The Jerlov Award

PRESENTED TO DR. TALBOT WATERMAN

October 9, 2008, Ocean Optics XIX Conference

INTRODUCTION BY DR. STEVEN G. ACKLESON, OFFICE OF NAVAL RESEARCH

Good evening ladies and gentlemen. It is my privilege and honor to summarize the achievements of Dr. Talbot Waterman, selected to receive the Jerlov Award tonight.

Dr. Waterman began his journey into fields of comparative physiology and optical oceanography at Harvard University in 1931. Inspired by the lectures of G.H. Parker on the compound eye structure of crustaceans, Tal soon began his own investigations on photoreceptor structure.

Tal's interest in the biological significance of natural polarization led him to test the effects of e-vector orientation on the electrical response of crayfish eyes and, in a 1950 *Science* paper, he presented the results of polarization sensitivity in the horseshoe crab. The positive results of those studies caused him to wonder whether other aquatic animals, even in the deep sea, were exposed to naturally polarized light and, if so, whether they too could sense and utilize such information for spatial orientation.

Tal became involved in summer research projects at the Bermuda Biological Station and began investigating the details of underwater polarization while snorkeling and SCUBA diving. His first in situ observations incorporated a polarizing ring sight developed during World War II. Though a crude device compared to modern-day standards, it allowed him to establish for the first time reasonable estimates of the degree of underwater polarization.

In the mid-1960s, Tal began establishing the physiological explanations for polarization sensitivity. He showed that spider crabs possessed two populations of light receptor cells—one sensitive to horizontal and the other to vertical e-vector orientation, and hypothesized that it was the precisely oriented microvilli and visual pigment molecules that were responsible for dichroism and the resulting signal response. This hypothesis was later confirmed based on microspectrophotometric studies and microelectrode recordings made inside single retinular cells in the crayfish eye. Subsequently, Tal and collaborators demonstrated polarization sensitivity in goldfish, a result that was recently confirmed in studies by other researchers.

ABOVE. Nils Gunnar Jerlov and his wife, Elvi. RIGHT. Alexandre Ivanoff. *Photos by Talbot Waterman*

I met first Dr. Waterman 12 years ago during the Ocean Optics Conference in Halifax, where he presented an invited lecture about life in the ocean twilight zone. His discussion about counter-illumination and predator/prey relationships thoroughly captivated the audience, demonstrating that the discipline that we call "ocean optics" is rich beyond the traditional pursuits of radiative transfer theory, ocean color, and the relationship between IOPs and AOPs. Tal's pioneering contributions to the body of knowledge regarding underwater polarization, and polarotaxis and phototaxis in aquatic animals forms the foundation of our understanding of these phenomena. His work continues to inspire new generations of researchers. It is fitting, therefore, that Dr. Waterman receive the Jerlov Award in recognition for his many distinguished contributions to the field of ocean optics.

ACCEPTANCE BY DR. TALBOT WATERMAN

Presentation of the Jerlov Award to Talbot Waterman. Left to right: Rick Spinrad, Talbot Waterman, Steve Ackleson, and Paula Bontempi. *Photo by Foto Pastrengo*

All of us experience substantial ups and downs in our personal and professional lives. My receipt of this 2008 Jerlov Award is really a peak for me both as a welcome personal honor and professional recognition. This euphoric state is lifted even higher by the fact that Nils Jerlov and I collaborated oceanographically on three main projects. Also, we became good friends over the course of more than 30 years beginning in the mid-1950s. For your interest, I would like to recount briefly how I became enamored of underwater polarized light and the results of that strong attraction.

To begin with, I was born, auspiciously, a Waterman. Much later, after a long interruption of my graduate career by World War II, I was taken on in 1946 as an Instructor in Zoology at Yale. Soon after, Karl von Frisch gave a department seminar on the honey bee dance language and how it depended on the polarized light patterns of the clear blue sky for short-range navigation. Somehow, this stimulus merged with my wartime experiences with radar navigation as well as a number of relevant earlier research projects in the laboratory and on board ship. In turn, this raised a big question in my mind. Why wasn't underwater polarization an important element in aquatic visual behavior?

To explore this question, a convenient polarimeter and a suitable marine lab at which to use it were necessary. Because I had as a graduate student become familiar with its oceanic islands environment, I chose the Bermuda Biological Station (recently rechristened as the Bermuda Institute for Ocean Science) as the place to look for polarization. In the first underwater observations, a hand-held "Waterman" interference polarimeter was used to see the patterns. Excitingly, the data showed that substantial partial linear polarization occurred everywhere in sunlit water at least to 20-m depth. The polarization patterns produced in situ depended on the underwater position of the sun's water-surface refracted direction and the observer's line of sight. The e-vector orientation and apparently the degree of polarization vary accordingly. To extend the depth of visual observations, photographs of such interference polarization images were made at 200-m depth off Barbados. They showed that considerable sun-influenced polarization was still present. Hence, these light patterns are not weak, superficial, or mostly fixed over time.

These early data proved that underwater polarization deserved an optically more sophisticated investigation in collaboration with underwater optics experts. In particular, these experts were needed for the design and effective use of appropriate polarimeters. During the second summer in Bermuda, SCUBA divers used an instrument designed and built by Bruce Billings to measure both the degree of polarization and e-vector orientation in horizontal lines of sight. The results revealed that at modest depths, the optical patterns were those expected of Rayleigh-type light scattering. In 1957, still another polarimeter designed and built by Alexandre Ivanoff provided horizontal scanning polarization data of several kinds. Importantly, in measurements in clear, deep ocean water, the patterns of polarization changed rather rapidly at about 50 m. Yet, sun-related differences persisted at our cable limit of about 120 m. During the summer of 1958, Nils Jerlov joined us for new measurements. Most interesting were those taken with a new beam polarimeter (provided by Ivanoff). The data indicated that the degree of inherent polarization was high (about 80%) and nearly the same from near-surface levels to nearly 240 m, another cable limit. Hence, path length through the water must be important in sunlight deep penetration.

The next year, Jerlov designed and built a more versatile polarimeter for a joint optics and zooplankton study down to 1200 m in the eastern Atlantic near Madeira. But, the polarimeter was accidentally lost at sea on its first lowering and personnel problems blocked proper analysis of the plankton catches. The only subsequent substantial in situ polarization measurements were made about a decade later by Bo Lundgren.