THE HISTORY OF MARINE RESEARCH IN THE NORTHWESTERN HAWAIIAN ISLANDS: LESSONS FROM THE PAST AND HOPES FOR THE FUTURE

BY

RICHARD W. GRIGG[1]

It is a well-known fact of history that the European discovery of the Hawaiian Islands was by Captain James Cook in 1778, and it is perhaps fair to say that this date marks the beginning of formal scientific discovery in the Hawaiian Archipelago. Of course, it is equally well known that over 1,000 years of natural history had already been accumulated by the Hawaiians.

It is perhaps therefore appropriate that my first lessons in coral-reef ecology were from a very experienced Hawaiian fisherman. His name was Buffalo Keaulana. Buffalo taught me how to spear fish with a three-prong spear, and he taught me that the best fishing grounds were in high relief areas, or fish houses called koas. He also taught me that huge waves were the major force that sculpted Hawaiian coral reefs. Some 15 years later, Dr. Steve Dollar and I documented this in the scientific literature in a series of papers between 1974 and 1982 (Grigg and Maragos, 1974; Dollar, 1982). In the last five years, this fact has been rediscovered by both the Coral Reef Assessment and Monitoring Program (CRAMP) in the Main Hawaiian Islands (MHI) and the Northwestern Hawaiian Islands Reef Assessment and Monitoring Program (NOWRAMP) in the Northwestern Hawaiian Islands (NWHI). The high correlation between high-relief areas and fish abundance also has also been documented in the scientific literature by Alan Friedlander and co-workers in recent years (Friedlander et al., 2003). These are but a few examples that demonstrate that our present knowledge has been built on multiple layers of history that go back generations.

In fact, it was 165 years ago that James Dana first recognized during the U.S. Exploring Expedition in 1840 that the Hawaiian Islands appear to be progressively older moving from the Big Island of Hawaii to Kauai. Dana assumed that all of the islands originated simultaneously, and so he surmised that they must have become progressively extinct first Kauai, then Oahu, Molokai, Maui and finally Hawaii, which, of course, is still volcanically active. Interesting, the Hawaiians had developed the exact same theory 100s of years earlier. They viewed Kauai as being the first home to the Goddess Pele, who then moved southeastward, jumping island by island, as they became extinct, until reaching Hawaii where her home is now Kilauea Volcano.

Of course, neither Dana nor the Hawaiians knew about plate tectonics, or about the hotspot under Hawaii, or that plate motion to the northwest is what spawned the island archipelago. They had no way of knowing that the crust of the earth upon which

---

[1]Department of Oceanography, University of Hawaii, 1000 Pope Road, Honolulu, HI 96822 USA, E-mail: rgrigg@soest.hawaii.edu

the islands were resting was steadily moving to the northwest. Thanks to the scientific achievements of great men like Harry Hess and Robert Dietz who discovered sea floor spreading in the early 1960s (Dietz, 1961), we now know that the floor of the Pacific is moving to the northwest at a relatively constant speed of 8-10 mm/yr., and that it has been doing so for over 70 million years. Nor did Dana or the Hawaiians know about the hotspot discovered by Jason Morgan in 1970 (Morgan, 1972). The hotspot is a relatively stable plume of lava anchored in the mantle of the earth that has been issuing forth a new Hawaiian island about once every million years producing all-toll all told about 107 volcanoes, all moving from southeast to northwest, as silent passengers on a great undersea conveyor belt. Over millions of years, this process has built the longest and oldest island archipelago on the face of the earth.

It was on the shoulders of these men, Hess, Dietz, and Morgan, that I conceived and tested the Darwin Point Hypothesis in the 1970s and 1980s (Grigg, 1982). By then, it was generally known that the long trail of islands in the Archipelago underwent gradual subsidence and erosion until they sank below sea -level at about 30 degrees North latitude. My idea was to measure the net upward growth of corals on every island from Hawaii at the beginning of the chain, to Kure Atoll at the very northwestern end, a span of distance of almost 1,500 miles (2,400 kilometers) and a displacement to the north of about 10 degrees latitude. What I discovered was that the corals steadily declined in growth rate reaching a net value of nearly zero at Kure Atoll, thus explaining why the chain ends where it does. The islands simply drown at that latitude because coral growth cannot keep up with subsidence and erosion, and I named it the Darwin Point after Charles Darwin who first described the mechanism by which atolls form.

