment also changes. Shifts in productivity of populations - typical of small pelagic fish species - challenge our ideas how fisheries science and management must cope with biomass reference points. The flexibility in spawning time within and between regions - in every month of the year there are herring spawning somewhere in the northern hemisphere - and the highly complex population structure with little or non-detectable genetic differences mean that we must question the standard concept of an unit stock. The concept that herring may “change their mind” and “learn” new migration routes leads to problems developing standard survey techniques and assessing stocks.

Herring occupy key positions in relatively simple trophic systems (e.g. Norwegian Sea and Baltic Sea) but also are found in more complicated systems (North Sea, Celtic Sea, Bay of Fundy and the eastern Pacific), and they are both predator on and prey of species such as cod. Determining their key

role in ecosystem functioning remains a challenge to scientists. One rule that holds true universally is that herring spawn benthic eggs; however, the substrate varies with stock from intertidal macrophytes to offshore gravel beds.

In many ways, herring are a model fish for study. Many stocks have been of great economic importance for centuries, which has contributed to long time-series of statistics and other data sets. Overexploitation of some stocks has resulted in their collapse, thus providing more empirical insight into the population dynamics at low biomass than is available for almost any other fish species. Because of its commercial importance to many fishing nations, the research has been extensive and also core to the work of ICES. Consequently, we have a large library of work from the last 150 years to use in drawing and testing hypotheses. The intensive surveying of many stocks provides valuable information about migrations, life-history strategies and population dynamics. Being spread across the boreal waters of the Atlantic and Pacific means there are many populations on which to test our ideas and assumptions.

Scientists who study herring are often asked “but why do you think herring are special?” Of course, the answer is that they are not, except in the way that any species is different from another. Each species is characterized by specific life-history strategies, physiological constraints, habitat requirements, etc. Nevertheless, there are certain things about herring that break the general paradigms for commercially exploited finfish and make them a bit special. Herring represent a successor of a very early teleost and some of their characteristics still show their fresh-water origin. The species can spawn at any time of year and its distribution ranges from almost fresh (Baltic) to oceanic (Norwegian Sea). As a consequence, herring fails to fit into a clear box (what we as scientists so often request). This issue may be illustrated by a recent debate between an author and an editor as to how to describe best the spawning habitat of North Sea autumn spawning herring and Norwegian spring spawning herring: coastal, off shore, along coast, off the coast? In terms of recruitment dynamics, the unusually high hatching densities of larvae emerging from the extensive egg beds make it likely that herring are different from fish producing pelagic eggs that are instantly spread out in space. As referred to at Linking Herring, the effective population size (in terms of genetics) of some herring stocks is often so large that it can’t be measured. This also contrasts with genetic studies on most other exploited fish stocks. From discussions on fisheries-induced evolutionary change, people investigating herring stocks appear to have failed to show evidence for the declining trends in maturity- and size-at-age as seen in cod or plaice (which are inferred to result from exploitation), despite - or perhaps because of - collapse and recoveries of populations. Is this an example of phenotypic plasticity reducing an evolutionary response?

So what did we learn at Linking Herring? The science of estimating biomass of exploited populations appears strong and adaptive to stock-specific problems and to the varying data sources available. John Simmonds showed for North Sea herring that the effort being given to improving methods for “counting fish” and to developing novel techniques is paying off in terms of assessment quality. More generally, the border between research surveys and information from commercial vessels is increasingly becoming blurred. Nevertheless, when trying to estimate a biomass or a number, one should always be aware that a population can suddenly change its behaviour in response to exploitation or to the environment. Nothing can be assumed to be fixed for all time. There is little information on the less-exploited stocks, which limits our understanding of the mechanisms operating at the edges of the distribution.

Audrey Geffen gave a stimulating presentation on recent advances in herring biology. Although fisheries scientists tend to think in terms of tonnes of fish, every single herring appears to be different.

The fertilisation rate of sperm differs among individual males and varies with each female. A choice is made at some point in time by each individual to invest in growth and or in maturation, and it is this choice that determines the rate of atresia in ovaries and the likelihood of skipping spawning during a particular year. The empirical evidence suggests that 'skipped spawning' is a rare event. Such choices may also determine spawning time. We were taught that the focus on herring as a pelagic species ignores its close association with specific substrates and topographic features. If we are too blinkered by the assumption of constant natural mortality in our assessment models, we forget that variable numbers of herring die through different processes every year. The general theme was that the biology of the individual should be accounted for when trying to model the population dynamics within an ecosystem.

