The Neglected Contributions of William Beebe to the Natural History of the Deep–Sea

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ICES Journal of Marine Science (2020), doi:10.1093/icesjms/fsaa053

Review Article

The Neglected Contributions of William Beebe to the Natural History of the Deep-Sea

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Received 26 January 2020; revised 24 February 2020; accepted 13 February 2020

William Beebe (1877-1962) was a very popular 20th century naturalist and an early proponent of studying all organisms in a habitat. Beebe's deep-sea work began with his *Arcturus* Oceanographic Expedition in 1925 with sampling closely modeled on the *Michael Sars* Deep-Sea Expedition. Dissatisfied with ship-based sampling of stations for a few days at best, he established a field laboratory in Bermuda to do intensive deep-water sampling. From 1929-1934, plankton net tows were carried out at the same site, over several months each year, totaling over 1,500 net tows in deep waters. Here the sampling efforts and results are reviewed from both the *Arcturus* expedition and the Bermuda station. Study of the deep sea samples yielded 43 scientific articles, published from 1926-1952, on a large variety of taxa. Beebe is still a popular figure connected in the public view with deep-sea exploration from his famous Bathysphere dives at the Bermuda site. However, his name rarely, if ever, appears in academic reviews of deep-sea biology or deep-sea expeditions. This paper is an attempt to draw attention to Beebe's considerable scientific deep-sea work and provide some speculation as to why his contributions might be neglected.

Keywords: deep-sea, deep-sea fish, history of oceanography

Introduction to William Beebe

Charles William Beebe, generally known as William Beebe, had a long and unusually full and productive life as attested to in book-length biographies of Beebe (Gould 2004; Welker 1975), and the detailed bibliography "William Beebe, an Annotated Bibliography" (Berra 1977). There is also a plethora of short biographies in popular books, (e.g., Ballard & Hively 2017; Cullen 2006, Morell 2019). However, the most authoritative account of Beebe's life is that of Gould (2004) as it is based on original source material, unavailable before the death of Beebe's second wife. The following brief account of Beebe's life, situating his deep-sea studies, is based on Gould's 2004 biography.

Beebe, from a young age, was drawn to natural history. By age 14 he was an avid collector of birds and their eggs, insects, shells and minerals. Age at 16, his last journal entry for the year 1893 was "To be a Naturalist is better than to be a King" and by age 17 he had his first article, on a bird, published in "Harper's Young People" (Beebe 1895). An exceptional student in high school, he was given advance placement at Columbia University, skipping the first year. At Columbia, Henry Osborn who would be a large figure in his life supervised him. Osborn was not only Chair of the Zoology Department, but also the president of the American Museum of Natural History as well as the head of the New York Zoological Society. Beebe split his days between lectures and labs at the University and days at the American Museum of Natural History. In autumn 1899, Osborne told Beebe that he had completed all the requirements for his degree in Zoology except for a math class he had been avoiding. Osborn gave a Beebe a choice between staying in school for another year to complete his missing class or he could go with Osborn to the new, still under construction, Bronx Zoo of the Zoological Society and apply for a job as an assistant curator of birds. The choice was quickly made. Beebe would spend his entire working life with the New York Zoological Society (now the Wildlife Conservation Society) and never would earn a college degree.

Beebe's career can be roughly divided into 4 periods. The *first period* of 1899 to 1908 consists of his early years as curator of birds. In 1908, with the aid of Osborn, he won a status similar to that of the staff scientists at the American Museum of Natural History with 2 months salary paid to conduct research. Thus, the *second period*, 1908-1916, was the start of long expeditions, primarily to South American jungles in this first period but also a year spent investigating pheasants worldwide. He later produced a monumental multi-volume monograph on pheasants regarded as one of the "vital books of science" (Bay 1948). By 1916 he secured funding for the establishment of a field station in British Guiana, a facility where intensive study of tropical life could be conducted over long periods of time. The *third period* of 1916-1924 then was primarily tropical fauna studies. During this period, Beebe's position evolved from Curator to Head of the Department of Tropical Research. Work conducted during this period has lead to Beebe's being declared the "Father of Neotropical Ecology" (Mendyk 2014). It also included an expedition to the Galapagos, financed by a wealthy zoo supporter; the expedition produced a best seller "Galapagos: World's End" (Beebe 1924). During this period he was awarded the Daniel Giraud Elliott Medal of National Academy of Science, an award for remarkable achievements in zoology. Later recipients of the prestigious award were G. Evelyn Hutchinson, Ernst Mayr, and Henry Bigelow. The *fourth period* of 1925-1939, is that of Beebe's field studies of marine fauna, the focus of this article. It begins with the oceanographic voyage of the *Arcturus* and ended with the approach of World War 2. The *Arcturus* voyage inspired Beebe to establish a field station devoted to deep-sea work. The Nonsuch field station in Bermuda was founded and intensive deep-sea studies were carried out from 1929 to 1935. It was also the site of the famous Bathysphere dives. These dives, one of which was broadcast on radio live, were celebrated in *Science* (Anon. 1930a) and *Nature* (Anon. 1930b), detailed in his book "Half Mile Down" (Beebe 1934), reported by Beebe in Science (Beebe 1932c), and in lavish articles in the National Geographic Magazine. The activities of this period, exclusive of the bathysphere dives, are dealt with in detail here in this article. The *fifth and last period*, from 1945 to his death in 1962, was a return to the studies of tropical fauna from but from another field station, one he installed in Venezuela.

