ICES Journal of Marine Science Advance Access published May 28, 2015

ICES Journal of Marine Science

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science; doi:10.1093/icesjms/fsv098

# Food for Thought

## Lessons from a career in fisheries science[‡]

Emory D. Anderson*

*22 Indian Pond Point, PO Box 950, Marstons Mills, MA 02648, USA*

**Corresponding author: tel: +1 508 420 2303; e-mail: emoryanderson@comcast.net*

Anderson, E. D. Lessons from a career in fisheries science. – ICES Journal of Marine Science, doi: 10.1093/icesjms/fsv098.

Received 3 May 2015; accepted 4 May 2015.

This article summarizes some of my accomplishments during a 45-year career in fisheries science that ranged from conducting fish stock assessments, working for an international marine science organization, and managing a variety of scientific projects and activities, to finally serving as a scientific editor. In doing so, I have tried to focus on lessons learned. Starting my working life as a high-school math teacher, I soon opted for a different career, returned to the university, and received a PhD in fisheries biology. The first 15 years of my career were at the Woods Hole Laboratory of the National Marine Fisheries Service (NMFS) doing fish stock assessments, where my main interest was Atlantic mackerel (*Scomber scombrus*). Until the USA declared a 200-mile Exclusive Economic Zone (EEZ) in early 1977, the focal point of my work was the International Commission for the Northwest Atlantic Fisheries (ICNAF). Lasting friendships with scientists from other countries developed during the ICNAF meetings and continued for years thereafter, some to the present day. During 1977 – 1985, my assessment activities were confined to domestic fisheries and interactions with regional fishery management councils, where I found that a cooperative attitude and the use of non-technical language made a positive impression and helped build trust. Involvement in ICES assessment working groups led, in 1985, to being appointed Statistician in the ICES Secretariat in Copenhagen and the start of an 8-year life in the international community that culminated in becoming General Secretary. Some major changes in ICES in which I was intimately involved are discussed. After my return to the USA in 1994, my career included managing a variety of activities and projects in Woods Hole and at NOAA/NMFS headquarters in Silver Spring, MD (where I was NMFS liaison to the National Sea Grant Office), finally concluding, after my retirement from NMFS in 2004, with continued engagement in fisheries science as an editor for ICES. Having benefited from experiences in science and administration and the lessons learned therein, it is a pleasure, via this article, to offer advice to young scientists contemplating potential paths to pursue in their careers.

**Keywords:** ACFM, Atlantic mackerel, fisheries management, fish stock assessment, ICES, ICNAF, NMFS, population dynamics, Sea Grant, VPA.



### Introduction

Fisheries science encompasses a broad range of topics, but my specific area of interest and expertise throughout the first 15 years of my career was fish population dynamics. During that time, I conducted fish stock assessments, attempting to estimate the size of exploited fish populations, calculate their mortality rates, and project potential harvest levels at various rates of exploitation as advice for fisheries management. When I entered this arena in 1970, fish stock assessment science was in its early stages of development. Work was strictly on a single-species basis, computers were just beginning to be used for "number crunching", and the concept of ecosystem-based fishery management had not been developed. During that time-span (1970–1985), there was steady growth in the development and use of new and more sophisticated models. Computers enabled quicker calculations, and new mathematical and statistical techniques facilitated improved data analysis and interpretation of

[‡]Food for Thought articles are essays in which the author provides their perspective on a research area, topic or issue. They are intended to provide contributors with a forum through which to air their own views and experiences, with few of the constraints that govern standard research articles. This Food for Thought article is one in a series solicited from leading figures in the fisheries and aquatic sciences community. The objective is to offer lessons and insights from their careers in an accessible and pedagogical form from which the community, and particularly early career scientists, will benefit.

The International Council for the Exploration of the Sea (ICES) and Oxford University Press are pleased to make these Food for Thought articles immediately available as free access documents.

results, all of which served, in my opinion, to enhance scientific productivity. Some might argue that those innovations also led to improved assessment advice, but they did not necessarily translate into better management of fish stocks. High seas fisheries remained largely uncontrolled, owing to the notion of freedom of the seas, until more and more nations began establishing 200-mile Exclusive Economic Zones (EEZs). Even after many of the world's productive fisheries resources (at least those residing over continental shelves) in the mid-to-late 1970s were contained within EEZs, lack of strong political will, nationally and within international regulatory commissions, to curb excessive harvesting capacity coupled with the absence of adequate controls over fishing activity led to fish stocks continuing to be overfished. During the subsequent 30 years, huge changes have taken place in the world of fish stock assessments in terms of computing capacity, complexity of analytical models, and the demands placed upon assessment scientists for advice by fisheries managers (e.g. Kuparinen *et al.*, 2012; Deroba *et al.*, 2015 and references cited therein). Despite these changes, I would argue that the management of fisheries resources throughout the world remains problematic for many reasons, but mainly because of excessive harvesting capacity.

My career also led me into administrative and non-quantitative work outside the domain of stock assessments, offering a broader perspective of fisheries science and the larger field of marine science, including problems facing national and research institution administrators such as budgeting, prioritization of activities, and political pressures, all of which directly or indirectly affect the basic work of the scientist. My entry into fisheries science began as a student who thought that it would be nice to work for a state conservation agency and enjoy the great outdoors. Little did I know where my career would take me, the great experiences that would be enjoyed, and that so much of the work would involve sitting behind a desk! In retrospect, my career was an evolving adventure and continual learning experience.

## Education and getting started

My undergraduate degree was in mathematics in 1961 from a small Danish Lutheran college in Blair, Nebraska: Dana College. I taught high school mathematics in southern Minnesota for two years, but quickly discovered that I was not suited to be a teacher. Although I enjoyed coaching football, I could not envision spending the rest of my working life in a classroom. Since I had always loved fishing and hunting, a profession in fisheries or wildlife, possibly working for a state conservation agency or being a forest ranger, seemed ideal. Therefore, I "switched gears" completely from mathematics and immersed myself in biology and related coursework at the University of Minnesota. Within a short time, I had decided that I preferred fisheries over wildlife, but I also became aware, mainly from comments by my professors, that an advanced degree would be desirable for subsequent employment. Six years later (2 years taking undergraduate biology and fisheries-related courses followed by 4 years in graduate school), I emerged with a PhD in fisheries biology having investigated factors affecting the abundance of lake herring (*Coregonus artedii*) in Lake Superior (Anderson and Smith, 1971). With a math background, I had opted to minor in biometrics, but in retrospect (mainly from becoming aware of courses offered at other universities), regretted receiving no formal instruction in quantitative fish population dynamics; such coursework simply was not available then at the University of Minnesota. I had to subsequently learn on the job. My minimal exposure to quantitative population dynamics was via Beverton and Holt (1957), which had been published the previous decade. In the first year of my doctoral programme, I had the privilege of meeting Sidney Holt, who was working for FAO in Rome. He was one of the "visiting firemen" invited by my major professor Lloyd Smith to present seminars to the fisheries graduate students. Because of my youth and inexperience then, I was unaware of the impact that Sidney Holt and Ray Beverton had already made on fisheries science. Only later would I realize how important Sidney Holt was in fisheries science. Looking back, the 4 years in graduate school were difficult for someone who was married and had two small children; it often seemed that the goal would not be achieved. On one occasion when my wife was in the hospital for back surgery, our young son and baby daughter were both sick, and I asked Smith for a few days off, his response was, "You and Job!" I learned that persevering under stress is a good teacher; keep your eyes on the target and do not give up.

