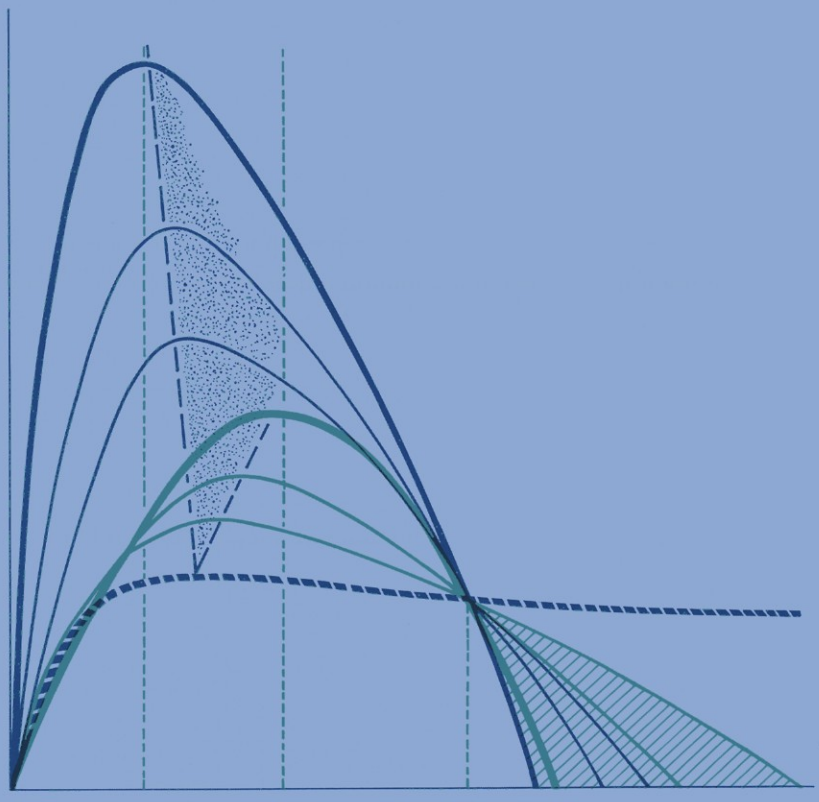
Raymond J.H. Beverton
and Sidney J. Holt

On the Dynamics of Exploited Fish Populations



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Fish and Fisheries Series 11

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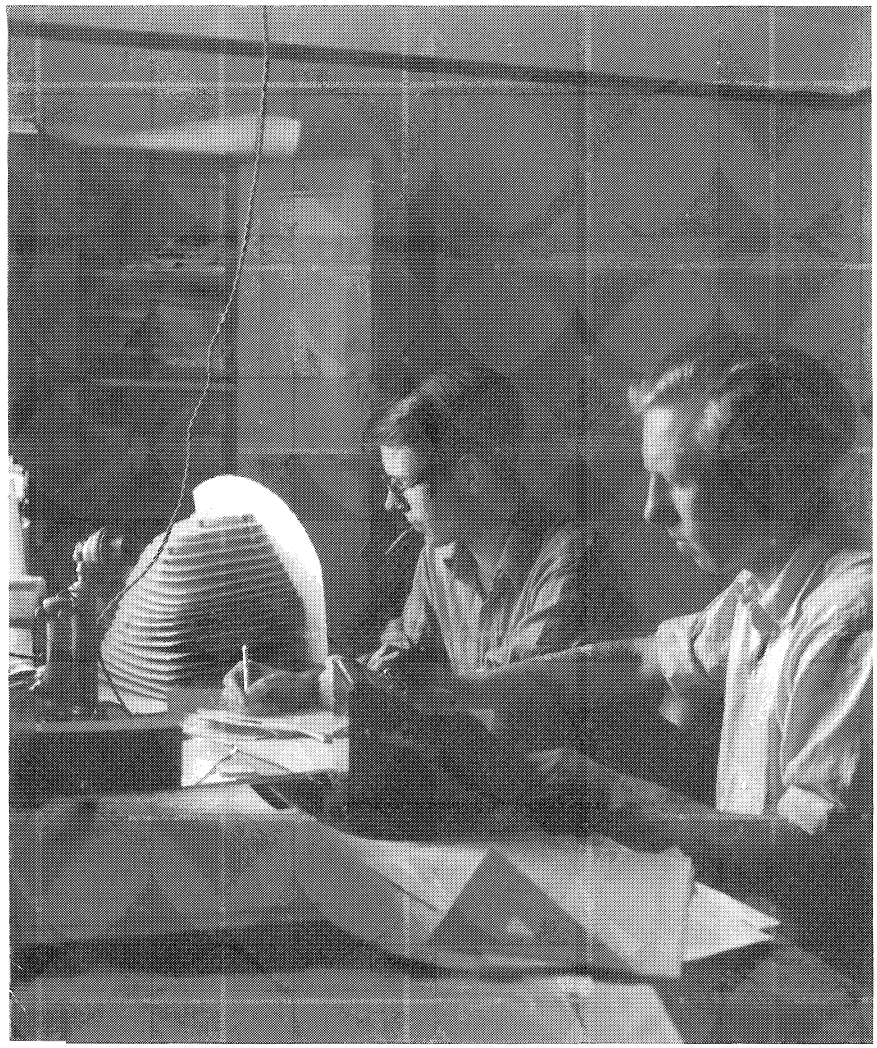