Beebe's Deep-Sea Work is Often Over-Looked

Beebe was immensely popular in his time (Gould 2004) and still in today's popular books is credited not only for drawing attention to the deep-sea with the

Bathysphere dives, but is also credited with being a pioneer ecologist because of his systematic sampling of the deep-sea (e.g., Ballard & Hively 2017; Cullen 2006, Morell 2019). In many academic works however, the considerable results (which will be shown below) from the *Arcturus* Expedition and the Nonsuch sampling are simply not mentioned. For example, in Mills' book "*History of Biological Oceanography*" (Mills 1989), one finds no mention, nor in Hedgpeth's article "History of Pacific Oceanography" (Hedgpeth 1974). Similarly, in their review of the oceanography of the Eastern Tropical Pacific, Fielder & Lavin (2006) mention only Beebe's popular books with no mention of the research reports from the *Arcturus* Oceanographic Expedition. Likewise, a history of deep-sea biology (Mills 1983), a history of deep-sea expeditions (Wüst 1964), and deep-sea plankton studies (Kimor 2002), contain no mention of Beebe's work, nor that of his colleagues. Even the general comprehensive book on deep-sea organisms of Marshall (Marshall 1979), cites but one of Beebe's many articles on deep-sea fish.

Histories of marine ecology give a nod to Beebe but not the deep-sea work. Riedl's review of the development of marine ecology (Riedl 1980) placed Beebe's work in the stage "Before its time" but only in reference to revealing 'the splendors of tropical shallow seas'. Likewise, Egerton's installment of his "History of Ecological Sciences: Marine Ecology featuring Beebe, Bigelow, Ricketts", while placing Beebe in admirable company, makes no mention of Beebe's deep-sea work (Egerton 2016). Ironically perhaps, Beebe while largely if not completely unknown to biological oceanographers, is recognized by physical oceanographers for his early observation of El Nino event during *Arcturus* Expedition (Wooster 1980; Quin et al. 1987).

What Follows

Here the sampling and results, first from Beebe's *Arcturus* Oceanographic Expedition, and then from the Nonsuch studies, are described in an effort to draw attention to a remarkable body of work. Study of the deep-sea samples yielded 41 scientific articles by Beebe and his colleagues on a large variety of taxa. Beebe's famous Bathysphere dives have been dealt with at length (e.g., Matsen 2005) and will only be considered here in relation to Beebe's scientific reputation. Finally, possible reasons for the fact that such a considerable body of work is often unremarked are considered.

Inspired by the *Michael Sars* North Atlantic Deep-Sea Expedition: The Arcturus Oceanographic Expedition

According to Gould (2004), Beebe's interest in the deep-sea can be traced to his reading about the *Michael Sars* expedition. She describes Beebe as having nearly memorized Murray and Hjort's "Depths of the Ocean" (Murray & Hjort 1912). Indeed, a *Michael Sars* inspiration can be seen clearly in comparing the illustration of the pelagic sampling from the "Depths of the Ocean" (Fig 1, from pg 49) with that of the *Arcturus* from Tee-Van (1926, pg. 70) shown in the top panel of Figure 2. Furthermore, in describing the equipment and re-fitting of the vessel, Tee-Van (1926) stated that they were indebted for much information, both before and during the expedition, to published accounts of other expeditions but especially to that of Murray and Hjort's "Depths of the Ocean". In 1925, few results were available from deep-sea expeditions other than *Michael Sars* and results from it were still emerging. The results of Danish "Great Atlantic Expedition of the *Dana* of 1921-1922" were as yet largely unpublished in 1925 (see Poulsen 2016).

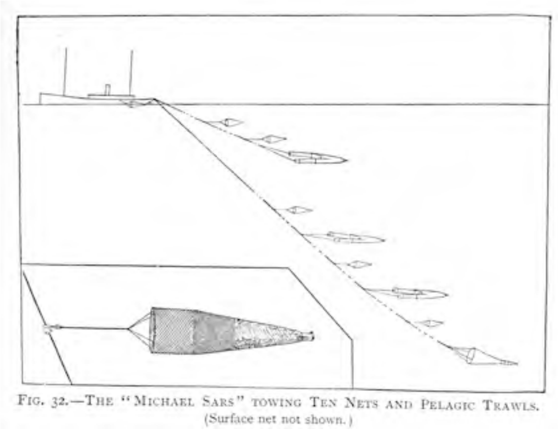

Fig. 1 *Michael Sars* pelagic sampling sampling from Murray & Hort (1912).

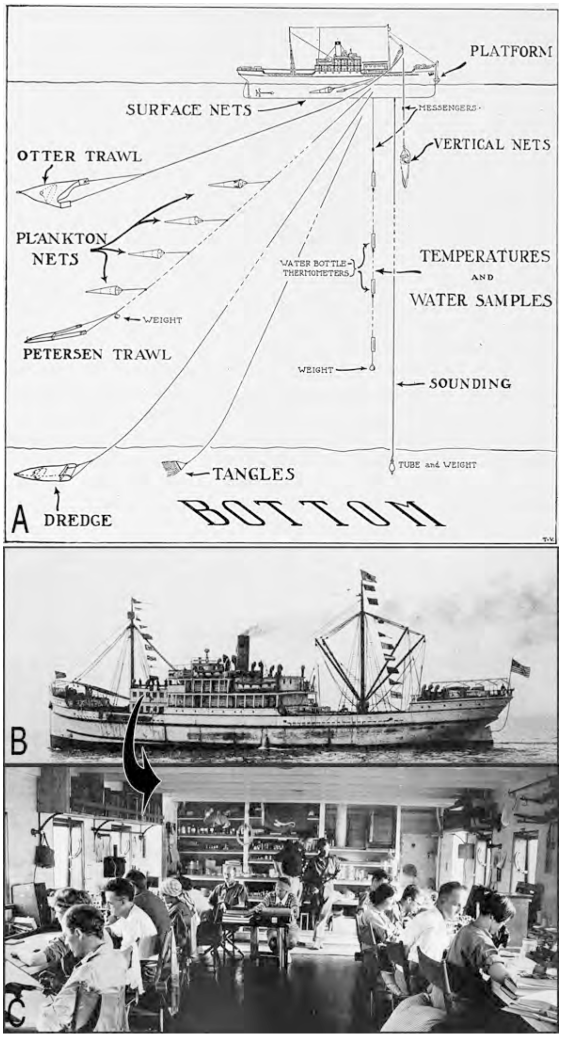

Fig. 2. The *Arcturus* Oceanographic Expedition from Tee-Van 1926: **A**. the sampling equipment, **B.** the vessel, a sturdy 82 m coal-burning steam-ship built 6 years earlier as trawler to work the Alaskan coast, re-fitted and re-named for the expedition **C.** The dry lab, location on the ship shown by the arrow, on the deck above the wet lab. Beebe is seated at the desk in the rear, facing the camera.

