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Quo Vadimus

Contribution to the Themed Section: "*A Tribute to the Life and Accomplishments of Sidney J. Holt*"

Sidney Holt on principles for the conservation of wild living resources, whaling in the Antarctic, and the Beverton–Holt stock–recruitment relationship

Marc Mangel [1,2,3]*

[1]*Department of Biology, University of Bergen, Bergen 9020, Norway*
[2]*Puget Sound Institute, University of Washington, Tacoma 98402, USA*
[3]*Institute of Marine Sciences, University of California, Santa Cruz, CA 95060, USA*

**Corresponding author: tel: 1-831-234-2970; e-mail: msmangel@ucsc.edu.*

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I review my interactions with Sidney Holt concerning principles for the conservation of wild living resources, the whaling case between Australia and Japan in the International Court of Justice, and the Beverton–Holt stock–recruitment relationship (BH-SRR). Holt and Lee Talbot published a monograph on principles for conservation in 1977; I lead the publication of an update ∼20 years later. I compare the two versions and discuss Holt's contributions. Holt was active in the world-wide campaign to cease whaling and in efforts to have the Japanese special permit whaling programme in the Antarctic recognized as violating the moratorium on commercial whaling. I describe my involvement in the case and my interactions with him during oral arguments in the case and when the International Court of Justice rendered its decision that the Japanese programme of special permit whaling contravened the international treaty for the regulation of whaling because it was not for purposes of scientific research. In response to a paper of mine concerning steepness, Holt wrote to me that the BH-SSR is a one-, not two-, parameter function. I explain my current understanding of his reasoning, which involves how we use the SRR in fishery management.

Keywords: conservation, special permit whaling, steepness, stock–recruitment relationship, wild living resources

Introduction

Sidney Holt lived a long life and was a polymath, so that when writing a piece about him, one has a wealth of material to choose from. I discuss three topics in which I had direct interactions with him. The first concerns principles for the conservation of wild living resources (Holt and Talbot, 1978, Mangel *et al.*, 1996). I discuss the background to the development of those principles, Holt's involvement in their development, and their relevance today. Second, I discuss my interactions with Holt during the case in the International Court of Justice "Whaling in the Antarctic: Australia v. Japan. New Zealand Intervening", in which the Court determined that the Japanese special permit whaling programme was not for purposes of scientific research and ordered it halted (de la Mare *et al.*, 2014; Mangel, 2016). Third, I discuss the Beverton–Holt stock–recruitment relationship (BH-SRR) (Beverton and Holt, 1957). In particular, as a result of a paper on steepness (Mangel *et al.*, 2013), Holt and I had an extensive discussion about how many parameters there are in the BH-SRR. Most of us think that the answer is two, but he asserted that there was only one parameter in the BH-SRR. This can be, at least partially, understood when one focuses on the role of an SRR in management. I use a simple example to illustrate Holt's point but believe that there is an opportunity for more thinking on this subject.

Principles for the conservation of wild living resources

In the mid-1970s, concern about world-wide depletions of many stocks of wild animal resources led to an effort to develop principles for their conservation. The effort was organized by Lee M. Talbot and sponsored by the President's Council on Environmental Quality, the World Wildlife Fund-US, the Ecological Society of America, the Smithsonian Institution, and the International Union for the Conservation of Nature and Natural Resources. The principles were developed through workshops at the Airlie House Conference Center in Virginia in February and April 1975; 34 individuals attended one or both meetings. The vast majority of attendees was from the United States or Canada; John Gulland and Sidney Holt were the only participants from outside North America. At that time, they both were based at the Fishery Resources and Environmental Division of the Food and Agricultural Organization in Rome, Italy.

The goal of the meetings and workshops was to produce a state-of-the-art report on principles for the conservation of wild living resources. The final report, edited by Holt and Talbot (1978), was the distillation of working papers, reviews of those papers, revisions, and redrafts assembled into a coherent whole on which all participants agreed.