This is yet another lesson from the past; that ideas are often the integration of many past theories, of many past researchers.

But let us return to the era of the great explorer/naturalists. James Dana on the U.S. Exploring Expedition, charted many of the Hawaiian Islands for the first time in the 1840s. The British Challenger Expedition passed through Hawaiian waters from 1872-1876 and produced 50 volumes of scientific results (Brook, 1889). Compare this to what we commonly produce today from our expeditions! Then there was the Albatross Expedition of 1902 that mostly dredged the deep waters around the Hawaiian Islands. Skipping over some smaller ventures, the next great expedition in the history of marine science in Hawaii was the Tanager Expedition of 1923-24. And like those that it followed, the Tanager Expedition was primarily designed to collect data and specimens. It was a second phase of exploration (after the Hawaiians) but perhaps the first one driven entirely by scientific inquiry.

The science conducted by the Challenger Expedition, the Albatross Expedition, and the Tanager Expedition was mainly biological surveys. Of course, one of the first steps in science is to simply describe what is there.

But the Tanager Expedition also documented something else at Laysan Island. And that, of course, was the many changes in vegetation and birdlife that had taken place by 1923 compared to the turn of the century, when mining for guano and the harvest of seals and birds for their eggs and feathers took an enormous toll on the island ecosystem. Out of 27 species of plants that existed there before these activities, only four remained in 1923. Among the plants that were lost was sandalwood. The introduction of rabbits to establish a rabbit-canning business (if you can imagine), wrought further havoc to the island. Today, nearly 100 years later, the terrestrial ecosystem there is nearly recovered except for those species driven to extinction. Interestingly, we could find no remnant damage or any clue of previous disturbance to the coral reef at Laysan during our quadripartite studies there in the early 1980s (see below). This, along with many similar findings in the Main Hawaiian Islands (MHI), suggests that terrestrial ecosystems in Hawaii are far more fragile and more vulnerable than their marine counterparts. One exception to this pattern was the near extinction of the pearl oyster at Pearl and Hermes Atoll near the beginning of the last century. Even today, it has still not fully recovered (James Maragos, personal communication).

During this great period of exploration and collection of data and specimens, there were other major events that punctuated history and should be mentioned, simply for the sake of completeness. Although not scientific, we should pause to point out the annexation of the Hawaiian Islands by the United States in 1898. Also, in 1909 Teddy Roosevelt established a National Wildlife Bird Reservation including all of the NWHI, except Midway Atoll. In 1940, the whole area was re-designated "The Hawaiian Islands National Wildlife Refuge." And then, of course, there was World War II between 1941 and 1945. Few people know that on that fateful day of December 7, 1941, when the Japanese attacked Pearl Harbor, they also bombed Midway Island. The battle of Midway in June of the following year in 1942 is famous and sometimes claimed as one of the turning points of the war in the Pacific.

But now let us turn to the next phase of scientific research in the NWHI that took place in the mid 1970s and early 1980s. It was a phase exemplified by cooperation and integrated research. Of course, what I am talking about is the well-known Cooperative Tripartite Program that in fact quickly evolved into the Cooperative Quadripartite Program. Its scientific name was "The NWHI Fishery Investigations" (NWHI-FI) (Fig. 1). The three major agencies involved were the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), and the Hawaii Division of Fish and Game (now Division of Aquatic Resources). These agencies were quickly joined by the University of Hawaii (UH) Sea Grant Program. The lead agency was the NMFS, and the major force in terms of leadership was Richard Shomura, the Director of the NMFS Honolulu Laboratory at that time.