The *Arcturus*, re-named for star of the mariners, was given to the New York Zoological society for the expedition by a wealthy patron, expressly for the expedition. The re-fitting and financial support for the expedition came from other patrons of the Zoological Society. The ship was modified to increase its range and suitability for deep-sea oceanographic work. The modifications included increasing coal storage and refrigerator space, adding a wet and dry lab, and installing custom-made trawling and dredging winches holding 8 Km of steel cable (Tee-Van 1926). The objectives of the expedition were simply stated as "investigating the Sargasso Sea and the Humboldt Current" (Beebe 1925a). The Sargasso Sea at the time was an area of great interest as it had been recently identified as the breeding site of the eel, previously a major mystery (Poulsen 2016), and in popular legend, the Sargasso Sea was a sea of ghost ships (e.g., Levick 1925). The second goal of investigating the fauna of the Humboldt Current, was quite possibly simply an excuse to return to the Galapagos.

The *Arcturus* left New York on February 11 1925 and returned to New York on July 30 1925. The cruise track of is shown in Figure 3. The first sampling of 22 Sargasso Sea stations began February 23 and ended on March 13. The *Arcturus* passed through the Panama Canal and on March 27 began the sampling of 38 stations along a cruise track from Panama to the Galapagos then the Cocos Islands and back through the Panama Canal to the Atlantic in late June. They failed to find the Humboldt Current, and Beebe's observations, reported in *Science* (Beebe 1926a), have been taken as one of the first observation of an El Nino event (Wooster 1980; Quin et al. 1987). On the return leg, 20 more stations were sampled between the Atlantic coast of San Salvador and the homeport of New York. The station locations and summary of ship operations is given in Beebe 1926b. A total of 251 samples were acquired from deep water (≥ 300 m depth) during the cruise, pooling all net, trawl, and dredge sampling.

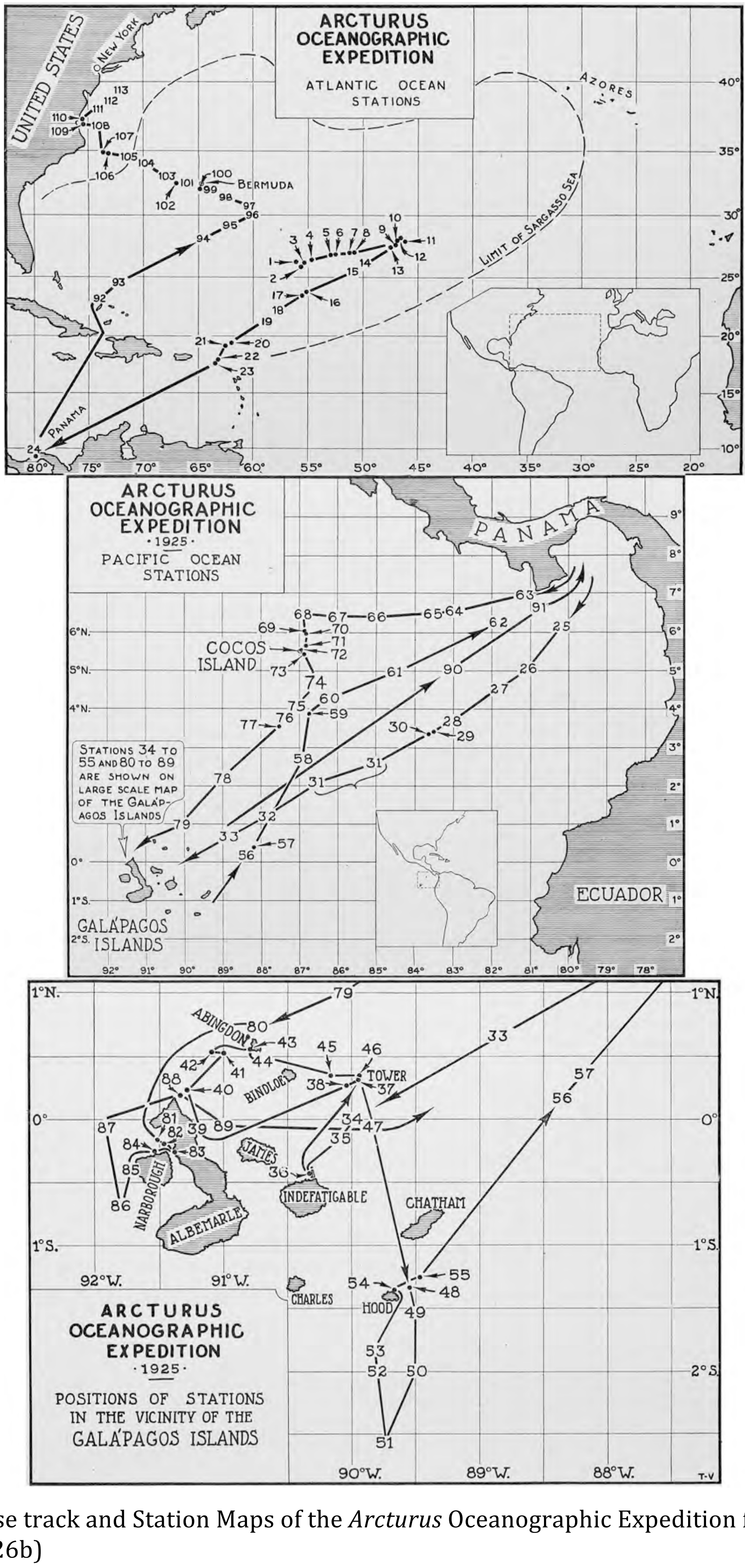

Fig 3. Cruise track and Station Maps of the *Arcturus* Oceanographic Expedition from Beebe (1926b)

The expedition was closely followed in the press, as no previous oceanographic expedition had been before, nor quite possibly has ever since been so closely followed in the popular press. For example, the New York Times published 35 articles on the expedition from Feb. 6 1925 to Aug. 30 1925, thus averaging over one article per week on the *Arcturus* Expedition. Many of the articles were simply transcripts of Beebe's periodically radioed reports of expedition activities. The coverage in the New York Times though also included multi-page articles with illustrations as well as several front-page articles (e.g., Anon. 1925). Beebe's popular book on the expedition, "The *Arcturus* Adventure" (Beebe 1926c) appeared in May 1926 and was glowingly reviewed in the New York Times (Duffus 1926).