Before graduation in late 1969, and at the advice of Lloyd Smith, I sent letters of inquiry to potential employers—university departments, research laboratories—and also submitted a blanket application to the US Federal Civil Service, a decision that rewarded me a year later. I do not know if doctoral students today still make similar employment inquiries, but I think it is sound advice. One of these queries resulted in me spending 14 months in a post-doctoral position at Michigan State University where I coordinated the fieldwork of a study comparing the ecology of three rivers with different degrees of eutrophication in which I supervised some of the work of five graduate students who were pursuing degrees in fisheries and related aquatic sciences. This was a great learning experience in that it offered some leadership opportunities and provided some insights into academic life from the faculty/staff perspective, a view I had not been privileged to observe while a student. Enjoying a university environment, I entertained thoughts of that as a potential career, but a new opportunity soon appeared.

## Woods hole and ICNAF

In late 1970, I received a telephone call asking if I would accept a position at the Woods Hole Laboratory of the National Marine Fisheries Service (NMFS). I do not know if people are still offered jobs that way today; maybe it is now via e-mails or letters. People were being hired for fish stock assessment positions, and my name was at the top of the Federal Civil Service list provided to the lab. It had proven to be a wise decision to submit the blanket Civil Service application the previous year. Being selected in this way reinforced my trust in early planning and perhaps in a little luck. I was thrilled to join the staff of the Woods Hole Laboratory, already aware of its reputation as the first permanent (constructed in 1885) fisheries laboratory in the USA (Galtsoff, 1962). When I arrived in late November, the agency had just changed its name from the Bureau of Commercial Fisheries (effective 1 October 1970) and had become part of the newly formed National Oceanic and Atmospheric Administration (NOAA).

The major focus of the laboratory's work at that time was the key offshore fish stocks in the Gulf of Maine, Georges Bank, and the Southern New England area that had hitherto been the exclusive domain of US fishing vessels, but, since the early 1960s, was being subjected to intensive harvesting of fish stocks by Soviet-bloc distant-water fleets (DWFs). By 1970, the USA and Canada were both mounting major efforts within the International Commission for the Northwest Atlantic Fisheries (ICNAF), established in 1950 for "the investigation, protection and conservation of the fisheries" in the Northwest Atlantic, to better assess and provide management

advice for setting catch quotas on the major fish stocks. During its first 20 years, ICNAF had struggled with relatively ineffective technical measures, mainly minimum trawl codend mesh sizes, for regulating the fisheries, all based on the underlying philosophy of maintaining maximum sustainable yield (MSY) and bolstered with the notion that appropriate mesh sizes were sufficient to achieve that (Anderson, 1998). During this time, over 20 different minimum mesh-size regulations were adopted (Halliday and Pinhorn, 1985). However, given that these measures failed to stem the ever-increasing catches by foreign fleets, member country scientists eventually provided the scientific conscience that convinced the ICNAF commissioners of the need for catch and effort controls. Very high catches of haddock (*Melanogrammus aeglefinus*) on Georges Bank in 1965 and 1966 that led to a sharp reduction in stock size (Anderson, 1998) finally triggered the adoption in 1969 of a total allowable catch (TAC) by ICNAF for 1970, reserved primarily for the USA and Canada. The switch in emphasis from mesh controls to catch quotas, therefore, provided the stimulus for more quantitatively trained scientists in Woods Hole and elsewhere, which is what led to my being hired in 1970.

My first assignment in 1970 was to assist in developing a quota allocation scheme (Anon., 1971). The scheme, first applied to allocate national TACs in 1972, was based on a formula that assigned 80% of the TAC in proportion to the historical performance of member countries in fisheries for the stock in question (40% in proportion to average catches over the most recent 10-year period and 40% in proportion to average catches over the most recent 3-year period), 10% of the TAC to the coastal countries, and 10% of the TAC for special needs (ICNAF, 1972). This was commonly referred to as the "40-40-10-10" formula.

The standard assessment tool in the early 1970s was virtual population analysis (VPA; Gulland, 1965) or cohort analysis (an approximation of VPA; Pope, 1972). This method provided the basis for generating catch projections, but required a database of landings, length compositions, age/length keys, and indices of relative abundance from commercial and/or research vessel survey catches. If such data, particularly age data, were unavailable, simpler tools were used such as the Beverton and Holt (1957) yield-per-recruit model or surplus production models (e.g. Schaefer, 1954; Pella and Tomlinson, 1969), the latter providing estimates of MSY. My first species assignments for stock assessments were silver hake (*Merluccius bilinearis*), red hake (*Urophysis chuss*), and Atlantic mackerel (*Scomber scombrus*), all targeted primarily by Soviet vessels. It required several years to fully assemble the necessary databases needed to run VPAs for these stocks. Reports summarizing these analyses were then submitted as ICNAF Research Documents (Res. Doc.) for peer review at the annual meetings of the ICNAF Assessments Subcommittee, a subgroup of the Standing Committee on Research and Statistics (STACRES), where they were either accepted or modified based on group discussion. Catch projections emanating from these assessments were then recommended to the Commission, where they were either accepted or modified.

Meetings of the Assessments Subcommittee (and its working groups) were, in my opinion, very exciting. After attending only a few of these meetings, I understood my good fortune to be in the company of some of the world's top fisheries scientists from ICNAF member countries and observer organizations (e.g. ICES, FAO) and to learn from their collective wisdom. My initial involvement in ICNAF coincided with that of John Pope (UK) and Øyvind Ulltang (Norway), both of whom subsequently became leaders in the global fish population dynamics arena. I benefited considerably from working with them both in ICNAF and later in ICES. My first Assessments Subcommittee meeting was in Washington, DC, in 1972. As a fairly junior scientist, I had not been officially approved by NMFS headquarters to attend, but the Woods Hole Director Robert Edwards, nevertheless, decided that I should be there to present my first assessment of silver hake. Therefore, I arrived on the second day of the meeting; on one occasion, I recall being told to duck into the men's restroom to avoid being seen by NMFS Director Philip Roedel. When I presented the results of the silver hake assessment (submitted as a working paper), it was subsequently critiqued rather harshly by John Gulland (FAO). In retrospect, the assessment had been based on rather preliminary and tenuous results, but the learning experience delivered by a master scientist was well remembered.

For some stocks, individual scientists brought prepared assessments to ICNAF meetings where they were presented, discussed, and sometimes modified based on input from other scientists. For other stocks, there might be several assessments presented by different scientists, with differences discussed and reconciled to agree on a single assessment. In yet other cases, no prepared assessments were available, but input data from countries participating in the fishery for the stock(s) in question were pooled enabling a group assessment to be performed and agreed upon. Many countries (e.g. Soviet-bloc) only sent one or two scientists to these meetings, but the USA and Canada generally sent many scientists. I remember one meeting at which one Soviet scientist (Vladimir Rikhter), accompanied by an interpreter, participated in discussions, sometimes contentious, on perhaps half a dozen different stocks with mainly US and Canadian scientists. The discussion on the last stock went into the evening hours; Rikhter finally had to concede and accept our version of the assessment owing to his exhaustion and hunger.