The whole idea of a massive cooperative study of the NWHI was not only an idea whose time had come but it was facilitated by a huge governmental mandate, the extension of U.S. jurisdiction to 200 miles off all U.S. States, Territories, Commonwealths, and other U.S. Possessions. This bill was passed by the U.S. Congress in 1976. The act created a Fishery Conservation Zone (FCZ) between 3 and 200 miles in which the federal government had regulatory power over all fisheries in these waters. Extended Jurisdiction (EJ) money, as it was known back then, amounted to about $30 million annually in the late 1970s, and it provided a huge source of funding for the Quadripartite Study. With the addition of the University of Hawaii Sea Grant Program, enlarging the Tripartite to a Quadripartite Program, additional monies from National Oceanic and Atmospheric Administration (NOAA) and the State of Hawaii were available to fund the research.

The NWHI-FI was a huge success. Actually, the studies encompassed all marine resources on the land, in the air, and of course the sea. In terms of agency responsibility, the nearshore research was done by the State and the UH Sea Grant Program, the NMFS studied offshore, bank and seamount resources, and the USFWS dealt with onshore and seabird resources.

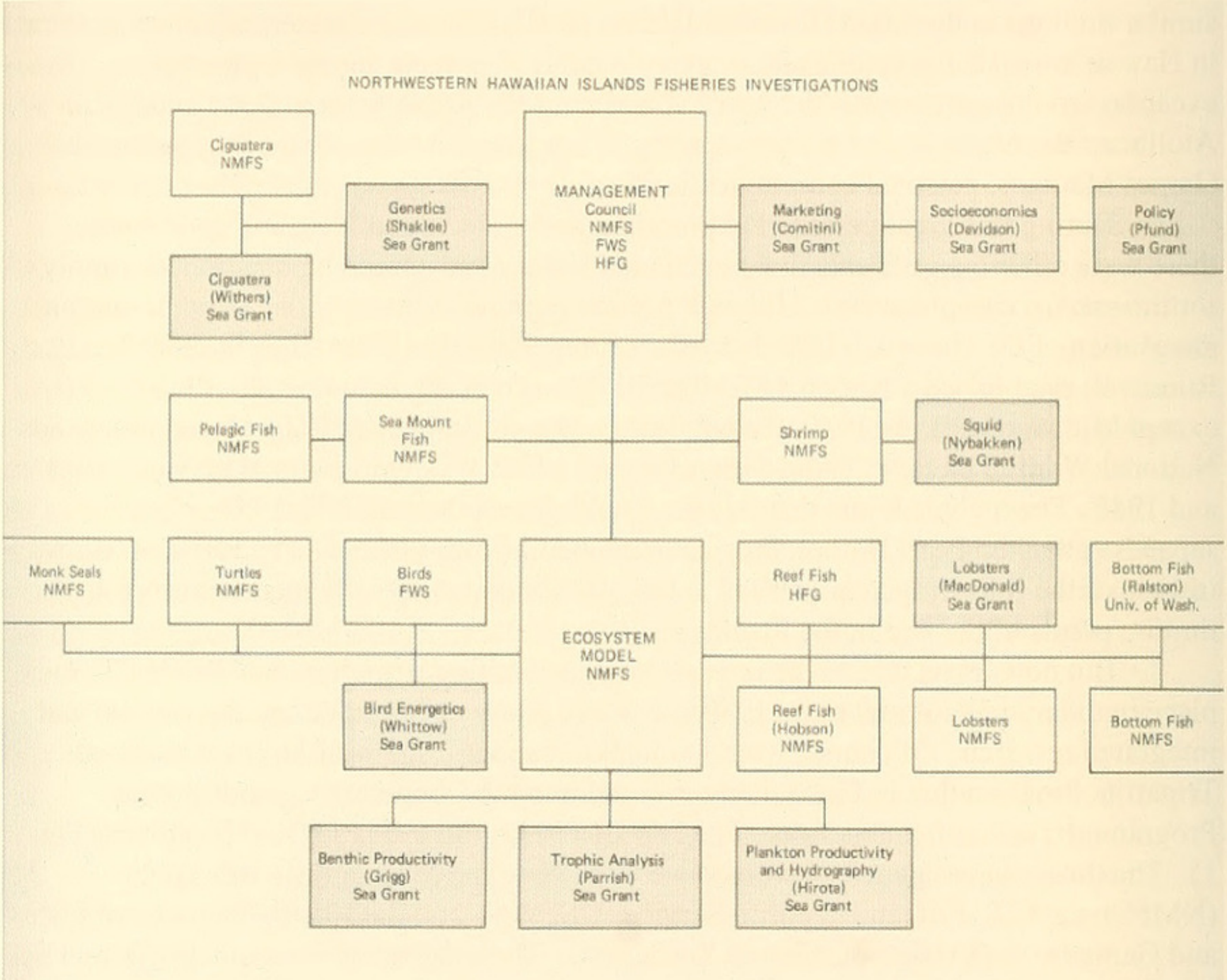

Figure 1. The organizational structure of the NWHI-Fishery Investigations in 1980.

At the beginning of the study, a Council for Coordinating Research (CCR) was established with representation from each agency. The Council met regularly once a month and did everything from establishing research priorities to coordinating day-to-day logistics. Overall, about 200 scientists participated in the study which eventually lasted about 8-10 years. Over this time period, approximately $10 million were invested in the Program. Two symposia were held to present the results of the study, the first on April 24-25, 1980 and the second on May 25-27, 1983. A total of 115 papers or abstracts were presented and now constitute three volumes of proceedings (Grigg and Pfund, 1980; Grigg and Tanoue, 1984).

Before briefly describing some of the results of the Program, I would like to comment on the underlying design of the research. Stock assessment of the major fishery resources and the data needed for their management were the over-riding themes that drove the research. Another was question-driven-science: testing of hypotheses and measuring ecological and oceanographic processes on large scales in space and time. We were intimately aware of the pitfalls of snapshot ecology and therefore tried to plan long-term programs. We recognized that ecological change is the norm, in both directions positive and negative, not just a downward shifting baseline as people often assume today.