Sample material gathered during the expedition was dispatched to renowned experts scattered around the globe. The scientific results took some time to appear, as is usually the case. The 10 publications resulting from the *Arcturus* Oceanographic Expedition are given in Table One. The scientific output of the *Arcturus* Expedition obviously was not of the same magnitude as large-scale expeditions such as the *Michael Sars* in 1910 and the *Dana* 1921-1922 or the expedition shortly after the *Arcturus*, the 1929 Cruise VII of the *Carnegie* (also under-appreciated, see Dolan 2011). However, the scientific results of the *Arcturus*, while perhaps not considerable compared to other expeditions, were not negligible either. Admittedly, none of the *Arcturus* reports can be called "highly-cited", but some are relatively well-cited (see Table 1) and continue to be cited in recent years such as Bigelow (1928, 1931), Robson (1948) and Treadwell (1928).

TABLE ONE
Arcturus Oceanographic Expedition Publications

Taxa	Reference	# cites
Siphonophores	Bigelow 1931	14
Medusa	Bigelow 1928	10
Echinoderms	Fisher 1928	6
Polychaetes	Treadwell 1928	21
Cephalopods	Robson 1948	12
Fish	Beebe 1926a	44
Fish	Beebe 1926d	0
Fish	Trotter 1926	26
Fish	Gregory 1928	12
Fish	Nigrelli 1947	7

The Nonsuch Studies

Beebe experienced frustration on the *Arcturus* with the very limited number of samples that can be gathered at a given station from a ship in open waters. His previous experience in sampling tropical terrestrial systems from field stations had involved intensive sampling of small areas over long periods of time. One of his best-known works is "Studies of a tropical jungle: one quarter of a square mile of jungle" (Gould 2004), the result of investigations over several seasons (Beebe 1925b). Beebe stated this his idea to establish a shore laboratory from which daily deep-sea sampling could be carried occurred to him on the return leg of the *Arcturus* Expedition, sampling at Station 100 near Bermuda (Beebe 1931a), the genesis then of the Nonsuch laboratory in Bermuda, established 4 years later.

Through his considerable social connections (see Kroll 1970), he obtained the use of a former hospital and quarantine facility on Nonsuch Island in Bermuda and the use, at cost, of a 28 m tugboat, the *Gladisfen*. Deep water, 1000 fathoms (or 1828 m), was only 8 km offshore. The winches and sounding machine from the *Arcturus* were brought from New York, mounted on the *Gladisfen*, and sampling began in March 13 1929 and in that first sampling season, lasted until Oct 22 1929. The sampling was always performed at the same site and involved towing nets across a transect of about 13 Km. Thus, the basic strategy was to use long horizontal net tows. The net-tow catches were roughly sorted on board, especially to isolate living organisms, and transported back to the Nonsuch laboratory for immediate intensive sorting and examination. Figure 4 shows the sampling site and method schematically, the *Gladisfen*, and the Nonsuch laboratory.

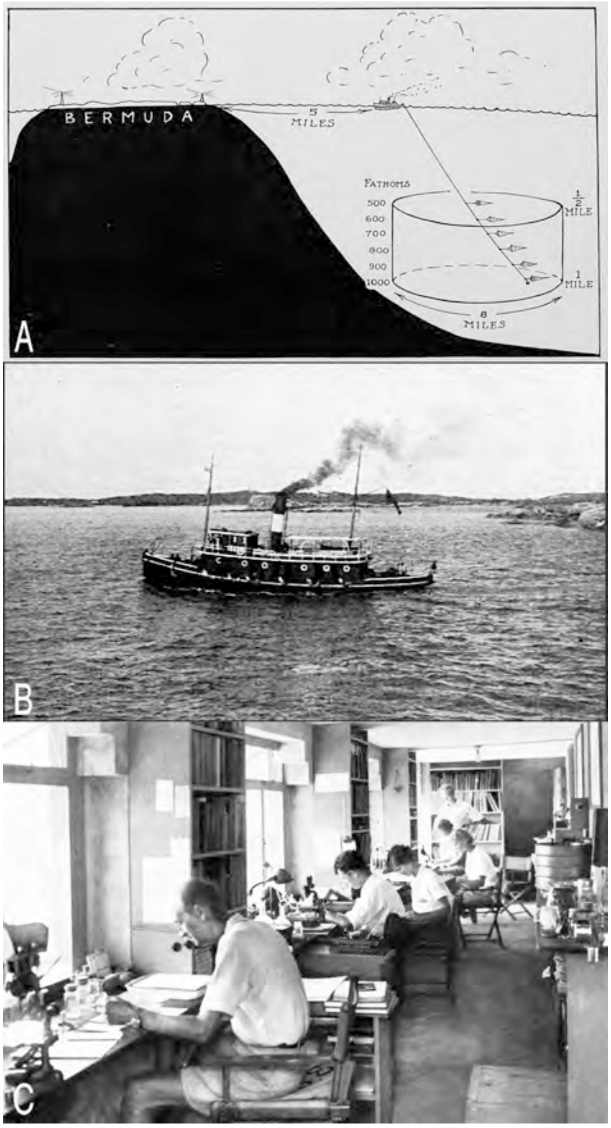

Figure 4. The Nonsuch sampling, vessel and laboratory: **A**. the sampling scheme, **B.** the *Gladisfen*, a 28 m tugboat **C.** The laboratory on Nonsuch Island. From Beebe 1931a. Beebe is seated at the first desk, far left.