As a young scientist, I found it immensely rewarding to see the results of my work immediately form the basis for internationally accepted TACs. This was in contrast to my experience in a university environment where papers were published, but where there was no immediate follow-through and implementation of the results. I still recall advice from Lloyd Smith a year or two following my graduation warning that I should decide soon whether to remain in government service or return to academia. I think his reasoning was that if I wanted an academic career, I should start working on that as soon as possible to establish a reputation, decide on a research focus, and begin writing and submitting grant proposals needed to fund research projects and graduate students. I am glad I chose the former, because I cherished the rewards noted above and preferred government service to a university career which, according to Smith, would have required the continuous writing of grant proposals. I also did not relish giving up the stimulating discussions on stock assessments with international colleagues.

Equally rewarding was the opportunity to establish friendships with colleagues from ICNAF member countries. With several ICNAF scientific meetings each year, camaraderie deepened over time, although there was keen competition and frequent differences of opinion on assessments between US/Canadian scientists and our counterparts from the USSR, Poland, and the German Democratic Republic (GDR), the three principle countries harvesting Atlantic mackerel in the early mid-1970s. Lasting friendships conceived during those meetings continued for years thereafter, some to the present day. One specific area where competition was particularly keen was in computational capability. The early 1970s signalled the advent of hand calculators, the first of which had little or no computing power, but they eventually progressed to the point of

being able to handle cohort analysis. It was a question of who would bring the latest and best hand calculator to the next meeting. Before personal computers were brought to meetings, I recall Vaughn Anthony (USA) and Albrecht Schumacher (Federal Republic of Germany—FRG) working for hours one night on a single run of a VPA for Georges Bank herring (*Clupea harengus*) in a hotel room in Rome during a 1973 special ICNAF meeting. Using a time-consuming iterative process, the correct value for $F_i$ would be determined from a table of values for the function $(F_i + M_i)e^{-(F_i+M_i)}/F_i[1 - e^{-(F_i+M_i)}]$ such that this function would equal the ratio $N_i + 1/C_i$. This function was derived from Baranov's (1918) catch equation,

$$C_i = N_i\left\{\frac{F_i}{F_i + M_i}[1 - e^{(-F_i+M_i)}]\right\},$$

where $C_i$ is the catch of a year class in year $i$ in numbers, $N_i$ the abundance of a year class in year $i$ in numbers, $F_i$ the instantaneous fishing mortality, and $M_i$ the instantaneous natural mortality.

The introduction of computers aided in the preparation/modification of assessments during meetings. I recall the May–June 1974 Assessments Subcommittee meeting in Dartmouth, NS, Canada, when the US scientific delegation brought a portable computer to run VPAs. The machine, resembling an electric typewriter, had a modem for connecting by telephone line to a GSA (US General Services Administration) mainframe computer in Atlanta, GA, and a paper feed for dispensing printout. For convenience, we had positioned the machine at the end of a table in the meeting room, with the computer paper feeding into the machine from a box and from the machine into a waste basket. The waste basket was used because of the large volume of paper being printed, only a fraction of which contained the desired numerical results. When running, the machine made considerable noise much like a teletype machine. For some of the participating scientists, it was their first viewing of a computer in action. Because of the paper being fed into a waste basket, and also because we realized that the VPA output was based on many assumptions and tenuous data, we joked that it was, "Garbage in, garbage out", which seemed appropriate.

The Assessment Subcommittee meetings were generally intense, and participants worked long hours, often into the evening, to complete their work. Despite the seriousness of the work, participants also found time for humour. As mentioned earlier, a report submitted to a meeting was identified as a Res. Doc. To inject some levity and poke fun at otherwise serious topics, it became popular to produce humorous cartoon-type, one-page "Dummy Documents" or Dumm. Docs. At the April 1975 meeting in Woods Hole, John Pope demonstrated his amusing, but clever, side with his famous "Dumm. Doc. 75/2" entitled "Estimation of Unknown Natural Mortality", in which, over five graphical iterations, he contrived a derivation of $M = 0.2$ by progressively manipulating the "?" in his initial "$M$ = ?" until it became ".2" (Figure 1). This parody adroitly poked fun at the way in which many estimates of natural mortality, particularly the commonly used $M = 0.2$, were derived.

Most scientific staff at the Woods Hole Laboratory participated in research vessel survey cruises. The laboratory's two vessels, RV "Albatross IV" and RV "Delaware II", were generally at sea much of the year. Although I went on several surveys aboard the "Albatross IV", I preferred working aboard cooperating foreign vessels (e.g. Polish, Soviet, and FRG), mainly because I discovered that I was less likely to suffer from seasickness on them (having realized early in my career that I was prone to "mal de mer"; an early embarrassment as a graduate student was becoming sick on a research vessel in near-calm conditions on Lake Superior). In addition to more stable conditions, foreign vessels provided me with the opportunity to gain insight into their scientific and fishing techniques as well as their social and political mores. I also established lasting personal friendships with scientists, officers, and crew.

By 1976, Atlantic mackerel had become a stock of high interest in ICNAF, primarily because it was supporting large catches by Soviet-bloc countries. Most evidence (at least in the US assessments) indicated that fishing mortality on this stock was increasing sharply and, conversely, that stock size was declining markedly (Anderson *et al.*, 1976). Analyses demonstrated the unreliability of DWF (stern trawl) catch per unit effort (cpue) as an accurate indicator of relative stock biomass for mackerel. This was a hotly contested issue among scientists in ICNAF as DWF cpue failed to show the sharp downwards trend in mackerel biomass in the early to mid-1970s, as indicated by US bottom-trawl surveys (Anderson, 1976). One of the main conclusions of the ICES Symposium on the Assessment and Management of Pelagic Fish Stocks held two years later in 1978 (Saville, 1980) was that catch and effort data from fisheries for schooling pelagic fish stocks cannot be utilized in estimating current abundance of such stocks because of strong evidence that the catchability coefficient increases as stock size decreases (Pope, 1980; Saville and Bailey, 1980; Ulltang, 1980).

Compared with all other years in which I was involved in assessing mackerel, 1976 was a high point for me personally. In all, 18 ICNAF Research Documents were submitted by NMFS Northeast Fisheries Science Center (NEFSC) staff to ICNAF that year (ICNAF, 1976, 1977), and I was the author or co-author of ten of them. The assessments produced that year by US and Soviet-bloc scientists differed considerably. Three ICNAF scientific meetings were held in 1976 (March/April, May/June, and November/December), with agreement on a TAC for 1977 not achieved until after the final meeting.

During my first 6 years at Woods Hole (1970–1976), when the results of our assessment activities were exclusively considered within ICNAF for the purposes of recommending TACs on offshore fish stocks, my colleagues and I experienced strong support from members of the US industry who were very anxious to see reduced quotas for the DWFs. We were rarely, if ever, subjected to criticism by industry advisers who served on the US ICNAF delegation. However, this changed following the third and last ICNAF assessment meeting in November/December 1976. At the first assessment meeting in March/April, data available at that time led all scientists, except those from the GDR, Poland, and the USSR, to recommend a zero TAC for 1977, an outcome obviously welcomed by the US industry advisers. At the May/June meeting, new data from the 1976 fishery were available, but, as at the earlier meeting, no scientific consensus could be reached; catch projections for 1977 under two possible options on the size of the 1975 year class ranged from 55 000 to 115 000 t (Anderson and Paciorkowski, 1980). Finally, at the November/December meeting, with all catch and research survey data from 1976 in hand, agreement on an assessment was finally reached, as noted above, resulting in a recommended TAC of 105 000 t for 1977 (compared with 310 000 t for 1976). At a US delegation meeting before the start of the Commission meeting, one of the lead industry advisers (Jakob Dykstra), very upset that the scientific advice had increased from a zero TAC in March/April to 105 000 t, pointedly accused me of

RESTRICTED TO SCIENTISTS

International Commission for the Northwest Atlantic Fisheries

Serial No. 000½
(WOW)

ICNAF Dumm.Doc. 75/2

ANNUAL MEETING - JUNE 1975

Estimation of Unknown Natural Mortality

by

J.G. Pope

M = ?