Therefore, we hoped that some of the elements of the program would continue, in some cases indefinitely, notwithstanding limitations in funding and personnel. This is where the cooperation between supporting agencies was very important. Again, we did not assume a negative shifting baseline, but rather, hoped to enumerate and evaluate seasonal as well as decadal change. One project focused on the paleoecology of the entire Archipelago, stretching back in time 70 million years, to the origin of the first island. We presume that island to have been Meiji, which, of course, now marks the end of the chain of volcanoes and is in the process of subduction back to the mantle from whence it came.

Compared to the first phase of research dominated by the explorer/naturalists, whose research design was to collect any and all data possible and to collect specimens, the Quadripartite Study was driven by questions and hypotheses designed to evaluate long-term processes in space and time. We were hopeful that many sites would be revisited over and over again well into the future.

Now let us review some of the results. First it must be said that much of the research was centered on species of commercial importance: bottomfish, crustaceans, precious corals, and pelagics. Out of all of this research, four fishery management plans (FMPs) were developed, one for each of the fisheries. The NWHI-FI provided the initial baselines from which these fisheries continue to be managed. Also, in terms of management, two recovery plans were created, one for the endangered Hawaiian monk seal and the other for the threatened Hawaiian green sea turtle. Since that time, the monk seal population has remained fairly stable between 1,200 and 1,450 animals although not uniformly throughout the Archipelago. The Hawaiian green turtle however, has increased in abundance dramatically. Finally, the USFWS wrote a master plan for the entire Leeward Islands.

At the time of the last symposium in 1983, the thinking about fishery development was much more proactive than it is today. A major question that faced the second symposium was whether or not to establish a mothership or barge to process, freeze, store, and ship the catch from a number of smaller catcher vessels fishing for bottomfish, tuna, alfonsins, shrimp, lobster, and precious coral at either Midway Island or Tern Island, French Frigate Shoals. In looking back, it is interesting to ask why neither of these potential developments took place. The answer has to do with the economics of the fisheries and a gradual and continuing shift in societal thinking toward environmental protection and the precautionary principle. For Tern Island, Skip Naftel, one of the high-liner fishermen of the era, put it this way. "To turn Tern Island into a fishing camp for support gear, fuel, R&R, or whatever is ludicrous. I'll tell you it's a no-win proposition to take on the environmental concerns there. We're going to lose." And, of course, it never happened.