Raymond Beverton and Sidney Holt at work in the Fisheries Research Laboratory, Lowestoft during 1949. Ray Beverton (left) can be seen working next to a 3-dimensional cardboard model of a yield isopleth diagram, a novel concept at the time. Sidney Holt can be seen operating a hand-Brunsviga calculating machine, the 1949 equivalent of a computer but requiring more effort to use.

On the Dynamics of Exploited Fish Populations

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and

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The investigations described in this book were undertaken during the years 1947–1953, during the first half of which both authors were on the staff of the MAFF Fisheries Research Laboratory, Lowestoft, Suffolk, UK. The MS was submitted for publication by HMSO in 1954.

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Cover illustration. The graph shows the response of long-term yield of North Sea haddock (*Melanogrammus aeglefinus* L.) to various levels of fishing mortality rate. Based on single-species models incorporating stock-and-recuitment, both alone and combined with density-dependent growth (from Beverton and Holt, 1957; Figs 18.6 and 18.17)

X-axis = Fishing mortality coefficient (F)
Y-axis = Average long-term yield
Blue lines = stock and recruitment models
Green lines = stock and recruitment models combined with density-dependent growth
Dashed line = constant parameter model (for comparison)
Dotted area = zone of F_{max} giving the highest average yield
Hatched area = theoretical extinction zone, if these high values of F were to be sustained until the stock had disappeared.

The point at which all the curves cross corresponds to the average value of F in the period 1929–39 (1.9); it is still nearly as high now (0.9)!

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Foreword

Being asked to write a foreword to a book such as this is an honor, almost comparable to being asked by Charles Darwin to write a foreword to his 'Origins', because:

(i) the work became a classic during its authors' lifetime, and it literally created a new field and the language used by its many practitioners; and

(ii) the work is still highly relevant to contemporary concerns and to the research emanating from these.

Fisheries science emerged as a distinct discipline of natural history sometime in the second half of the last century, and the first question it posed was whether the large fish stocks then being exploited could ever be depleted by the various fisheries. Most of the naturalists who expressed their opinion on this at the time – notably T. Huxley and F. Buckland – considered that the answer was no, the stocks were much too large ever to be affected by fishing.

A few decades later, near the turn of the century, another group of naturalists found themselves being asked, this time by the fishery sector itself, a far more ominous question: 'Why did the catch per effort of sail and steam fishing vessels decline?'

Attempting to find an answer to this brought together giants such as C.G.J. Petersen, F. Heincke and others – the first true 'Fisheries Scientists', and their collaboration led to the formation of the International Council for the Exploration of the Sea (ICES), in 1902.

These were the roots of fisheries science; but two major branches sprouted right away, each representing a different approach to finding the solution to the above question. One of them was based on the assumption that it was mainly the fisheries themselves that determined the structure and size of

stocks, and thus fisheries research should focus on regulation of these fisheries.

The other branch assumed that it was mainly the environment which structured fish stocks and determined their size. Fisheries research should therefore be concerned with understanding how the environment affects stocks (mainly through the variable survival of larvae), the long-term goal being to predict future recruitment and to enable fishing fleets to anticipate changes.

F.I. Baranov, although not a member of the initial group of fisheries biologists behind ICES, was the most successful representative of the first branch. Unfortunately, he published in Russian, and used extensive mathematics, at a time when neither of these languages were accessible to most European and North American fishery scientists, and so his early lead was lost.