M = ?

M = .2

M = .2

M = 0.2

EUREKA!!!

**Figure 1.** ICNAF Dumm. Doc. by John Pope drawn at the April 1975 meeting of the ICNAF Assessment Subcommittee entitled "Estimation of Unknown Natural Mortality".

altering the assessment at the direction of the US State Department, presumably for political reasons. Happily for me, the no-nonsense head of the delegation, Ambassador Rozanne Ridgway, Deputy Assistant Secretary of State for Oceans and Fisheries, sharply rebuked Dykstra and demanded that he either apologize or be expelled from the delegation. He chose the former option! I viewed that brief encounter as a lesson for both me and Dykstra. For me, it reinforced my ethic that honesty is the best policy and that it

usually prevails at the end of the day. For Dykstra, I can only surmise that he learned quickly and decisively that it was unwise to voice wrongdoing by either the State Department or a government scientist in the presence of a Deputy Assistant Secretary of State!

A few months after this ICNAF meeting, the USA declared a 200-mile EEZ (effective 1 March 1977) and withdrew from ICNAF. Now, instead of providing assessment advice to ICNAF, management of US fisheries was under the control of regional fishery management councils, as mandated by the Magnuson–Stevens Fishery Conservation and Management Act (MFCMA) of 1976. At Woods Hole, we interacted with the New England Fishery Management Council (NEFMC) and the Mid-Atlantic Fishery Management Council (MAFMC). With the large foreign fleets gone, US fishers had exclusive access to fish stocks in the US EEZ and felt that catch quotas were unnecessary. Dewar (1983) noted that, once the foreign vessels were excluded, the US industry felt more confident about the preservation of fish stocks because, in contrast to the foreign fleets, New England fishers used larger mesh, lacked the technology for midwater trawling, and did not have the harvesting capacity that had caused the earlier damage to the stocks. It was a frustrating time for those of us who had been intimately involved in the ICNAF machinery and had collaborated for years with highly respected European colleagues. Although ICNAF, as well as most other international fisheries commissions then and now, was unsuccessful in implementing fully effective conservation measures on the stocks, ICNAF, nevertheless, claimed a number of firsts: (i) establishing control of the overall level of exploitation, (ii) adopting TAC regulations, (iii) adopting national allocations of TACs, and (iv) attempting multispecies management by "second-tier" TACs (Anderson, 1998). To this day, I feel privileged to have played a role in those efforts. After the extension of EEZs by the USA and most other countries, the greatly reduced quota allocations for distant-water fishing countries in the Northwest Atlantic eliminated the need for strong national scientific delegations to the Northwest Atlantic Fisheries Organization (NAFO), the successor organization to ICNAF. Consequently, the principal international forum for fisheries science in the North Atlantic shifted to ICES, where it has remained to this day. Instead of attending ICNAF (now NAFO) scientific meetings, many of the scientists at Woods Hole began participating in ICES fish stock assessment working groups. The first such meeting I attended was of the Mackerel Working Group in 1978; I subsequently attended again in 1982, 1984, and 1985, serving as chair the last two times. I consider it an honour to have been the first US scientist to be invited to chair an ICES assessment working group.

The assessment scientists at Woods Hole viewed participation in ICES Working Groups as mainly a learning opportunity. We were not necessarily interested in the particular TAC advice being generated by the working groups, but were more attracted by the prospects of learning new assessment methods developed by European scientists, and, conversely, being able to introduce some of our ideas and techniques for their consideration. I feel strongly that international exchanges and collaborations such as these help immensely in promoting improved scientific advancements as well as furthering personal and professional development. My own career is clear testimony to this (see below), and I have always encouraged young scientists to take advantage of such opportunities. One has only to peruse the scientific literature to be made aware of the many, many advances in fisheries science resulting from international partnerships.

In 1978, I was invited to present a major review paper (Anderson and Paciorkowski, 1980) on the Northwest Atlantic mackerel stock at the ICES Symposium on the Assessment and Management of Pelagic Fish Stocks (Saville, 1980). This was my first such invitation and the first opportunity to interact with senior-level ICES scientists and to present my work for their consideration. As will become clear below, this helped, in some ways, open the door to new career opportunities for me.

Much of what I enjoyed about fish stock assessments was the challenge of trying to make scientific sense out of previously unassembled or unanalysed data. Nearly all the species on which I worked were in that category. While not considering myself to be on the cutting edge of new developments, I nevertheless still did my best to develop new techniques to solve problems and achieve objectives. One innovation that I successfully devised in assessing mackerel was employing a cpue time-series from the relatively small inshore US commercial floating trap fishery to generate a fishing effort index for the entire international fishery (by dividing cpue by total international catch), with the latter (i.e. fishing effort index) regressed against fishing mortality ($F$) from a previous VPA via a power curve relationship ($r = 0.894$) to predict the terminal $F$ for initiating a new VPA (Anderson, 1982). The cpue time-series proved to be a valid and reliable measure of mackerel biomass, and the fishing effort index derived from the cpue time-series proved equally valid and reliable as a means of estimating the terminal $F$ for VPA. This demonstrated how an index of abundance from a small segment of a fishery could play an important role in assessing the status of a major fish stock.

By this time, our assessment work in Woods Hole was coming under greater scrutiny by the US industry, particularly when our results conflicted with fishers' at-sea observations. The industry particularly distrusted the results of the NEFSC research vessel bottom-trawl surveys (Grosslein, 1969) that were based on a stratified random sampling design and utilized a standard trawl that they felt was inadequate for catching most fish species. Most did not understand the concept of random sampling, and felt that is was a waste of time to tow the trawl over grounds that they knew, from their own experience, were devoid of fish, or at least a particular species. Our scientific reports also typically employed technical language, and scientists unfortunately tended to also use technical language when making public presentations; consequently, communication between scientists and the public proved unsatisfactory. Despite genuine efforts to improve this situation, I am not convinced that these problems have been substantially resolved over the years, partly because it is inevitable that any profession, be it medicine, law, engineering, or science, is encumbered by its own set of jargon, terminology, and acronyms. Lastly, although former fishers served as crew aboard the NEFSC research vessels, those actively fishing were rarely invited to participate in any cooperative research activities. However, I am pleased to observe that such collaboration is now much more common. As a member of the Scientific and Statistical Committee of the MAFMC during 1977–1985, I interacted closely with MAFMC and industry members and found that a cooperative attitude and the use of non-technical language when explaining stock assessment information made a positive impression and helped build trust. Over a 4-year period (1981–1985), I also managed a winter/spring research fishery for Atlantic mackerel in the Mid-Atlantic area employing Polish factory trawlers. In exchange for being able to fish, the Polish captains were asked to assist interested US fishers who were attempting to learn more about offshore mackerel fishing. This entire endeavour proved to be a very good public relations effort, resulted in one of the Polish captains being honoured by the MAFMC for his

cooperation and cast a positive light on that aspect of the scientific work at Woods Hole.