As for Midway, economics, distance, and competing interests with the military and the USFWS, acting together, although not intentionally, prevented this idea from materializing there.

Mention should also be made of the results of more basic scientific studies during the Quadripartite Program. I have already described the Darwin Point study and its hypothesis concerning the birth and death of all the emergent Hawaiian Islands. Another very important product of the NWHI-FI was the creation of the ECOPATH Model by Jeff Polovina (Polovina, 1984). What Polovina did was to integrate the results of several dozen studies at French Frigate Shoals at all levels of the ecosystem, from measurements of benthic primary productivity on the coral reef, to trophic studies of herbivores, to primary, secondary and tertiary carnivores, all the way up the food chain to tiger sharks. He built the model from the bottom up, and he then tested it from the top down. Now he has refined and extended the predictive capabilities of the model which he has relabeled ECOSIM. ECOSIM can be and should be used by resource managers to predict outcomes of many different management scenarios and strategies.

During the NWHI-FI, we also discovered three new species of *Acropora* coral, as well as their probable route of colonization to Hawaii by way of Wake Island and Johnston Island within the Subtropical Counter Current. This southwesterly route has probably been the route of colonization for all 57 or so Hawaiian corals since all are Indo-West-Pacific in origin and all are temperature-sensitive. Another cooler route of origin was discovered by Ted Hobson for some Hawaiian fishes with Japanese affinity that probably arrived in Hawaii by way of the North Pacific Drift (Hobson, 19843). Fishes such as the sling-jaw wrasse probably arrived by way of this oceanic pathway.

I could continue describing more of the results but time of course limits the discussion. One final point to mention, is that all of these basic findings have been published in the scientific literature and like many of the lessons we have learned from the Hawaiians and the early explorer/naturalists, they add to that huge knowledge base upon which present day research should be based.

Let us now turn to the present day and what I call for in my title "hopes for the future." Some of what I have to say may sound a bit critical but my remarks are intended to be taken positively in terms of how we can improve research in the future.

I must also limit my critique to just coral-reef studies in the NWHI because of time constraints. And for this I must digress for a few brief moments in order to explain a little history.

In 1993, a symposium entitled "Global Aspects of Coral Reefs; Health, Hazards and History" was held in Miami, Florida and was attended by 125 coral reef scientists. In brief, this exercise was the beginning of what was to become "The Year of the Reef" in 1997. This event in turn led to the creation of a U.S. Coral Reef Task Force several years later. The Coral Reef Task Force was made up primarily of government personnel and environmental organizations. Very few scientists have had the time to participate in what was to become a series of very lengthy and bureaucratic meetings.

The main worry then and the main worry now, is that coral reefs were and continue to be in ecological crisis. It is commonplace to hear today, mostly in the media, that 20% of all coral reefs in the world are now irreparably degraded and that another 30-50% will follow suit in the next decade or two. I will not argue here the validity of these numbers except to point out that nothing ecological under the sun is irreparable, except, of course, extinction. There is not one species of the 700 plus species of coral that exist in the world today that has recently become extinct. .

Now the upshot of all this has been another huge mandate, and like EJ money back in 1976, the U.S. Congress has generated about $30 million annually for coral reef research, filtering down this time mostly through NOAA. It should also be understood that several areas of research have been heavily earmarked for study as a result of political advice from the Task Force. The buzz words are monitoring, mapping, and assessment. For Hawaii, this means all three activities in the NWHI, the U.S. Territories of Samoa and Guam, the Commonwealth of the Northern Marianas, and the U.S. Pacific Island possessions of Johnston, Jarvis, Baker, Wake, Howland, Palmyra Islands, and Kingman Reef.

The NWHI received particular emphasis because several studies showed erroneously that the NWHI constituted about 70% of all reefs under U.S. Jurisdiction (Hunter, 1995; Miller and Crosby, 1998). This number has been recently revised downward recently by NOAA to about 5%! The magnitude of this error was caused basically by omitting the reef habitat on the west Florida shelf which constitutes about 84% of the total (Rohmann et al., 2005).