Usually used at all depths were 1 meter diameter *Sars* Nets, mesh size of 366 µm, without any closing apparatus, and a glass jar protected with padding, for the cod-end. The first net set, the deepest net (see scheme in Fig. 4.A.), fished for the longest time period and the last, surface layer net, fished the shortest time along the transect. Beebe gave a summary of a 'typical' deep-sea net tow at 1463 m (Beebe 1936a), summarized in Table Two. In the example he gave, the catch included about 150 fish of 11 species for just one of the 6 deep-water nets towed that day. Figure 5 shows the number of plankton net tows carried by month from the 1929 sampling campaign to the 1935 sampling campaign. A total of over 1,500 net tows were made at the Nonsuch sampling site.

Table Two.

Typical Deep Water Nonsuch Net Tow Catch

From Beebe (1936a), the example from a tow at 800 fathoms (1463 m) depth on July 5, 1930. The net was the usual one meter diameter Sars net, mesh size 366 µm, towed for 4 hours (time from Beebe 1931b) on a transect of 12.9 km distance yielding a putative volume sampled of 12,875 m3. The tintinnid listed as Parafavella, a genus of boreal sea tintinnids, was likely Parundella acuta as found by Wailes later in the Nonsuch samples (Wailes 1936).

Invertebrates

1) Copepods, a dozen or more species, mostly calanoids, with also *Corycaeus*, *Oithona*, etc.
2) Schizopods, chiefly small species of *Euphausia*, with a dozen others belonging to two or three genera.
3) Shrimps, one specimen, *aff. Pandalus danae*.
4) Ostracods, a few of one or two species.
5) Amphipods, few and small, a dozen individuals of four or five species.
6) Sagitta, apparently two or three species.
7) Polychaetes, one *Tomopteris septentrionale*.
8) Siphonophores, *Diphys truncata*.
9) Sponges, fair number of spicules of various kinds.
10) Radiolaria, large numbers of portions of a hexagonal framework and a few small, conical specimens mostly incomplete ; numbers of perforated spherical species and Astrophaeroidea.
11) Diatoms: One each *Asteromphalus heptactis*, *Melosira moniliformis*, *Coscinodiscus*.
12) Tintinnoinea, one *Tintinnopsis cylindrica* and one *Parafavella* near *P. acuta*.
13) Foraminifera, few, of two or three species.

Fish

1) Fish larvae: 3 specimens
- one of a deep-sea species, with very large lower jaw and black spots on sides.

2) Fish, adolescent and adult:
- *Bregmaceros macclellandii*, 45 mm (1 specimen)
- *Cyclothone microdon* (117 specimens)
- *Cyclothone pallida* (1 specimen)
- *Cyclothone signata* (14 specimens)
- *Lampadena chavesi* (1 specimen)
- *Lampanyctus warmingi*, 11 to 21 mm (6 specimens)
- *Lestidium intermedium*, 87 mm (1 specimen)
- *Myctophum benoiti*, 11 to 12 mm (3 specimens)
- *Myctophum laternatum*, 12 mm (13 specimens)
- *Omosudis lowi*, 11 to 38 mm (2 specimens)
- *Stomias ferox*, 80 mm. (1 specimen)

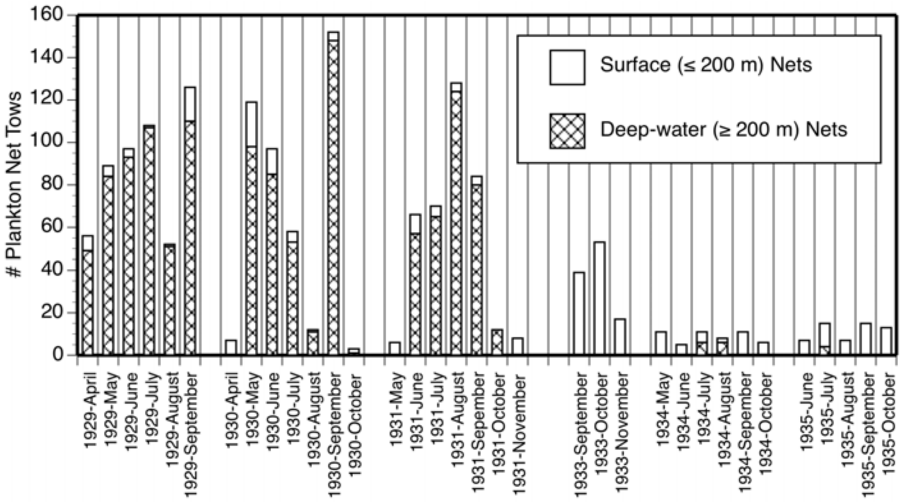

Figure 5. The number plankton net tows performed by month from 1929 to 1935, separated into surface layer and deep-water sampling. No net sampling was done in the 1932 season dedicated to Bathysphere dives.

Although Beebe never cited Haeckel, he followed his dictum concerning the importance of sampling the same site over a period of years (Haeckel 1891). The amount of deep-sea material collected over relatively long periods of time at different depths at the same location was unprecedented at that time and, to my knowledge, has never been repeated. Regular deep-sea sampling has, in recent years, been conducted at other sites such as the Bermuda Atlantic Time Series Station and off Los Angeles at the San Pedro Ocean Time-Series Station but at only monthly, not daily, intervals and typically focused on microbial populations (e.g. Kim et al. 2013; Vergin et al. 2013). Thus the data gathered by Beebe is difficult to compare with any contemporary sampling, hindering possible assessment of long-term changes in the deep-sea ecosystem off Bermuda.