## ICES and a new life

By 1985, one of the more interesting parts of my professional life had become serving as chair of the ICES Mackerel Working Group, a responsibility that had begun in 1984. Consequently, when the vacancy announcement for the position of Statistician in the ICES Secretariat in Copenhagen was released in January 1985, I optimistically submitted my application. On 15 May, my wife's birthday, I received a call from Basil Parrish, the General Secretary, informing me of my selection. As a US government employee, I was able to obtain a 5-year leave of absence to accept the position. Three months later, our family of five moved to Copenhagen, not knowing that it would be our home for the next 8 years.

The Statistician was responsible for the Secretariat's activities concerned with fish stock assessment relative to the Council's fisheries management advisory function, processing and preparing for publication catch and associated fisheries statistics supplied by member countries, providing scientific/technical services for the Advisory Committee on Fishery Management (ACFM) and its assessment working groups, and serving as secretary to ACFM. Editing all working group and ACFM reports as well as preparing minutes of ACFM meetings comprised a major part of the workload. Together with the ACFM chair, the Statistician represented the Council at annual meetings of the North-East Atlantic Fisheries Commission (NEAFC), International Baltic Sea Fishery Commission (IBSFC), and North Atlantic Salmon Conservation Organization (NASCO).

When I assumed this post, assessment working groups were still using the same computational software (e.g. basic VPA and forecast programmes) that had been implemented by ACFM in 1977 on the Secretariat's Norsk Data computer system (Hoydal, 2014). A few new "wrinkles" such as separable VPA (Pope and Shepherd, 1982) had been introduced. An interesting observation that I made during this time was the concern expressed by some working group members that the new methodological advances intended to "fine-tune" assessments (e.g. separable VPA) produced results (i.e. tables of numerical output) not fully understandable by many biologists and that more emphasis was seemingly being placed on statistical improvements while sometimes ignoring basic biological information. Interestingly, Ray Beverton, commenting about the reluctance to embrace stock and recruitment in fisheries management in his 1995 Larkin Lecture at the University of British Columbia (Beverton, 1998), noted that "biology became subservient to maths". Do we place too much emphasis on achieving the best possible statistical fit of data to models at the expense of ensuring a better biological understanding of exploited fish populations? Scientists need to always be aware of the need to ensure a proper balance between statistics and biology in stock assessments.

One of the things that excited me about working in the ICES Secretariat and interacting with member country assessment scientists who came to Copenhagen for their annual working group meetings was the serious nature of their work and knowing that the products of their efforts provided the basis for advice being recommended to the client regulatory commissions. To me, it was analogous to turning the clock back 10 years to the ICNAF days. I was back in the company of some of the scientists with whom I had interacted in ICNAF, but I also became friends with many more scientists. It was particularly satisfying to "rub shoulders" with some of the older, eminent scientists who were still working, but who would retire during my time in the Secretariat.

In 1987, Basil Parrish announced his retirement as General Secretary, effective early 1989. By this time, I was really enjoying my work at ICES and began to consider whether I could manage the responsibilities of being General Secretary. Aware of some strong support for me within ICES and convinced that I possessed the ability to do the job, I applied. Happily, I was selected by the Council at the 1988 Statutory Meeting in Bergen, Norway, and assumed the post the following April. I then applied for and received a 3-year extension to my leave of absence from NMFS, the maximum allowed by US law.

Although many important events and changes occurred in ICES during my nearly 6 years as General Secretary (April 1989–December 2003), I am particularly proud of several major transformations in which I played a key role. This stems from my personal philosophy to address problems requiring attention and deal with them as soon as possible. Within the first year of my appointment, several such problems became evident. I initiated a number of long overdue improvements to the Secretariat's physical facilities and conditions of service for staff bringing the salary/pension/allowances more in parity with those in other non-UN international organizations and increasing office and meeting-room space in response to growing needs and requests for service from both member countries and client organizations. In addition, a new computer system consisting of PCs, workstations, and peripheral equipment, which was approved by Delegates at my first Statutory Meeting in October 1989 (ICES, 1990) and was fully installed and implemented in 1991, replaced the 10-year-old Norsk Data system. All these improvements led to an enhanced work environment for both staff and visiting scientists and upgraded the attractiveness of the Secretariat internationally as an employer. I had personally experienced the previous working conditions while serving as Statistician and felt that all the upgrades made good sense and were long overdue. It is fair to say that staff morale improved considerably as a result, and visiting scientists participating in working group meetings greatly appreciated the vast improvement in computing facilities.

My second major accomplishment was with the ICES publication series. Almost all of them had French titles, and their covers were rather drab and old fashioned. Early published Council reports were mainly in French text (with English given secondarily); French was then and still is one of the world's most important languages for diplomats and international organizations. Hence, when ICES was established in 1902, it was logical that French be used. Even today, English and French are still the two official languages of ICES. However, in 1989, the Secretariat proposed English titles for ICES publications to improve their marketability to people and areas unfamiliar with ICES and to join the growing trend for scientific journals, even those produced in France, to switch to English titles, the predominant language of science. The proposal to adopt English titles (while retaining French subtitles) was approved by the Council in 1990 (ICES, 1991). It was also agreed at the 1990 Statutory Meeting that the publication of the "ICES Journal of Marine Science" (formerly "Journal du Conseil") would, beginning in 1991, be published by Academic Press. Before this, ICES was the publisher, with printing done by AiO Tryk AS in Odense, Denmark. In addition to the title changes, new attractive covers were designed for all the publication series. Clearly, the name changes, new covers, and subsequent enhancements to all the publication series proved to be an extremely important stimulus in helping to make ICES and its

publications, particularly the "Journal", better known within the international marine science community. In contrast to my years in the Secretariat, the number of countries represented at ICES Annual Science Conferences has grown exponentially; the number of countries with manuscripts accepted for publication in the "Journal" totalled 56 in 2014 compared with 10 in 1989; and the number of issues of the "Journal" increased from three (309 pages) published in 1989 to nine (2642 pages) in 2014. The Journal's impact factor in 2014 was 2.5, the highest ever, placing it 3 out of 50 among fisheries journals in the world. To me, the lesson here is to act when faced with an obvious need for change and to not succumb to the temptation to remain conservative and retain something that has always been that way.