Now if you combine this sudden influx of government funding with the mandate to survey a gigantic chunk of the Pacific and combine that with all the new high-tech instrumentation that is now available to science, ranging from remote sensing satellite imagery, to multibeam acoustic bottom profilers, to Doppler current meters, to satellite tracked drifter buoys, to anchored wave/weather buoys, to CTDs (spell out), to temperature loggers, to seal cams, etc., what we have upon us today is another age of discovery.

The research design is once again one of massive data collection and discovery, not unlike the explorer/naturalist phase of scientific research in the Hawaiian Islands over 100 years ago. One must also add the deep-sea and the high-tech submersibles now available for study. This is truly a new phase of discovery, and I do not infer that this is bad.

For the past 5 years an enormous amount of new information has been gathered. By necessity, the approach has been somewhat "shotgun" in nature. One could even describe it as fragmentary, and like the early expeditions of discovery, the idea was to collect as much data about as many subjects as possible. Some correlations will undoubtedly result from the data analysis, and this is happening as I speak.

And now comes the exciting part, for I think we are entering once again into a new phase of research which may be one of synthesis. With understanding there can be focus. Hypotheses can be erected and tested. A wealth of new information is coming to light, as we will hear in this symposium. All of this these new data need to be synthesized and integrated within the existing literature. A new paradigm can be built by combining new information with the old. This is exactly what happened in 1970 when Jason Morgan discovered the hotspot and combined it with the knowledge of plate tectonics. Suddenly, the Hawaiian Islands were moving in the opposite direction; instead of eroding sequentially to the southeast, they were drifting on the Pacific Plate to the northwest!

But before any of this can take pace we need to take stock of where we are. We need to develop a 5- or 10- year plan. This means cooperation and coordination among agencies and scientists. Priorities for research need to be identified and agreed upon. A cohesive program needs to be built and it should be put together by scientists, not politicians. Resource managers need to identify their information needs but the actual plan should be put together by scientists who have first-hand experience in the NWHI. The model provided by the Western Pacific Regional Fishery Management Council (WPRFMC) is a very good one. Decision-making by the Council is based on the work of the Scientific and Statistical Committee (SSC), and of advisory panels, and plan teams.

In 2000 and 2001, President William Clinton issued Executive Orders (EO 13178 and 13196) that created the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve from 3-50 nm around the NWHI, which in turn will likely be redesignated as a National Marine Sanctuary in the near future. If the new Coral Reef Reserve is to become a National Marine Sanctuary, an organizational structure similar to the WPRFMC will become all the more important to establish. Scientists, fishermen, and other people with first-hand knowledge should be the basic decision-makers for generating a long-term operational research plan. Most importantly the science should be driven by scientific problems, not politics.

In my view, the focus should be on specific issues and the problems. A partial list is given below following management priorities that existed during the Quadripartite Study in the 1980s but are still extremely relevant.

- Abundance levels (varying baselines) of commercial species, such as bottomfish, lobsters, precious corals, and pelagics need to be known.
- The same information is needed for seabirds, monk seals, and green sea turtles, and other major species in the ecosystem.
- We need to understand the natural variability of the systems: the reef, primary production of the surrounding ocean, the current systems, annual temperature patterns, etc.
- All of these new and basic data should be updated and reanalyzed in the ECOSIM Model.
- Is coral bleaching in the NWHI a first-time event? Will the corals recover? Corals have been there for at least 35 million years. Future studies must be retrospective in design, not just surveys and snapshots.
- Marine Protected Areas (MPAs) need to be identified by location and size.
- Marine debris must be understood as a process not just removed. Rates of recruitment, decay and actual impacts vis-à-vis natural disturbance (storms) need to be quantified.
- Impacts from vessel groundings need to be objectively assessed. An acre of blue green algae around a grounded vessel may add to the biodiversity of the bottom and may not actually damage the reef.

- Impacts from introduced species need to be studied and understood.
- We need to know what the present-day managers plan to do, and what their information needs are.
- We need to know what the present day managers plan to do, and what their information needs are.

