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WORLD FISHERY TECHNOLOGY

HARVEY BULLIS

Thank you, Mr. Chairman. Two aspects to my comments should be explained. First, if Wib Chapman had talked for another ten minutes, he would have covered my talk beautifully, and second, they made me promise that it would be sufficiently controversial to give plenty of opportunity for debate.

I am going to have an entirely different cast to my presentation than the previous three speakers, who I think did a beautiful job of providing the group an objective perspective. I have never been able to do this with the question of fishing technology. I find myself deeply immersed in it, with highly subjective feelings on the subject, and I am afraid you are going to find all of my comments tainted. With these comments, I will start off with a rather terse statement that I don't think we have anything that can be given the categorical term of WORLD FISHERY TECHNOLOGY.

Mechanization, increased vessel size, increased power, synthetic fibers, are transitional elements in world fisheries. To categorize them as a technology in a static sense is misleading. In a sense, fishing technology has developed as it was needed.

If we look to the future, there are indications that the present technology is not going to be adequate. Our fisheries are in transition, either moving toward adequate or inadequate technology. I would say the groundfish fisheries in New England and perhaps the Pacific Northwest seem to be moving toward inadequacy while others such as our tuna fisheries are moving in a satisfactory direction. Fishing technology responds to a long list of social and economic factors. These dictate how successful technology will be. Value-of-catch factors say that high value of a product permits great inefficiency and a very low-value product demands very high efficiency. An example in our area of ownership claims on resources or on environments that produce resources would be the menhaden fishermen versus the sportsfishermen controversy. So, regardless of fishing efficiency and abundance and availability, social controversy has a strong bearing on whether or not the menhaden fishing operation in a particular area is "successful." Another example—a small commercial fishery for snook in Florida was recently legislated out of business. Whereupon sportsfishermen started selling snook to the market and you can buy as many snook as you could before. Instead of two or three commercial operations, we now have 5,000 or 6,000 sportsmen producing the catch.

Since you were so kind as to donate coho salmon to the Great Lakes, we can see what has recently happened. The position of the State is that this is a sport species. Since sportsfishermen can't seem to catch them, the State has moved in and established a State-run commercial fishery. We have market systems that frequently work against the fisherman. In the system that says to buy cheap and sell high, the fisherman sits right at the bottom of the pile. When production is the highest, the prices are the lowest.

So, fisheries technology operates within wide parameters of availability, proximity, values, skills, materials, subsidies and supports, restriction, and management. To develop a concept of WORLD FISHERY TECHNOLOGY is too confusing to attempt at the present time. But if we did, I think we would see that the strategy or tactics of one country or possibly one region is not necessarily successful elsewhere. Things like need for food in the homeland, demand for special products, foreign investment opportunities, and need for foreign exchange all have a tendency to shape technology.

From this point on, I would like to view it from the interests of the producing segment of the United States industry.

Here we see strange phenomena. In the Western Hemisphere there is an interesting range of the fishing effectiveness. The lowest catch-per-man per year is about 500 pounds. This is in the Netherlands Antilles and applies to full-time fishermen. In contrast, is the high catch-per-man of about 3,000 tons in the industrial trawl fishery in the Gulf of Mexico. However, regardless of how effective or how efficient a particular piece of fishing equipment may be, the fisherman is responding to a series of economic pressures. In Puerto Rico we found that in spite of the rather depressing levels of catch that were coming out of certain areas, the fishermen wanted no assistance in increasing the catch. They maintained that if the circumstances warranted, they could do this without help from the Government. While the Government wanted to give them free nets, free boats, etc., they had sort of tuned themselves to certain size landings, certain volumes, that they could bring in without upsetting the market price. They could catch a lot more fish but, by keeping the landings at a certain level, they could maintain a price level that they figured was a fair return for their effort. Until the entire marketing scheme could be changed, they were not about to move out of this position. I think we could find a number of more subtly disguised examples in our United States fisheries.

So try to look at what "success" means in fishing technology in the United States. There is always some relationship to profit but not necessarily to maximum profit potential. A producing segment that is tuned to the marketing system is not anxious to adopt a new system. In fact, there is fear on the part of some fishermen of new and more efficient systems. They are going to upset the apple cart!

So, from a positive point of view, I would say that we could probably do much better if there was proper motivation. There are wide areas of fishing technology that haven't been explored. In taking a rather broad look, if it is possible to do so, at the success stories in United States fisheries, there are criteria that seem to emerge. One would be having the value of the catch retain some parity to production costs. The shrimp fisheries in the Gulf of Mexico are an example. If shrimp prices had not gone up to where they are right now, most of our shrimp fishery would be on the rocks. The other, and perhaps more important, is the adaptability of the production units to change. An example would be the purse seine revolution on the tuna fisheries. The willingness of the industry to make a major technological change when it did probably averted disaster.