The third major change that I am most proud of pertains to enhancing the interdisciplinary role of ICES. I first brought this matter to the Council's attention in 1989 after observing that ICES was providing environmental advice to groups or commissions that appeared to know little about the Council or had minimal involvement in its scientific work. ICES had traditionally been a fisheries-oriented organization, but the 1970s–1980s had witnessed a major and steadily increasing growth in interest in the status of the marine environment (i.e. components other than fisheries). At the 1991 Statutory Meeting, I presented a white paper to Delegates summarizing various concerns and problems, progress that had been made, and a list of action items for the Council to consider to enhance its interdisciplinary role and broaden its umbrella to include more environmental science representation in both the scientific and policy-making work of ICES (ICES, 1992). Some of these proposed action items, partly at the national level and partly within ICES, included fisheries and environmental ministries in member countries sharing the national financial contribution to ICES and each having an appointed Delegate, greater representation on subject/area committees from non-fisheries institutions, and greater promotion of interdisciplinary national research and ICES activities. The paper also proposed that the Council give serious consideration to making the composition and membership of the Advisory Committee on Marine Pollution (ACMP) similar to that of ACFM (i.e. national representation) so that individual member countries, as for ACFM, would be more prone to claim ownership of advice emanating from ACMP. Considerable progress ensued over the next year in addressing this matter. At the 1992 Statutory Meeting, the Council adopted the suggestion to change the membership of ACMP from co-opted experts to national representation and to change its name to the Advisory Committee on the Marine Environment (ACME; ICES, 1993). Some countries also adopted the proposal of having one of their two Delegates from the environment side. I feel that my initiative to enhance the interdisciplinary role of ICES was necessary, came at an opportune time, and subsequently led to a major transformation in the overall functioning of ICES and its perception by the outside world.

At the end of 1993, primarily because my 8-year leave of absence from NMFS had expired, but also because we wanted to be closer to our three children who were living in the USA, I concluded my work as General Secretary and returned to the NEFSC in Woods Hole. I found it very difficult to leave ICES and Copenhagen. It was a huge let-down professionally to relinquish the job as General Secretary and return to the much lesser position that I had vacated 8 years earlier. Returning to the USA after years abroad resulted in culture shock which required several years of readjustment. I have often said that the years on the Secretariat staff and living in Copenhagen were the best of my life. My time as General Secretary was clearly the capstone of my career. I take great pride in being the only American to ever serve in that post. I will forever treasure ICES because of its unique spirit of collegiality, its ability to have transcended national political differences since its establishment in 1902, and the many lasting personal friendships that were forged. There are many reasons for the long and successful life of ICES, but a major one has been its exclusive focus on promoting and coordinating marine science without taking on the additional task of resource management. National politics that often plague fisheries management have successfully been circumvented with the ICES model. It is a lesson worth passing on to bodies that incorporate both science and management in their portfolio.

## Post-ICES experiences and projects

By 1994, I had been removed from assessment research for over 8 years, although I had remained somewhat abreast of new developments and techniques while serving as ICES Statistician when I assisted the assessment working groups. Upon my return to Woods Hole, I was again assigned to the Populations Dynamics Branch, but did not assume specific assessment responsibilities. I learned that an absence of even 8 years from a rapidly changing technical discipline such as stock assessments made it very difficult to catch up. Instead, to a large extent, I was given the luxury of handling some special projects.

One such task was assuming managerial responsibility in 1995 for seven data-rescue projects at the Atlantic Research Institute of Marine Fisheries and Oceanography (AtlantNIRO) in Kaliningrad, Russia. In light of my earlier interactions and friendships in ICNAF with some of the AtlantNIRO scientists, coupled with my recent international experience in ICES, this assignment seemed like a good fit. Many of the data in question had been gathered in conjunction with cooperative US–USSR research vessel bottom-trawl surveys conducted in the Northwest Atlantic from 1967 to 1981. The final and largest project, my favourite, was a detailed history of the Soviet fishery in US and Canadian waters in the Northwest Atlantic during 1961–1977. The book was first written in Russian then translated into rough English in Kaliningrad before it was sent to me for editing, a process that lasted several years before the book was published in 2006 (Chuksin, 2006). The book project was particularly rewarding for me because, as a young scientist, I had played a small role in the book's story that chronicled the political, economic, and scientific organization, management, and performance of the world's largest distant-water fishery. I had been involved in some of the scientific work reported in the book (joint US–USSR research surveys) and had also witnessed firsthand, during research cruises in the 1970s, the vast armadas of DWF fishing vessels operating on Georges Bank and adjacent areas. My interactions with the author gave me a totally new perspective on the Soviet distant-water fishery and the people involved. It was particularly revealing to learn about both the strengths and the weaknesses of this huge enterprise, and what eventually led to its demise. This experience taught me the value of sticking with an assignment even when the ultimate outcome may initially appear unclear or uncertain.

In May 1994, shortly after I returned to Woods Hole, Ray Beverton presented three lectures at the NEFSC, his first stop in a tour of NMFS laboratories in the USA. Ray had intended to eventually publish the lectures, but regrettably he became ill and passed away in July 1995 before starting work on the manuscripts. Because the Woods Hole lectures had been videotaped and also because Ray had been a close friend owing to our frequent

interactions during my years in the ICES Secretariat while Ray was editor of the "Journal", I undertook, in my spare time, the task of transcribing and editing the lectures for publication. The book was eventually published in 2002 (Anderson, 2002a) and became a valuable reference for stock assessment scientists both because of the lecture topics and because of Ray's popularity and the respect for his thinking, particularly in his final years. The unique opportunity to prepare this book led eventually to my renewed contact with Ray's colleague Sidney Holt and to writing several papers describing their early work in Lowestoft (Beverton and Anderson, 2002; Anderson, 2011). The lesson learned is that interpersonal relationships, whether old or new, deserve maintaining because unexpected rewards often ensue.

My last venture into the world of stock assessments was in 1996–1998 when I was appointed chair of the Northeast Regional Stock Assessment Workshop (SAW) process and its Stock Assessment Review Committee (SARC). The SAW process had been launched in late 1985, following my departure to the ICES Secretariat, to ensure adequate peer review of NEFSC fish stock assessments by federal, state, university, and other external experts for submission to the regional fishery management councils. By 1996, the process was well developed, consisted of semi-annual SARC meetings to evaluate assessments of scheduled stocks, and was a respected source of assessment advice for the two regional fishery management councils (NEFMC and MAFMC). Participants at each SARC meeting generally included a highly-respected international expert. In addition to chairing these meetings, my responsibility consisted of serving as NEFSC liaison to the NEFMC and MAFMC and making formal presentations of the SARC advice. Advice on some stocks was often contentious and unpopular with the fishing industry, requiring careful explanations in easily understood language. During my time as chair, industry representatives were first invited to participate in SARC meetings and to input their personal observations to the scientific discussions. The lessons learned are that fishers have valuable information that can be used in evaluating stock status and that their participation can lead to greater acceptance of assessment results by the industry and enhanced communication and mutual respect.

In 1996, I was appointed by ICES to serve as convenor of a scientific symposium to help commemorate the centenary (2002) of the organization. Assisted by a steering committee, planning took place over a multiyear period, with the symposium being held in August 2000 in Helsinki. The symposium proceedings were published in 2002 (Anderson, 2002b). The symposium was unique and important historically because it summarized the full breadth of scientific achievement under the ICES umbrella during the organization's first century. The proceedings and two major histories by Went (1972) and Rozwadowski (2002) together form a comprehensive historical account of the first 100 years in the life of ICES. As an admirer of history in general and a firm believer in the value of history in guiding future endeavours in all facets of human enterprise, I consider it important for young fisheries scientists, in particular, to be fully aware of the accomplishments of their predecessors. Therefore, I was very appreciative that ICES invited me to convene the symposium. In the process, I learned many new things about ICES and the scientific achievements of early researchers.