The work of J. Hjort, representing the second branch, was more accessible, and his early lead orientated an entire generation of fishery scientists towards environmental and larval studies, aimed at identifying critical periods in the early life history of fishes. Unfortunately, this branch of fisheries science has not advanced much since Hjort's seminal paper of 1914; it still falls short of providing 'handles' for fisheries management. Perhaps the major reason for this is that the relevant scales in space and time, identified by R. Lasker, are only those few centimeters of food-rich microlayers required by most first feeding larvae and the days needed for the build up of these microlayers. Such scales are too small for synoptic sampling, and hence for prediction of recruitment.

Russell's classic paper of 1931, on the 'overfishing problem' and M.R. Graham's 'Fish Gate' helped to move fisheries back to center stage, but it took another war – and its consequent reduction of fishing effort – for the structuring impact of fisheries on exploited fish stocks to be fully realized.

The medium through which this occurred was the classic work presented here, and the messengers were Raymond Beverton and Sidney Holt, two young zoologists with a strong mathematical bent – now recognized as an ideal combination of skills for fisheries scientists.

Their key message was the need to balance the two branches of fisheries science. Thus, they proposed a strong emphasis on studying the impact of fishing on the age/size composition of exploited fish stocks (both because of its actual importance for the dynamics of these stocks, and because of the 'handles' for management intervention that this provides), and avenues for studying the less tractable issues of environmental impacts and density dependent effects on early life history stages.

It is this balance, and the operational language Beverton and Holt developed for analyzing exploited stocks, that enabled fisheries science to grow. As it now appears, maintaining that balance – Beverton and Holt's legacy – is crucial if fishery science is to continue as a discipline in its own right, rather than being resorbed by a more generalized environmental science.

The clarity of the concepts and language developed by Beverton and Holt, notably their catch equation, provided the basis for the formulation of virtual population analysis (VPA) – now a major tool of fishery scientists – and

eventually the development of multispecies VPA, arguably the greatest achievement of fisheries research in the past decade. The task now will be to maintain the balance while building on these achievements *viz* to develop models with 'handles' allowing for finely tuned management interventions, while incorporating as many environmental effects and socioeconomic considerations as can reliably be done.

As mentioned by the Series' Editor, Beverton and Holt, far from having 'just' developed the yield-per-recruit concepts and provided its conceptual framework, anticipated many other important lines of fishery science, such as length-based assessments and multispecies modelling, now vibrant areas of research, the results of which have enabled the application of Beverton and Holt's theory to tropical fish stocks, and made it a truly global paradigm. I would like to conclude this foreword by adding a further example to this and by pointing out another line of inquiry also anticipated by Beverton and Holt, which is likely to grow in importance throughout the 1990s and beyond. This is the issue of 'refugia' or 'sanctuaries': the use of areas closed to fishing, as a major management tool.

Ours is a time when biodiversity is threatened, in the aquatic as much as in the terrestrial realms. Fishery management can no longer continue to aim for 'maximum' yields. Ours is also a time when – in the tropics at least – rural poverty is such that millions of landless farmers are driven into fishing as a last resort occupation. These new, 'non-traditional' fishers create fisheries that are extremely hard to regulate by classical methods, such as mesh size and/or effort, and in which destructive gears, explosives, poisons, and 'catch-all' traps and beach seines often predominate. The new schemes that are being proposed in various parts of the world to deal with this phenomenon, now called 'Malthusian overfishing', generally use area closures as focal management tools. Sanctuaries thus may serve both to maintain within- and among-species biodiversity, and to sustain a communally managed resource, protected from all fishing and providing recruits to adjacent, fished areas.

Such schemes, implemented around several coral islands in the Philippines and documented in the work of A. Alcala and colleagues, appear to be able to double or triple local catches in a sustainable fashion and hold back, at least in the medium term, the spectre of Malthusian overfishing.

These concerns, one might think, are far removed from the single species, industrialized fisheries analyzed by Beverton and Holt. Yet their classic also deals with refugia – on pp. 365–368, we find an account of the potential impact, on the North Sea plaice fishery, of a sanctuary, unexploited because World War II mines rendered it too dangerous for trawling. Thus, here again, our classic provides 'several pages of carefully argued text and equations, a clear worked example and a fresh and unexpected perspective on the problem', as so well stated by Dr Pitcher.

I wonder what example will be used for illustrating Beverton and Holt's anticipation of ideas when, in a few years or decades, another reprint of *On the Dynamics of Exploited Fish Populations* is presented to a new generation of fishery scientists? I have no doubt that one will be found.

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