An underlying and fundamental concept in the resulting principles is that resource conservation must accompany resource exploitation because utilizing a wild living resource is a privilege with concomitant responsibilities. Holt and Talbot summarized these responsibilities in four principles, which can be recognized as the foundations of many modern programmes for resource management and conservation:

(1) *Ecosystem*: The ecosystem should be maintained in a desirable state such that (i) consumptive and non-consumptive values could be maximized on a continuing basis, (ii) present and future options are ensured, and (iii) risk of irreversible change or long-term adverse effects as a result of use is minimized.

(2) *Precaution*: Management decisions should include a safety factor to allow for the facts that knowledge is limited and institutions are imperfect.

(3) *Bycatch and incidental take*: Measures to conserve a wild living resource should be formulated and applied so as to avoid wasteful use of other resources.

(4) *Monitoring*: Survey or monitoring, analysis, and assessment should precede planned use and accompany actual use of wild living resources. The results should be made available promptly for critical public review.

Not long after the publication of these principles, Holt was co-author on a paper (May *et al.*, 1979) that laid the foundation for the ecosystem-based approach to management embodied in the Convention for the Conservation of Marine Living Resources.

In the early-1990s, John Twiss, Executive Director of the US Marine Mammal Commission, identified the need for updating the principles in Holt and Talbot (1978). He outlined frameworks for comprehensive, international consultations with resource scientists and managers, and for a subsequent international symposium on conservation principles. He also arranged support and that the meeting concerning them also be held at Airlie House.

Twiss asked me to chair the symposium Steering Committee consisting of Douglas Chapman, Paul Dayton, Robert Hofman, Stephen Kellert, William Perrin, Tim Smith, Lee Talbot, and himself; he also asked that I be lead author of the symposium report. We had roughly the same number of people as were at the Airlie House meetings in the 1970s, but a more international representation. Furthermore, every participant is listed as co-author of the principles. Sidney Holt was thus deeply involved in the development and revision of the document. At the meeting, I took copious notes but did not generally attribute them; one exception is that I noted Holt saying "We cannot control ecosystems, but we can influence them through human action. To conserve wild living resources, target social process".

Events after 1975 that prompted the reanalysis of the principles in Holt and Talbot (see Appendix II in Mangel *et al.* (1996) for the full list) included: (i) developments in ecological and biological understanding (e.g. that ecosystems are not in steady state and predictable but are dynamic and probabilistic; the emergence of conservation biology and landscape ecology); (ii) developments in economics (particularly bioeconomics and ecological economics; new techniques for the valuation of non-market resources); (iii) the recognition that established institutions may not adequately promote the solution of the problems of conservation; and (iv) the development of new technologies and computational methods.

Mangel *et al.* (1996) identified seven principles and described mechanisms for implementing them (I have reorganized them slightly from the 1996 publication):

(1) *Human population growth*: Maintenance of healthy population of wild living resources in perpetuity is inconsistent with unlimited growth of human consumption of and demand for those resources.

(2) *Diversity*: The goal of conservation should be to secure present and future options by maintaining biological diversity at the genetic, species, population, and ecosystem levels; as a general rule, neither the resource nor other components of the ecosystem should be perturbed beyond natural boundaries of variation.

(3) *Precaution*: Assessment of the possible ecological and sociological effects of resource use should precede both proposed use and proposed restriction or expansion of ongoing use of a resource.

(4) *Ecosystem*: Regulation of the use of living resources must be based on understanding the structure and dynamics of the ecosystem of which the resource is a part and must take into account the ecological and sociological influences that directly and indirectly affect resource use.

5–7. *Social sciences*: (5) The full range of knowledge and skills from the natural *and* social sciences must be brought to bear on conservation problems. (6) Effective conservation requires understanding and taking account of the motives, interests, and values of all users and stakeholders, but not by simply averaging their positions. (7) Effective conservation requires communication that is interactive, reciprocal, and continuous.