Five years of data collection is now maturing to a point where it represents a time series; patterns are emerging, and various pieces of the ecosystem puzzle are beginning to fall into place. It is time to reanalyze this new database. It is time to identify priorities and develop a plan. This, in fact, is a major objective of this symposium.

In summary, what have we learned from past lessons? First, a vast inventory of integrated knowledge has been accumulated by many generations of scientists and also by the Hawaiians, who in some instances have been our teachers. Secondly, and very interestingly, terrestrial ecosystems appear to be more fragile than their marine counterparts. This may be due to the "openness" of marine ecosystems to constant colonization (recruitment). In other words, marine ecosystems appear to be much less isolated than terrestrial ecosystems. Third, we have learned that team research produces not only cooperation but also a synergy of understanding. Fragmented data can only lead to fragmented ideas. Finally, the science should not be driven by politics. Rather, it should be a response to ecological problems in need of solution.

Looking back, we have seen four historical phases of formal research; first, the era of the discover/naturalists and massive data collection; second, a phase of synthesis; third, a new phase of discovery and data collection brought on by new instrumentation and high technology; and finally, a phase that we are now entering, which again may be a phase of synthesis. I can think of no better way to end my paper than to quote William Shakespeare in *Julius Caesar* in which he said, "There is a tide in the affairs of men, when taken at their flood leads on to fortune." Indeed, it does appear that "it is on such a full sea that we now stand, and we must take the current as it serves, or lose our ventures."

LITERATURE CITED

Brook, G.
1889. Report on the Antipatharia. Gt. Brit. Challenger Office. H.M.S. Challenger Exped. Sect. 5, 32 (80):1-222.

Dietz, R.S.
1961. Continent and ocean basin evolution by spreading of the sea floor. *Nature* 190:854-857.

Dollar, S.J.
1982. Wave stress and coral community structure. *Coral Reefs* 1:71-81.

Friedlander, A.M., E.K. Brown, P.L. Jokiel, W.R. Smith, and K.S. Rogers
2003. Effects of habitat, wave exposure, and marine protected area status on coral reef fish assemblages in the Hawaiian Archipelago. *Coral Reefs* 22:291-305.

Grigg, R.W.
1982. Darwin Point: a threshold for atoll formation. *Coral Reefs* 1:29-34.
Grigg, R.W., and J.E. Maragos
1974. Re-colonization of hermatypic corals on submerged lava flows in Hawaii. *Ecology* 55:387-395.
Grigg, R.W., and R.T. Pfund
1980. Proceedings of the Symposium on Status of Resource Investigations in the NWHI. UNIHI-SeaGrant-MR-80-04. 333 pp.
Grigg, R.W., and K.Y. Tanoue
1984. Proceedings of the Second Symposium on Resource Investigations in the NWHI. UNIHI-SeaGrant-MR-84-01. 491 pp.
Hobson, E.S.
1984. The structure of reef fish communities in the Hawaiian Archipelago. In: Grigg and & Tanoue (eds.). UNIHI-SeaGrant-MR-84-01, 101-122.
Hunter, C.L.
1995. Review of status of coral reefs around American flag Pacific islands and assessment of need, value, and feasibility of establishing a coral reef fishery management plan for the Western Pacific region. Final report prepared for the Western Pacific Regional Fishery Management Council. 39 p.
Morgan, J.
1972. Deep mantle convection plumes and plate motions. *Am. Assoc. of Pet. Geol. Bull.* 56:203-213.
Miller, S.L., and M.P. Crosby
1998. The extent and condition of U.S. coral reefs. In: NOAA's State of the Coast Report. Silver Spring, Maryland, p. 1-34.
Polovina, J.J.
1984. Model of a coral reef ecosystem. Part I. *Coral Reefs* 3:1-11.
Rohmann, S.O., J.J. Hayes, R.C. Newhall, M.E. Monaco, and R.W. Grigg
2005. The areas of potential shallow-water tropical and subtropical coral ecosystems in the United States. *Coral Reefs*. In press.