The unique intensive sampling performed allowed Beebe and his colleagues to work out details of the development and ecology of individual forms and their inter-relationships. An example is the working out the life-history of a deep-sea fish, characterized by morphologically odd developmental stages, and sexual dimorphism: *Idiacanthus fasciola*. Below is a very brief summary of Beebe's short report in *Science* (Beebe 1933a) and his detailed report of 94 pages (1933b) in *Zoologica*.

The odd stalk-eyed deep-sea fish shown in the top panel of Figure 6 was previously thought to be the species *Stylophthalmus paradoxa* Brauer 1902. It was iconic of the odd morphologies of deep-sea forms, for example, decorating the cover of Chun's book on the *Valdivia* German Deep-Sea Expedition (Chun 1903). The middle panel of Figure 6 shows the intermediate forms Beebe found allowing him to identify putative *S. paradoxa* as actually the larval form of *Idiacanthus fasciola*. His brief report in *Science* stated that the stalk-eyed forms were mostly found in samples from above 200 m depth while post-larval forms were found in samples from about 750-1500 m depth (Beebe 1933a). In his detailed report (Beebe 1933b) he also showed that forms thought to be larvae of *Idiacanthus fasciola* (the small forms in the bottom panel of Figure 6), were non-feeding adult males with enlarged livers and degenerate digestive tracts. The remarkable sexual dimorphism discovered by Beebe is among the most extreme known among fish (Fairbairn 2013).

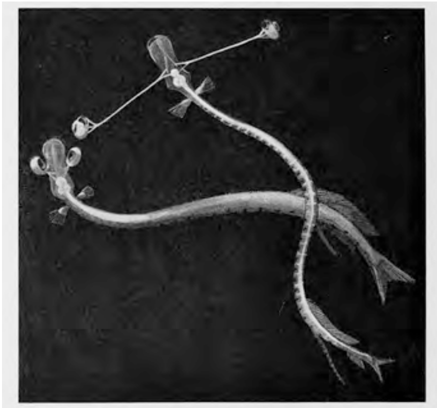

Fig. 51. Stalk-eyed larva and post-larva. (From a painting by Else Bostelmann).

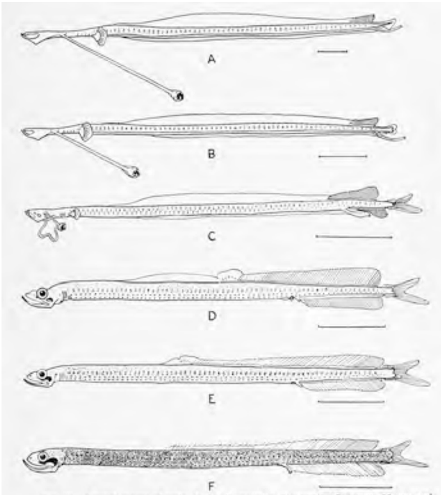

Fig. 50. Growth stages of male: A and B, sexually indeterminable larvae, 16 mm and 25 mm, respectively; C, male post-larva, 40 mm; D, male adolescent, 35 mm; E, male transitional adolescent, 35 mm; F, male adult, 38 mm. The relative size of the specimens is indicated by the straight lines. For ease in comparison the larvae of Fig. 49 (A and B) are reproduced in this figure also.

Fig. 47. The Gleaming-tailed Sea Dragon. *Idiacanthus fasciola* Peters. Nearly adult females (length, about 130 mm.) and adult males. Originally intended to illustrate post-larvae and adults, before their life histories were understood. (From a painting by Else Bostelmann). (*Frontispiece*).

Figure 6. Life-history stages and sexual dimorphism in *Idiacanthus fasciola*. Top panel shows the stalk-eyed larvae previously thought to be another species. Middle panel shows developmental stages of the male. Bottom panel shows the relatively small transparent males and dark females. All figures from Beebe 1933b**.**

Trophic relationships were also studied with the Nonsuch samples. For example, the large amount of data gathered on the depth distribution of a variety of taxa in the deep layers allowed diagnosis of where predators from surface layers, for example tuna, fed, and based on the gut contents of the tuna prey, what prey the tuna were both directly and indirectly consuming. Beebe (1936b) analysed the gut contents of 58 black-finned tuna to reconstruct, in part, tuna food webs as the gut contents of the prey ingested by the tune were identified. Thus, not only was the tuna prey revealed, but also the food of the tuna prey were revealed. Figure 7 shows the gut contents of a tuna specimen and the partially re-constituted food web of the individual.

Figure 7. Gut contents of Black-Finned Tuna from Bermuda (upper panel) and a re-constituted food web from prey items recognizable in the guts of the tuna's prey (lower panel, from Beebe 1936b.

The 33 publications resulting from analysis of Nonsuch samples are given in Table Three. While a large variety of taxa were studied, most of the publications were on deep-sea fish and authored by Beebe. Many of Beebe's studies of fish included ecological information such as gut contents, observations of parasites, seasonal occurrences, frequencies of occurrences, as well as occurrences in the gut tract of other species, thus identifying the fish's "enemies".

TABLE THREE

Publications from Nonsuch Sampling

Taxa	Reference	# Cites		Taxa	Reference	# Cites
Tininnids	Wailes 1936	1		Fish	Beebe 1929b	1
Copepods	Wilson 1936	5		Fish	Beebe 1933c	6
Euphausids	Tattersall 1936	2		Fish	Beebe 1933a	0
Siphonophores	Totton 1936	8		Fish	Beebe 1933c	6
Medusa	Bigelow 1938	22		Fish	Beebe 1933d	6
Shrimp	Chace 1940	62		Fish	Beebe 1933e	1
Polychaetes	Berleley 1936	0		Fish	Beebe 1933f	9
Polychaetes	Treadwell 1941	23		Fish	Beebe 1933g	2
Amphipods	Shoemaker 1945	44		Fish	Beebe 1935a	11
Ribbon Worms	Coe 1945	4		Fish	Beebe 1935b	4
Cephalopods	Pickford 1950	5		Fish	Beebe & Crane 1936	12
Fish	Beebe 1932a	22		Fish	Beebe 1937	25
Fish	Beebe 1932b	0		Fish	Beebe & Crane 1937a	2
Fish	Beebe 1933b	0		Fish	Beebe Crane 1937b	9
Fish	Beebe & Vander Pyl 1944	35		Fish	Beebe & Crane 1939	27
Fish	Beebe & Tee Van 1932	3		Fish	Harry 1951	13
Fish	Beebe 1929a	4		Fish	Harry 1952	6