Comparing and contrasting the two sets of principles allows us to identify changes in thinking between 1975 and 1995. Four points of comparison are these. First, nature is not stable and deterministic (1975) but dynamic and probabilistic (1995). We must learn to think about outcomes in terms of probability distributions, not single steady state. Second, the 1975 principles are mainly single species; the 1995 principles recognize diversity at all levels as important and that effects of human action on other components of the ecosystem must be clearly considered. In the 1975 principles, there was concern about bycatch and incidental take; by 1995, we were moving towards an ecosystem-based approach to management in which a wider range of biological interactions is considered when contemplating taking a target stock. Third, the size and growth rate of the human population is absent in the 1975 principles but the very first principle in 1995. To be sure, this issue continues to vex the conservation of wild living resources (Mann, 2018). Fourth, the social sciences are, at best, obliquely mentioned in the 1975 principles, but are clear and prevalent in the 1995 principles. Advances have been made to integrate the natural and social sciences since 1995 but much still needs to be done.

It is a testimony to Sidney Holt that, although he was lead author on the 1975 principles, he could put aside ego to be one of many authors in the latter principles because he recognized the importance they attribute to human population growth and the social sciences.

The International Whaling Commission, conservation of whales, and the Antarctic whaling case in the International Court of Justice

Sidney Holt was deeply involved and concerned with whaling across the entire world. For example, he was very involved in discussions about catch limits for minke whales in the western North Pacific and the eastern North Atlantic. My interactions with him were through whaling in the Antarctic, particularly the whaling case in the International Court of Justice, so that is my focus in this section.

The story of commercial whaling in the 20th century is ably told by Tønnessen and Johnsen (1982), Gillespie (2005), Epstein (2008), and Burnett (2012), but some background is helpful for setting Holt's contributions. Land-based whaling in the Antarctic started at South Georgia in 1904, while pelagic whaling, using factory ships with a stern slipway, began in 1923 in the Ross Sea and quickly spread around the Antarctic. By 1930/1931, there were 41 pelagic factories with over 200 catching vessels working in the Antarctic. However, during the 1930/1931 Antarctic whaling season, more whale oil was produced than the world market could absorb. Because of this, the whaling companies agreed to limit their output and devised a plan to regulate catches by the amount of oil produced. Since the species of major commercial take in the early 20th century were the blue, fin, sei, and humpback whales, an effort was made to put them into a common currency. One blue whale was considered the same as 2 fin, 2.5 humpback, or 6 sei whales, giving rise to the notion of the blue whale unit (BWU) (Gambell, 1999; Gillespie, 2005).

The intergovernmental International Whaling Commission (IWC) was established in 1946 through the International Convention for the Regulation of Whaling (ICRW). The ICRW consists of two parts: the convention itself, and a schedule of regulations intended to govern whaling operations. Contracting Parties to the ICRW subscribe to (i) safe-guarding for future generations the great natural resources represented by whale stocks; (ii) protecting all species of whales from further overfishing; (iii) seeking the optimum level of whale stocks; (iv) providing an interval for recovery for species of whales that are depleted in numbers; and (v) establishing a system of international regulation for the whale harvest to ensure proper and effective conservation and development of whale stocks (Gillespie, 2005, pp. 396–397).

From its inception until about 1972, the IWC regulated Antarctic whaling using the BWU. The overall catch limit was initially set to 16 000 BWUs, with no reference to specific species except that some species (initially only right whales, but then blue and humpback whales) were designated as protected. This was essentially an open-access fishery, in which nations raced to catch as many whales as possible before the quota was reached, leading to waste during processing, an uneconomical increase in the number of catcher boats, and poor conservation of whales (Clark, 1973; Donovan, 2002). Furthermore, the quotas were often exceeded.

In 1960, Holt (then at the Food and Agriculture Organization of the UN), Douglas Chapman (University of Washington), and K. Radway Allen (Fisheries Department of New Zealand) were asked by the IWC to review the status of the Antarctic whale stocks and the methods of analysis used for management (International Whaling Commission, 1961). Although John Gulland joined them in 1961, the committee continued to be known as "The Committee of Three". Their final report (Chapman, 1964) estimated the sustainable catch in 1962/1963 for blue, humpback, fin, and pygmy blue whales, the maximum sustainable yield (MSY) of rebuilt stocks, and the number of years to rebuild the stocks if no catch occurred after 1961/1962 (more than 50 years for both blue and humpback whales). Furthermore, the committee called for complete protection for blue and humpback whales, a 75% reduction in fin whale catches, the elimination of the BWU, separate quotas for each species, and that population analysis be continued based on data pooled from all countries whaling in the Antarctic. The final two recommendations were implemented in 1965, while the call to abolish the BWU was not implemented until 1972.