We have heard people ask how such a 'primitive' teleost could be so resilient to exploitation? Although it is true that herring has sustained huge fisheries and also appear able to recover quickly after collapse, managing these fisheries for sustainable exploitation remains problematic. It is by definition difficult to sustain industries on a boom-and-bust basis without a strong resolve to maintain agreements about targets and associated actions. When the North Sea herring stock collapsed in the 1970s, the assessments relied on CPUE as an indictor of abundance. This index of abundance was found to be misleading for a schooling species and high-intensity surveys have been used since to provide fishery-independent indices of abundance. Some stocks support fisheries that are large enough to warrant the costly surveys that provide valuable additional data for ecologists as well as for assessment scientists. However, the approach cannot be used for small stocks and recent financial constraints may necessarily lead to cuts and changes even for the larger stocks. The over-reliance on surveys has induced some inertia, and may have blinded fisheries scientists to the development of cheaper options; now new ways are being sought for closer cooperation and partnerships with fishers to tackle stocks for which less data are available. We must accept that information-poor situations demand risk-averse management and, consequently, lower target yields.

As our understanding increases, the concept of the unit stock is being more and more questioned. Does it really matter for sustainable exploitation whether populations mix or are connected? New thinking is required to address the complex meta-population structure. Evidence for inter-stock connectivity is seen in the signals from both commercial and research-vessel catch compositions at the regional level, which are not identified at the stock-area level. Luckily, these questions are attracting scientists from outside the assessment world because the species provides an interesting model for studies of population integrity and connectivity. Dave Secor described potential approaches for testing hypotheses about herring at the meta-population level and many contributions addressed techniques for tracking individuals originating from different components. Nearly all involved apportioning dead fish to a particular origin, but tagging has also been proven a useful tool. Still, more research is needed to better understand the interactions of population size, recruitment, growth, drift, migration and mixing. Simulation frameworks to test various ideas were presented and they may help us address this issue for a variety of unit stocks.

The ultimate objective of Linking Herring was to consider herring as the focus in the dynamic ecosystems in which it is present. Andrew Bakun showed that this is a challenging concept. He described herring – in relation to cod - as "zebras that eat lion cubs" and illustrated a range of conceptual scenarios that might be considered appropriate. All of the possible outcomes were difficult to investigate on the basis empirical data, particularly because it is unlikely that any system would remain stable and therefore relationships would be continuously changing. The examples given of herring impacting on whales, salmon, zooplankton, cod, seals, and pelagic fish eggs strongly supported this message. The lack of presentations on herring as indicators of ecosystem well-being

suggests that research has not matured in this field, although there is a tendency to manage herring as a core component in the Baltic. Examples were also given of the impact of disease on herring populations and a broad discussion noted that it was our naivety that prevented us from really accounting for the underlying dynamics of mortality. Why do we think that fish, and especially a highly schooling and abundant fish such as herring, do not suffer disease leading to reduced growth, reducing recruitment or increased mortality? Disease may not matter when managing herring as a single stock using within-year surveys but it probably would influence projections of stock dynamics and the management of herring within an ecosystem.

The session on managing change again centred on single-stock management. Most contributors acknowledged that population characteristics are not stationary, but yet one must try to achieve resilience to exploitation. There was also consensus with Martin Pastoors that management plans must be developed in liaison with stakeholders. The move to harvest control rules and the testing of these rules through simulations was seen as a positive advancement, but again almost all simulations treated herring as though operating in isolation of the system and solely being controlled by its own dynamics.

According to expectations, Linking Herring was an exciting symposium that successfully described the state of the art in herring science and management. However, there are still huge challenges ahead, particularly in understanding its role within the ecosystem approach and how to translate this into actual management measures. Fixed rules appear to be few, and any current paradigm is likely to shift in future. Exploiting herring in a sustainable manner may never be possible as its populations naturally come and go, even without exploitation. The example of Norwegian spring-spawning herring shows us that the choices of individuals belonging to a highly plastic species results in populations that adapt and vary over time. Our most important task is to ensure that any assumptions underlying the management advice reflect this feature of plasticity, even if we don’t understand its genetic and phenotypic origin completely.

Regretfully, these proceedings cannot include all oral and poster presentations or even cover the total range of issues addressed. However, we feel that that they provide a historic perspective, the current landscape and a panoramic prospect, which in combination may serve as another milestone in herring research in the broader context of sustainable exploitation of our seas. We thank Niels Daan for his energetic and constructive editing of these proceedings in the ICES Journal of Marine Science.