Deep-Sea Fish Descriptions

Beebe described over 80 species of fish (Berra 1977). According to the WoRMS database, at present, the descriptions of 37 accepted species are credited to Beebe and colleagues (WoRMS 2020). Of the 37 accepted species described by Beebe and colleagues, 16 are deep-sea forms (Table 4). In addition to those 16 species, 2 other deep-sea species, presently accepted as valid, were described by Harry (1952) from Nonsuch samples and named after Beebe's colleagues: *Cetomimus teevani*, and *Cetomimus craneae* for John Tee-Van and Jocelyn Crane. Thus 18 species of deep-Sea fish were first described from Beebe's deep-water samples.

TABLE FOUR

Deep-Sea Fish Species Descriptions Attributed to Beebe

Original name	Accepted name	Expedition	Sampling Depth	Referrence
Diabolidium arcturi Beebe, 1926	Linophryne *arcturi* Beebe 1926	Arcturus 1925	915	Beebe 1926d
Linophryne brevibarbata Beebe, 1932	*Linophryne brevibarbata* Beebe 1932	Bermuda 1929	1647	Beebe 1932a
Saccopharynx harrisoni Beebe 1932	*Saccopharynx harrisoni* Beebe 1932	Bermuda 1931	1647	Beebe 1932 a
Dolopichthys gladisfenae Beebe, 1932	*Spiniphryne gladisfenae* Beebe, 1932	Bermuda 1930	1281	Beebe 1932a
Chaenophryne draco Beebe 1932	*Chaenophryne draco* Beebe 1932	Bermuda 1931	1098	Beebe 1932a
Eustomias schiffi Beebe 1932	*Eustomias schiffi* Beebe 1932	Bermuda 1930	1098	Beebe 1932a
Photichthys nonsuchae Beebe, 1932	*Woodsia nonsuchae* Beebe 1932	Bermuda 1929	1098	Beebe 1932a
Leptostomias bermudensis Beebe 1932	*Leptostomias bermudensis* Beebe 1932	Bermuda 1931	915	Beebe 1932a
Dolichopteryx binocularis Beebe, 1932	*Dolichopteroides binocularis* Beebe 1932	Bermuda 1931	732	Beebe 1932a
Eustomias satterleei Beebe 1933	*Eustomias satterleei* Beebe 1933	Bermuda 1929	1830	Beebe 1932a
Bathophilus altipinnis Beebe 1933	*Bathophilus altipinnis* Beebe 1933	Bermuda 1929	1464	Beebe 1933c
Photostylus pycnopterus Beebe 1933	*Photostylus pycnopterus* Beebe 1933	Bermuda 1929	1464	Beebe 1933c
Psammobatus spinosissimus Beebe & Tee-Van, 1941	*Bathyraja spinosissima* Beebe & Tee-Van 1941	Arcturus 1925	1400	Beebe & Tee-Van 1941
Gigantactis perlatus Beebe & Crane 1947	*Gigantactis perlatus* Beebe & Crane 1947	Zaca 1938	915	Beebe & Crane 1947
Himantolophus azurlucens Beebe & Crane 1947	*Himantolophus azurlucens* Beebe & Crane 1947	Zaca 1938	915	Beebe & Crane 1947
Linophryne quinqueramosa Beebe & Crane 1947	*Linophryne quinqueramosa* Beebe & Crane 1947	Zaca 1938	915	Beebe & Crane 1947

Why Are Beebe's Contributions of the Natural History of the Deep-Sea Ignored?

According to Occam's Razor, for any given question, the simplest explanation is the most likely to be true. The simplest explanation for the neglect of Beebe's contributions is that the contributions are of no consequence and so need not be acknowledged. However, judging scientific contributions as inconsequential or considerable is obviously subjective. There are no clear means to estimate the present value of past studies other than the obvious landmark works such as Darwin's On The *Origin of the Species* (Darwin 1859). The quantity and originality of Beebe's contributions have been described here so the position taken is not ***should*** Beebe's contributions to our knowledge of deep-sea be recognized, but rather ***why are they not***?

While there are possibly many reasons, below will be considered three major, but not mutually exclusive, reasons why Beebe's contributions, consciously or unconsciously, may have been slighted. The first is that the quasi-totality of his deep-sea scientific work appeared in one journal possibly lacking a reputation of rigor, *Zoologica*. The second is that Beebe's scientific reputation suffered from his having described 4 deep-sea fish species from visual observations during the Bathysphere dives. The third is that Beebe was an early victim of the "Sagan Effect" wherein media-driven fame negatively effects scientific reputation.

The journal *Zoologica* was created as an outlet for the scientific work conducted by those working for the New York Zoological Society or its facilities or collections. According to Matsen (2005, pg 157), *Zoologic*a was "not considered to be in the top ranks of taxonomy because of inconsistencies in their peer review", unfortunately citing no sources for the statement. Thus, there is no evidence other than one undocumented opinion.

The possibility that Beebe's scientific reputation was damaged by his description of 4 deep-sea fishes based solely on visual observations (none of the species are currently recognized) appears in biographies of Beebe (Welker 1975; Gould 2004; Matsen 2005) without, however, any documentary evidence beyond noting the sharp criticism of Beebe's Bathyscape-based descriptions in a review of Beebe's book "Half Mile Down" by the ichthyologist Carl Hubbs in *Copeia* (1935). Notably, Hubbs later cited Beebe's articles on surface and deep-sea fish in *Zoologica* as authoritative (Hubbs & Kampka 1946, Hubbs et al. 1953) suggesting that he did not doubt all of Beebe's work nor that *Zoologica* article were untrustworthy. Other reviews of Half Mile Down appeared in *Nature* (Anon 1935a), the *Quarterly Review of Biology* (Anon. 1935b), the *Geographical Journal* (CMY 1936) and two by the Ichthyologist John Nicolls, one in *Natural History* and the other in the *Saturday Review of Literature* (Nicolls 1935a,b). None of the reviews other than Hubb's contain overt criticism of the description of fish from visual observations only.