After 1972, the IWC abandoned the BWU; in 1974, the IWC adopted a realignment of its management procedures through the development of a New Management Procedure (NMP). The NMP was designed to calculate catch limits for whale populations using the fundamental principles of population dynamics. The goals of the NMP were to bring each of the whale stocks to a population level above which MSY could occur (today we would say that this approach made MSY a limit reference point rather than target reference point) and to protect stocks whose population sizes were estimated to be below a fixed fraction of their pre-industrial exploitation level (Gambell, 1999; Donovan, 2002). When it was introduced, the NMP had features that fisheries control rules did not have for decades, including the protection level and a cap on catch limits (i.e. non-constant fishing mortality, varying with stock size).

However, over time, it became clear that the NMP had serious problems (Cooke, 1995; Holt, 2004). The NMP was based on

MSY, but the data required to calculate MSY were lacking, and we have subsequently learned that the default assumption for the MSY rate (MSY catch divided by population size giving MSY) was (at 4%) too high for several species. Thus, two *ad hoc* rules were added. First, stocks that had been subject to stable catches over considerable periods of time would continue to be harvested as long as there was no evidence of a decline. Second, for stocks that had not been subject to serious previous exploitation, catches would be limited to 5% of the estimated size of the stock. This rule was precautionary in the sense that before harvest began, population estimates had to be obtained. However, the NMP did not deal with the question of how to incorporate the uncertainty in the estimates of population size. Thus, implementation difficulties of the NMP included that it did not stipulate how existing data were to be used to assess the state of the stock and that it could not handle uncertainty regarding the status of the stock in a robust manner (Cooke, 1995, p. 652).

Because of the problems with implementation of the NMP due to its incompleteness, in 1982, the IWC adopted a moratorium on commercial whaling, setting catch limits for all stocks at zero effective in the 1986 coastal and 1985/1986 pelagic seasons. The commercial whaling moratorium remains in force today. One goal of the moratorium was the development of a comprehensive assessment of the status of whale stocks in the Antarctic, concomitant with a Revised Management Procedure (RMP), which Holt described in his introduction to the republication of Beverton and Holt in 2004: "Although the RMP uses a population model for the estimation of stock status and the calculation of catch limits, the model itself is hugely simplified. It does not attempt to emulate the dynamics of any real whale population, and, in fact, does not even explicitly include demographic parameters such as natural mortality rate. Rather, the simple model is part of a freely invented algorithm that has been shown, by simulations, to meet the targets efficiently and to be robust to errors and such things as environmental changes" (Holt, 2004, pp. xii–xiii).[1]

Simultaneous with the start of the moratorium, Japan initiated the Japanese Whale Research Programs Under Special Permit in the Antarctic (JARPA) by authorizing the taking, via special permit under Article VIII of the treaty, 400 minke whales per year by the Institute of Cetacean Research. Many scientists, Holt included, argued that the JARPA and its successor JARPA II were commercial whaling in another guise that took advantage of a loophole in Article VIII of the ICRW. Japan continues a North Pacific version of JARPA, but I will not discuss it.

In May 2010, after nearly 25 years of trying by diplomatic means to convince Japan to stop whaling in the Southern Ocean, Australia initiated a case in the International Court of Justice in the Hague. In its application to the Court, Australia asked that the Court order Japan to: (i) "cease implementation of JARPA II"; (ii) "revoke any authorizations, permits or licences allowing the activities which are the subject of this application to be undertaken", and (iii) "provide assurances and guarantees that it will not take any further action under the JARPA II or any similar program until such program has been brought into conformity with its obligations under international law."