In December 1998, I transferred from the NEFSC to NOAA/NMFS headquarters in Silver Spring, MD, to assume a newly created position as liaison from NMFS to the National Sea Grant Office (NSGO) located in NOAA's Office of Oceanic and Atmospheric Research (OAR). In this capacity (until my retirement in 2004), I served as Program Director for Fisheries responsible for promoting fisheries research within the Sea Grant network, improving collaboration between Sea Grant and NMFS, and managing several competitive research and fellowship programmes. Like other senior staff in the NSGO, I also served as programme officer for several state Sea Grant programmes. This 6-year appointment was one of the more enjoyable of my career in that it afforded me the opportunity for extensive interactions with university administrators, scientists, and students and gave me immense satisfaction in being able to facilitate some much-needed collaboration between NMFS and Sea Grant. I had not been aware of the lack of general collegiality between the two entities nor of the outright hostility in some areas, particularly regarding fisheries extension work, a specialty of the state Sea Grant programmes, where agents residing mainly in the communities they serve provide science-based technical information to address local problems. My efforts helped improve the lack of collaboration between NMFS and Sea Grant and taught me that difficulties such as those that I encountered are often due to a lack of understanding and communication and can be repaired through better personal contact and cooperation.

One example where cooperation resulted in something mutually beneficial was the NMFS/Sea Grant Joint Graduate Fellowship Programs in Population Dynamics and Marine Resource Economics that were begun in 1999. I helped launch and administrate this initiative that was intended to (i) encourage qualified applicants to pursue careers in either population dynamics and stock assessment methodology or in marine resource economics, (ii) increase available expertise related to these fields, (iii) foster closer relationships between academic scientists and NMFS, and (iv) provide real-world experience to graduate students and accelerate their career development. Two fellowships with 3 years of funding in population dynamics and 2 years of funding in economics were awarded each year to PhD students. Fellows were required to work summers at a NMFS facility and also collaborate closely with a NMFS mentor. This initiative proved to be very successful and has resulted in many of the recipients of these fellowships now employed by NMFS or academic institutions as successful scientists. The lesson learned here is that a gamble with no guarantee of success paid dividends by providing benefits both to qualified applicants and their subsequent employers and improving collaboration between NMFS and Sea Grant.

Another example was a programme involving graduate student fellowships coupled with symposia co-sponsored mainly by the American Fisheries Society (AFS) and Sea Grant, but also by various other government agencies (including NMFS) and professional societies, on timely scientific topics. Each fellow, with 18 months of funding, was required to (i) organize an international symposium (with assistance from a steering committee made up of representatives from the co-sponsoring agencies) to be held at an AFS annual meeting, (ii) solicit papers and manage the peer-review process, and (iii) synthesize and edit the final draft of the proceedings for publication by AFS. I had the privilege of mentoring three such fellows and their symposia: "Fisheries in a changing climate" in 2001 (McGinn, 2002), "Aquatic protected areas as fisheries management tools" in 2003 (Shipley, 2004), and "Partnerships for a common purpose: cooperative fisheries research and management" in 2005 (Read and Hartley, 2006). It was a wonderful opportunity for aspiring students to take on a challenging project, work with (and receive insight and advice from) senior scientists in natural resources agencies, and gain valuable experience in furthering their careers. It was personally gratifying to work with these

students and observe their growth in experience and confidence during the period of their fellowships. As with the Joint Graduate Fellowship Programs in Population Dynamics and Marine Resource Economics, this venture taught that taking a chance with a qualified, but unproven, young student can result in a very successful outcome.

## Concluding thoughts

Since my retirement from NMFS in 2004, I have been fortunate to remain engaged in fisheries science through scientific reviews, consulting, and editing. The latter activity, since 2008 with ICES, has been the perfect culmination of a 45-year career, allowing me to make effective use of accumulated knowledge, experience, and personal contacts. Serving as an editor of the "ICES Journal of Marine Science" and of the "ICES Cooperative Research Report" series has enabled me to keep abreast of progress in research in fisheries and related marine science topics, remain in contact with scientists in my field, contribute the added value of my experience to authors and their publications, and thus continue to be of service to my profession.

In retrospect, I have been privileged to experience a career with multiple phases: fish stock assessment scientist, staff member and administrator of the world's oldest intergovernmental marine science organization, manager of various scientific projects and activities, mentor to graduate students, and now editor. I have authored, co-authored, or edited well over 100 scientific reports, published papers, book chapters, and books as well as more than 100 reports and documents, mainly administrative in nature, while serving as ICES General Secretary. The majority of these were not primary publications, the metric commonly used to measure success in science. Many of my scientific reports were Woods Hole Laboratory Reference Documents or ICNAF Research Documents which were the basis for recommendations to fishery management bodies. I have witnessed dramatic changes in assessment techniques that have enabled scientists to better extract meaningful results from highly variable databases, observed the sharp reduction in many exploited fish stocks, and noticed that even the most advanced analyses are still unable to accurately predict what nature controls. Although great strides have been made in cooperative research activities between scientists and fishers, there is still mistrust of assessment results by the fishing industry. This is because assessment science will always be plagued by immeasurable levels of uncertainty; even the most sophisticated tools will fail to provide sufficiently accurate results that remain consistent from year to year. Consequently, when assessment results for a given stock abruptly change for the worse in a given year, it is understandable that those whose livelihoods are dependent on that stock will be disconcerted and angry and will question the validity of the science. Unfortunately, I see no easy solution to this dilemma.

With respect to ICES, dramatic changes have occurred in the past 20 years since my departure from the Secretariat. The number of member countries increased from 18 to 20, the 12 subject/area committees during my time have been replaced by four scientific steering groups under a Science Committee, an Advisory Committee (ACOM) now replaces the old ACFM and ACMP/ACME, the annual scientific meeting (the Annual Science Conference) now attracts 600–700 participants instead of half that many, the "ICES Journal of Marine Science" has grown in size and stature with an Editor-in-Chief and 47 editors instead of an Editor-in-Chief and two assistant editors, and the Secretariat staff now numbers 56 compared with 38 in 1993. These are only some of the physical changes; programmatic improvements have also been implemented. Based now on the perspective of an observer, I have to conclude that growth in ICES has been positive, reflecting necessary changes to keep abreast of new requirements and challenges in acquiring a more integrated understanding of marine ecosystems needed to accommodate growing demands for the comprehensive management of all aspects of the marine environment.

With the benefit of my experiences in science and administration and the lessons learned therein, I feel qualified to offer advice to young scientists contemplating potential paths to pursue in their careers. First of all, begin with a solid, broad-based education coupled with a determination to succeed. Do not let difficulties or distractions deter you from pursuing your dreams or reaching your goals. Consider new opportunities for work or scientific collaborations carefully before making final commitments. Remain abreast of the literature and new developments in your field. Set and maintain high standards for performance and ethics. Continually challenge yourself to improve. Exercise common sense, trust your intuition, and cultivate personal relationships. When unique opportunities are presented, take them because they may turn out to be life-changing and career-making experiences.

## Acknowledgements

I thank Howard Browman for inviting me to write this Food for Thought article and for his constructive suggestions. I thank also the many people who assisted me in my career.

## References

Anderson, E. D. 1976. Measures of abundance of Atlantic mackerel off the northeastern coast of the United States. ICNAF Research Bulletin, 12: 5–21.

Anderson, E. D. 1982. The use of commercial cpue data in assessing the Northwest Atlantic mackerel stock. ICES Document CM 1982/H: 34. 25 pp.