The last major possibility to consider is that Beebe was an early victim of the "Sagan Effect". This phenomenon posits that scientists who receive lots of media attention have their scientific work de-valued by the scientific community. It is based on the view that the astronomer Carl Sagan was denied election to the Academy of Science (USA) despite ample qualification because of his status as a media figure (Gwynne 1997). Another well-known scientist, the paleontologist, Stephen Jay Gould, is also thought to have had his scientific reputation suffer from the "Sagan Effect" (Shermer 2002) as he was also a "Celebrity Scientist" (Fahy 2015). The phenomenon may appear odd to us today. In recent years, with outreach efforts often mandated, any stigma associated with media attention is thought to be negligible with media attention actually linked to increases in citation rates (Russo 2010).

As time goes on, any or all the effects considered above should diminish. Knowledge of the relative prestige of *Zoologica*, the unorthodox naming of 4 out of the over 80 fish species, and the amount of media coverage given Beebe, should all decline with time but perhaps not at the same rate. Do any measures of prestige show a temporal change indicating an abrupt shift at some point in time, for example in the late 1930's following the Bathysphere dives? Two metrics were examined simply because data were relatively accessible: the number of marine species named for Beebe from the WoRMS website (WoRMS Editorial Board 2020), searching for marine and freshwater species containing the term 'beebe' and citations per year to Beebe publications using the Web of Science (www.webofknowledge.com, consulted Jan 20, 2020). Cumulative numbers of species named for Beebe with time and total citations to Beebe articles with time are shown in Figure 8.

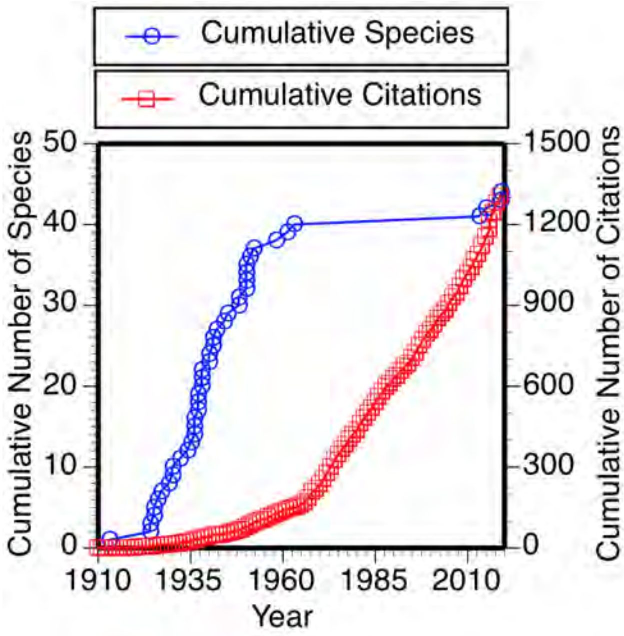

Figure 8. Cumulative number of species named for William Beebe and cumulative number of citations to Beebe's work with time.

Surprisingly, the point in time corresponding to changes in both temporal trends is in the mid 1960's is following Beebe's death (in 1962) and the changes in the two measures show opposite trends. Following Beebe's death, there is an abrupt halt to naming species for Beebe that begins again only in recent years, since 2013. With regard to citations to Beebe articles, there appears to be an increase in citation rates following his death. The opposing temporal trends are very difficult to explain. The paired negative inflections of species naming declining and increase in citation rate increasing may simply reflect a shift in academic activity away from taxonomy and towards an increasing importance of publishing. Regardless though, both metrics show no sign of a shift corresponding with the Bathysphere dives, a source of a great deal of media attention as well as the contentious fish descriptions. In conclusion there lacks clear evidence of any particularly strong reason behind the apparent slighting of Beebe's deep-sea work by the scientific community.

Finally, there are two additional facts that may have contributed to a lack of recognition for Beebe's work by oceanographers. The first, following Anthony

Adler, is an adherence in the history of the marine sciences to what he terms the "great ship narrative" in which developments are linked to large-scale expeditions to the detriment of work done in laboratories and field stations (Adler 2019). Nonsuch was the first, and remains the only, field laboratory devoted to deep-sea research. The second is the fact that, unlike most well-known scientific figures of the 20th century, Beebe did not train any students, nor did his close collaborators in his deep-sea work, John Tee-Van and Jocelyn Crane, as they all were employed by the New York Zoological Society. Following the Nonsuch laboratory days, John Tee-Van moved into administrative posts of the New York Zoological Society, eventually assuming the directorship (Gould 2004) and Jocelyn Crane became a very well-known expert, not on deep-sea life, but on hermit crabs (Yost 1959). One could say then that Beebe had no "academic children" for his deep-sea work, a factor perhaps contributing to a lack of recognition for his deep-sea work.

Conclusion

Here is shown that the contributions of William Beebe to our knowledge of the natural history of the deep-sea are considerable, ranging from the descriptions of many new forms to observations on developmental stages and basic ecologies of many species. The reason (s) behind the fact that his contributions appear to be largely neglected remain unclear. However, hopefully this attempt to shed light on Beebe's contributions will lead to their recognition.

Acknowledgements

Archivists at the Wildlife Conservation Society, Madeleine Thompson and Cassandra Paul kindly provided copies of the N.Y. Zool. Soc. Bulletin. I am indebted to Tim Berra, Ted Pietsch, and Eric Mills who provided valuable information and encouragement. The advice of the anonymous reviewers and handling editor on earlier versions of the manuscript led to significant improvements.

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Handling editor: Bo Poulsen