I served as an Independent Scientific Expert Witness in the case (de la Mare *et al.*, 2014; Mangel, 2016), working with Bill de la Mare, who was an advisor to the Government of Australia concerning its case, and Nick Gales, who also served as expert witness (particularly about the functioning of the Scientific Committee of the IWC).

Once the case started in The Hague in summer 2013, I received frequent messages from Sidney. He commented on arguments by both sides and on my testimony, particularly how to improve presentation of some of the quantitative ideas. I incorporated those when I subsequently spoke about the case.

The Court released its judgement on 31 March 2014 (International Court of Justice, 2014) findingoverwhelmingly in favour of Australia. The case was contentious to its very end: 11 of the 16 judges wrote separate or dissenting opinions (these can be found at https://www.icj-cij.org/en/case/148/judgments). On hearing and reading the judgement, Sidney wrote to Bill de la Mare, Nick Gales, and me, "Best news for a decade since we got the Antarctic sanctuary. Sidney" (received 31 March 2014, 4:10 am in California).

The saga of Japanese whaling continues. Subsequent to the ICJ decision, Japan did not conduct special permit whaling in the 2014/2015 Australian summer and prepared a new special permit program (NEWREP A; https://www.icrwhale.org/NEWREP-AgaiyouEng.html) which Japan considered to address seven key elements in the decision of the Court. The Scientific Committee of the IWC coordinated two rounds of review, including one by an independent expert panel (International Whaling Commission, 2015, 2016) that concluded that lethal sampling had not been justified (Brierley *et al.*, 2016). The case in the ICJ also lead to a large body of writing in which science and law are intertwined; one starting point is Fitzmaurice and Tamada (2016). In December 2018, Japan withdrew from the International Whaling Commission effective 30 June 2019 and announced the resumption of commercial whaling in 2019. I did not correspond with Sidney about this, but at the best, it would be bittersweet since Japan is no longer whaling in the Antarctic or using science to justify whaling targets but is also continuing to whale in other waters.

In his long life, Sidney Holt made many contributions, but his sustained effort concerning the conservation of whales remains a remarkable achievement.

How many parameters are there in the BH-SRR?

In an article on steepness (Mangel *et al.*, 2013) in which the BH-SRR played a key role, we referred to the BH-SRR as a two-parameter model. Sidney wrote to me and tried to very patiently explain how I was wrong: that the BH-SRR is a one-parameter model. He was also annoyed that we followed a now-common practice and related recruitment (number of new individuals) to spawning biomass rather than egg production. The second point was easy to see, and I agreed that it would have been better to do the analysis using egg numbers (there are no differences in the main results). It has taken me some time and effort to understand the point about the BH-SRR being a one-parameter function; I am not certain that I have captured what he had in mind but think it is in the right spirit.

[1]When reviewing this paper, Andre Punt noted "He [Sidney] refers to the RMP, but this is really the CLA. The RMP is the CLA [catch limit algorithm] plus features to handle uncertainty about stock structure. This text is, of course, interesting in the context of Sidney's own argument during the 1991 meeting of the IWC SC (IWC, 1992, pages 91,134–135) where he focused on 'design features' rather than performance (although in the end that argument was not supported by the Scientific Committee".

Beverton and Holt (1957, 2004) gave a mechanistic derivation of the relationship between the number of eggs E produced by a spawning population and the number of recruits R to that population at some time t_R later. Their derivation was based on Kostitzin (1939); we let $n(t)$ denote the number of individuals from the start of the egg and larval period to time t. Thus, $n(0) = E$; if one assumes that there are both density-independent and density-dependent sources of *per capita* mortality and that they are separable, then the dynamics of recruits are:

$$\frac{1}{n}\frac{dn}{dt} = -(m_1 + m_2 n), \tag{1}$$

where m_1 and m_2 are, respectively, the intensity of density-independent and density-dependent mortality. Equation (1) can be solved exactly by the method of partial fractions (Mangel, 2006, p. 213). The solution is:

$$n(t_R) = \frac{(e^{-m_1 t_R})E}{1 + (m_2/m_1)(1 - e^{-m_1 t_R})E}, \tag{2}$$

and we interpret the number of recruits from E eggs to be $R(E) = n(t_R)$. Equation (2) makes clear the way that m_1, m_2, and t_R interact (also see Kindsvater *et al.*, 2017). The coefficients of E on the right-hand side can be viewed as parameters of the relationship between eggs E and recruits $R(E) = n(t_R)$. Beverton and Holt (1957, 2004, equation 6.10, p. 49) wrote (2) as:

$$R(E) = \frac{E}{\alpha E + \beta}, \tag{3}$$

where the parameters α and β can be identified by the comparison of (2) and (3) after multiplying the top and bottom on the right-hand side of (2) by $em^1 t^R$. The BH-SRR in (3) is commonly used, although sometimes the roles of α and β are switched (e.g. He *et al.*, 2006). Beverton and Holt simply stated the solution to the differential equation in the form given by (3) (their equation 6.10 on p. 49 and some of the others between equations 6.8 and 6.10), so we do not know why they chose to write it in that form.

In light of (2), my preference (Mangel *et al.*, 2010, 2013) is to write:

$$R(E) = \frac{aE}{1 + bE}, \tag{4}$$

where the identification of the parameters a and b is clear by comparison with (2).

It appears that the right-hand sides of (3) or (4) have two parameters; I will use (4) for further analysis. We obtain mechanistic interpretations for the parameters by first noting that when $1 \gg bE$, recruits are approximately aE so that a is the maximum probability that an egg survives to recruit to the population. Since the denominator on the right-hand side of (4) is 1/2 when $bE = 1$, $1/b$ is the number of eggs at which recruitment is 1/2 of its maximum value. In addition, when E is very large, the number of recruits is approximately a/b, providing another interpretation of b, but this does not help us understand why Sidney would consider the BH-SRR to be a one-parameter function.

My current thinking is that the resolution of this conundrum lies in recognizing that an SRR makes the most sense when we use it in the context of fisheries management. To illustrate the idea, I employ a simple production model, but the results can be generalized (Mangel *et al.*, 2010, 2013).

Let us consider a situation in which $N(t)$ denotes the size of the adult population, φ denotes the *per capita* fecundity of adults (so that egg production is φN), M denotes the rate of natural mortality, and the egg and larval period is so short that we can treat recruitment as going directly to the adult population. Then, the dynamics of the population are:

$$\frac{dN}{dt} = \frac{a\varphi N}{1 + b\varphi N} - MN. \tag{5}$$

Without losing any generality, we can redefine $a\varphi$ to be a and $b\varphi$ to be b, so that we have:

$$\frac{dN}{dt} = \frac{aN}{1 + bN} - MN. \tag{6}$$

This is a three-parameter (a, b, and M) model for the population dynamics. The unfished population size is found by setting the right-hand side of (6) equal to 0; denoting it by N_0, we have:

$$N_0 = \frac{1}{b}\left(\frac{a}{M} - 1\right), \tag{7}$$

and is determined by only two parameters: the density parameter b and the ratio of productivity at low population size to the rate of natural mortality.

Furthermore, if we compute ratio of recruitment [the first term on the right-hand side of (6)] when $N = 0.2N_0$ to recruitment when $N = N_0$ (the steepness of the SRR, denoted by h), we find (Mangel *et al.*, 2010, 2013):

$$h = \frac{a}{a + 4M}, \tag{8}$$

which only depends upon two of the three parameters in (6): one of the parameters of the SRR is not needed. The same reduction in the number of parameters happens with an age-structured model (Mangel *et al.*, 2010, 2013), and the analysis is just a bit more complicated. In both cases, it is not clear before the analysis that steepness will not involve the density-dependent parameter.