Anderson, E. D. 1998. The history of fisheries management and scientific advice—the ICNAF/NAFO history from the end of World War II to the present. Journal of Northwest Atlantic Fishery Science, 23: 75–95.

Anderson, E. D. (Ed). 2002a. The Raymond J. H. Beverton lectures at Woods Hole, Massachusetts. Three lectures on fisheries science given May 2–3, 1994. NOAA Technical Memorandum NMFS-F/SPO-54. 161 pp.

Anderson, E. D. (Ed). 2002b. 100 years of science under ICES. Papers from a symposium held in Helsinki, 1–4 August 2000. ICES Marine Science Symposia, 215. 610 pp.

Anderson, E. D. 2011. Standing on the shoulders of giants. ICES Insight, 48: 4–13.

Anderson, E. D., and Smith, L. L., Jr. 1971. Factors affecting abundance of lake herring (*Coregonus artedii* LeSueur) in western Lake Superior. Transactions of the American Fisheries Society, 100: 691–707.

Anderson, E. D., and Paciorkowski, A. J. 1980. A review of the Northwest Atlantic mackerel fishery. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 177: 175–211.

Anderson, E. D., Wood, P. W., Ackerman, B. B., and Almedia, F. P. 1976. Assessment of the mackerel stock in ICNAF SA 3-6. ICNAF Research Document 76/XII.137. 21 pp.

Anon. 1971. Canada–U.S. notes on quota allocation procedures. ICNAF Commissioners' Document, 18. 11 pp.

Baranov, F. I. 1918. K voprosy o biologicheskikh osnovaniyahk rybnogo khozyaistva (On the question of the biological basis of fisheries). Nauchnyi Issledovatelskii Ikhtiologicheskii Institut Izvestiya (Report of the Division of Fish Management and Scientific Study of the Fishing Industry), 1: 81–128 (In Russian).

Beverton, R. 1998. Fish, fact and fantasy: a long view. Reviews in Fish Biology and Fisheries, 8: 229–249.

Beverton, R. J. H., and Anderson, E. D. 2002. Reflections on 100 years of fisheries research. ICES Marine Science Symposia, 215: 453–463.

Beverton, R. J. H., and Holt, S. J. 1957. On the dynamics of exploited fish populations. Ministry of Agriculture, Fisheries and Food. Fishery Investigations, London, Series II, XIX. 533 pp.

Chuksin, Y. V. 2006. From Cape Hatteras to Cabot Strait. The history of the Soviet fishery on the Atlantic continental shelf of the United States and Canada. NOAA Technical Memorandum NMFS-F/SPO-71. 291 pp.

Deroba, J. J., Butterworth, D. S., Methot, R. D., Jr, De Oliveira, J. A. A., Fernandez, C., Nielsen, A., Cadrin, S. X., *et al.* 2015. Simulation testing the robustness of stock assessment models to error: some results from the ICES strategic initiative on stock assessment methods. ICES Journal of Marine Science, 72: 19–30. doi:10.1093/icesjms/fst237.

Dewar, M. E. 1983. Industry in Trouble: The Federal Government and the New England Fisheries. Temple University Press, Philadelphia, PA. 252 pp.

Galtsoff, P. S. 1962. The story of the Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, Massachusetts. U.S. Bureau of Commercial Fisheries, Circular 145. 119 pp.

Grosslein, M. D. 1969. Groundfish survey program at BCF Woods Hole. Commercial Fisheries Review, 31: 22–35.

Gulland, J. A. 1965. Estimation of mortality rates. Annex to Arctic Fisheries Working Group Report. ICES Document CM 1965/Gadoid Fish Committee: 3. 9 pp.

Halliday, R. G., and Pinhorn, A. T. 1985. Present management strategies in Canadian Atlantic marine fisheries. Their rationale and the historical context in which their usage developed. *In* Towards the Inclusion of Fishery Interactions in Management Advice. Proceedings of a Workshop at the Bedford Institute of Oceanography (October 30–November 1, 1984), pp. 10–33. Ed. by R. Mahon. Canadian Technical Reports of Fisheries and Aquatic Sciences, 1347. 221 pp.

Hoydal, K. (Ed). 2014. History of the ICES Advisory Committee on Fishery Management, 1978–2007. ICES Cooperative Research Report, 322. 143 pp.

ICES. 1990. Procès-Verbal de la Réunion 1989. Conseil International pour l'Exploration de la Mer. 319 pp.

ICES. 1991. 78th Statutory Meeting 1990 Copenhagen. ICES Annual Report. 304 pp.

ICES. 1992. 79th Statutory Meeting 1991 La Rochelle. ICES Annual Report. 259 pp.

ICES. 1993. 80th Statutory Meeting 1992 Rostock—Warnemünde. ICES Annual Report. 280 pp.

ICNAF. 1972. Report of the 22nd Annual Meeting, 25 May–2 June 1972. Part 2. ICNAF Annual Proceedings, 22: 17–66.

ICNAF. 1976. Standing Committee on Research and Statistics. Proceedings of Special Meeting September 1975, Special Meeting January 1976, Annual Meeting May-June 1976. ICNAF Redbook 1976. 219 pp.

ICNAF. 1977. Standing Committee on Research and Statistics. Proceedings of Special Meeting December 1976, Annual Meeting May-June 1977. ICNAF Redbook 1977. 116 pp.

Kuparinen, A., Mäntyniemi, S., Hutchings, J. A., and Kuikka, S. 2012. Increasing biological realism of fisheries stock assessment: towards hierarchical Bayesian methods. Environmental Reviews, 20: 135–151.

McGinn, N. A. (Ed). 2002. Fisheries in a Changing Climate. American Fisheries Society, Symposium 32, Bethesda, MD, USA. 295 pp.

Pella, J. J., and Tomlinson, P. K. 1969. A generalized stock production model. IATTC Bulletin, 13: 419–496.

Pope, J. G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. ICNAF Research Bulletin, 9: 65–74.

Pope, J. G. 1980. Some consequences for fisheries management of aspects of the behavior of pelagic fish. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 177: 466–476.

Pope, J. G., and Shepherd, J. G. 1982. A simple method for the consistent interpretation of catch-at-age data. Journal du Conseil International pour l'Exploration de la Mer, 40: 176–182.

Read, A. N., and Hartley, T. W. (Ed.). 2006. Partnerships for a common purpose: cooperative fisheries research and management. American Fisheries Society, Symposium 52, Bethesda, MD, USA. 270 pp.

Rozwadowski, H. M. 2002. The Sea Knows No Boundaries: A Century of Marine Science under ICES. University of Washington Press, Seattle, WA, USA. 456 pp.

Saville, A. (Ed). 1980. The assessment and management of pelagic fish stocks. A symposium held in Aberdeen, 3–7 July 1978. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 177. 517 pp.

Saville, A., and Bailey, R. S. 1980. The assessment and management of the herring stocks in the North Sea and to the west of Scotland. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 177: 112–142.

Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. IATTC Bulletin, 1: 26–56.

Shipley, J. B. (Ed). 2004. Aquatic protected areas as fisheries management tools. American Fisheries Society, Symposium, 42. Bethesda, MD, USA. 301 pp.

Ulltang, Ø. 1980. Factors affecting the reaction of pelagic fish stocks to exploitation and requiring a new approach to assessment and management. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 177: 489–504.

Went, A. E. J. 1972. Seventy Years Agrowing. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 165. 252 pp.