We add fishing mortality to (6) by replacing MN on the right-hand side by $(M + F)N$. From the modified equation, we can compute steady-state yield and fishery management reference points: the rate of fishing mortality F_{MSY} giving MSY, the population size N_{MSY} giving MSY, and the ratio SPR_{MSY} of egg production at MSY to egg production of an unfished population. The density-dependent parameter of the BH-SRR is missing from all of these:

$$\frac{F_{MSY}}{M} = \sqrt{\frac{4h}{1-h}} - 1, \quad \frac{N_{MSY}}{N_0} = \frac{\sqrt{\frac{4h}{1-h}} - 1}{\frac{4h}{1-h} - 1}, \quad \text{and } SPR_{MSY} = \sqrt{\frac{1-h}{4h}}.$$

Brooks *et al.* (2010) derived an analogue of the equation for SPR_{MSY}. When the major reference points for fishery management do not depend upon one of the parameters of the SRR, we might indeed say that the SRR has one fewer parameter than appears from cursory perusal.

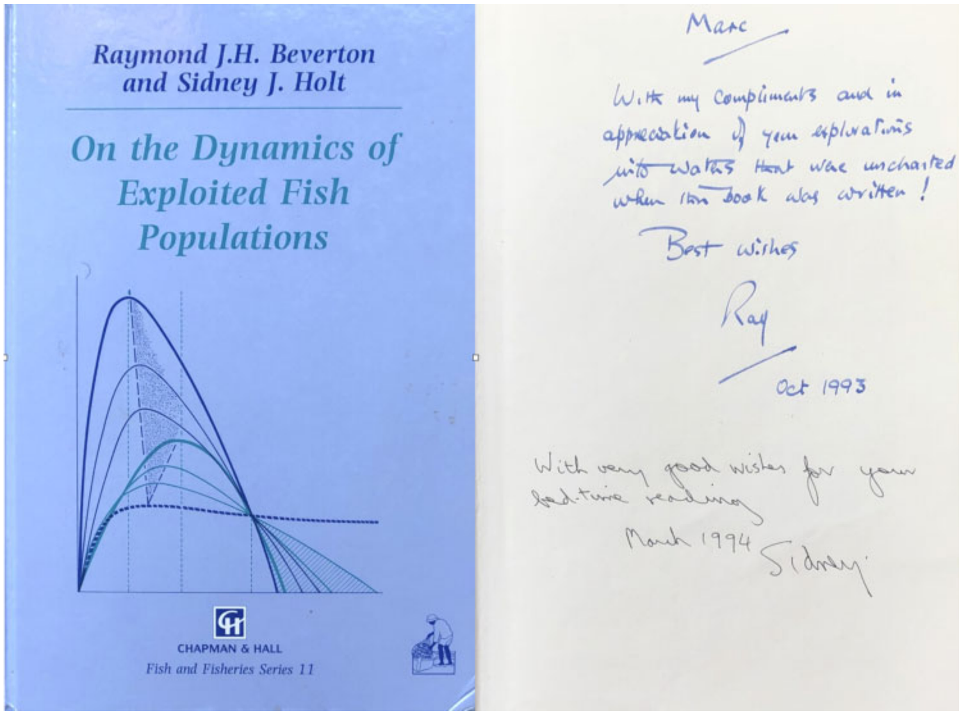

Figure 1. Cover of the republication of the Beverton and Holt (1957) book in 1993 (Beverton and Holt, 1993) with inscriptions by both Beverton and Holt to Marc Mandel on the inside of the cover.

I continue to be grateful to Sidney for having reached out to me in 2013 and showing how we can still learn from the SRR that he and Ray Beverton created in their twenties.

Conclusion

As shown in the previous section, Sidney Holt continued to ask probing questions to the end of his life. Indeed, it is still not clear to me that the question about how many parameters there are in the BH-SRR is resolved.

My last interactions with Sidney occurred in 2016, when I was working on a completely different topic, concerning life histories (Mangel, 2017). This was inspired by work that Holt (1958) and Beverton and Holt (1959) did. I extended their analysis that predicted age at maturity from somatic growth rate, the rate of natural mortality (assumed to be constant), and the exponent relating length and weight to the case of size-dependent natural mortality. When I sent a preprint of the paper to Sidney for his comments, he asked me to elaborate certain points, which lead to Figure 3 in Mangel (2017). Once again, I thanked him for insightful comments and questions.

Although can no longer interact with him, I expect that through his body of scientific work and his efforts in conservation, Sidney Holt will continue to inspire many future generations of scientists.

Data availability

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