Another example of adaptability to change was brought up in the discussion of Wib's paper; broadening the resource base. Certainly in the Gulf, this is the basis of the success in the fisheries over the last 20–30 years rather than any gear technology innovations.

Some more personal ideas are perhaps best expressed in some of the programs that we are conducting. I would now like to get into the area of controversy that you asked of me and explain what we are trying to do in the development of a vast latent stock of fish and the techniques that we are using to assist the industry in expanding production in this area. In very general terms the matrix of this program is wrapped around four generalized roles. These are to broaden the resource base by identifying and assessing latent stocks; particularly in looking for new grounds for commercially established species and identifying populations of unused species that would seemingly offer marketing compatibility with species that are being utilized that could be slipped into a marketing structure without creating serious problems. So our goals are (1) to identify those species groups that show innovative investment opportunities, (2) to provide improved time and space intelligence for the established commercial species, (3) improvement of extraction technology, and (4) to evolve good communication with the industry to effectively implement the adoption and development of the above.

The calico scallop project is perhaps familiar to you. The initial role of this project was to help a group of fishing vessel owners who had found themselves in a technological bind. Their vessels were no longer large enough for effectively competitive trawling for shrimp.

In the following I will present a series of figures that, hopefully, will illustrate some of our activities.

Figure 1 shows the catch taken in a typical 15-minute drag of an 8-foot tumbler dredge on the scallop beds off east Florida.

Figure 2 is an example of superimposing a grid on an aerial photograph for estimating school size. There are no reliable methods of estimating stock size of unexploited species. The biological tools at our disposal pretty much depend upon monitoring the exploitation of the species. We are dealing with about 40 species, all considered surface schoolers. Of the 40 species, only one is being harvested—menhaden. Our catch data for the past 20 years indicate that menhaden is not the most abundant species in the Gulf. There is no way to determine the margin of error in estimating school size. We have conducted a number of experiments with professional fish spotters. They are working on menhaden with a 50% error factor. As soon as they move off to the other 39 species, we operate with error factors on orders of magnitude of 5 or 10 or 20 times. Much of the effort of fisheries development in the Gulf area is delineating the pelagic stocks of coastal pelagic schoolers in particular. In the last 3–4 years, we have more or less submerged all of our other activities to try to develop new techniques for quick survey and assessment of schooling species.

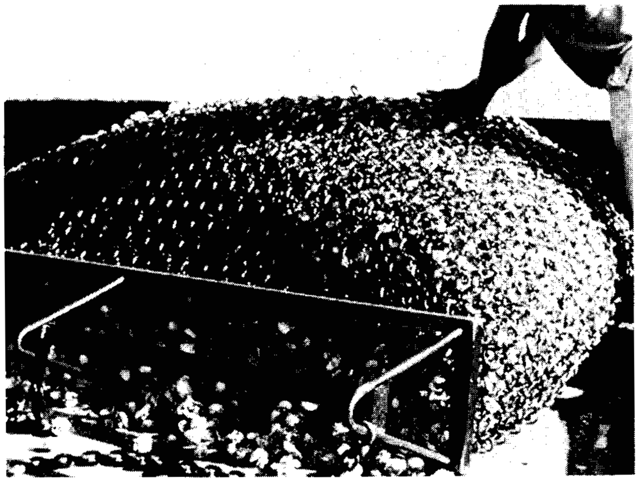

FIGURE 1. Calico scallop taken in a typical 15-minute drag of an 8-foot tumbler dredge on the scallop beds off east Florida.

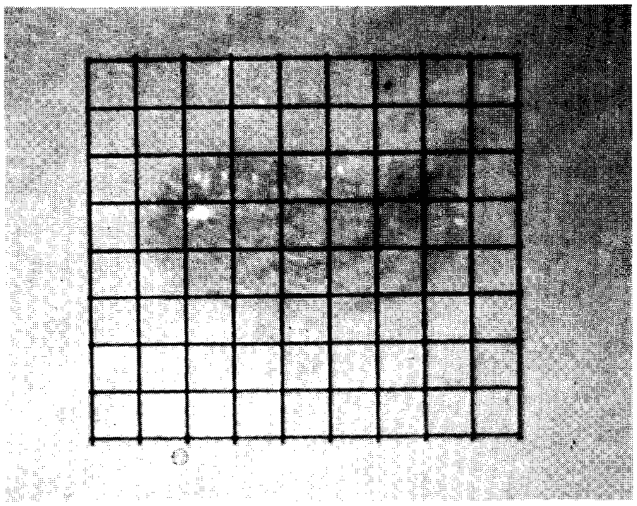

FIGURE 2. An example of superimposing a grid on an aerial photograph for estimating a school size.

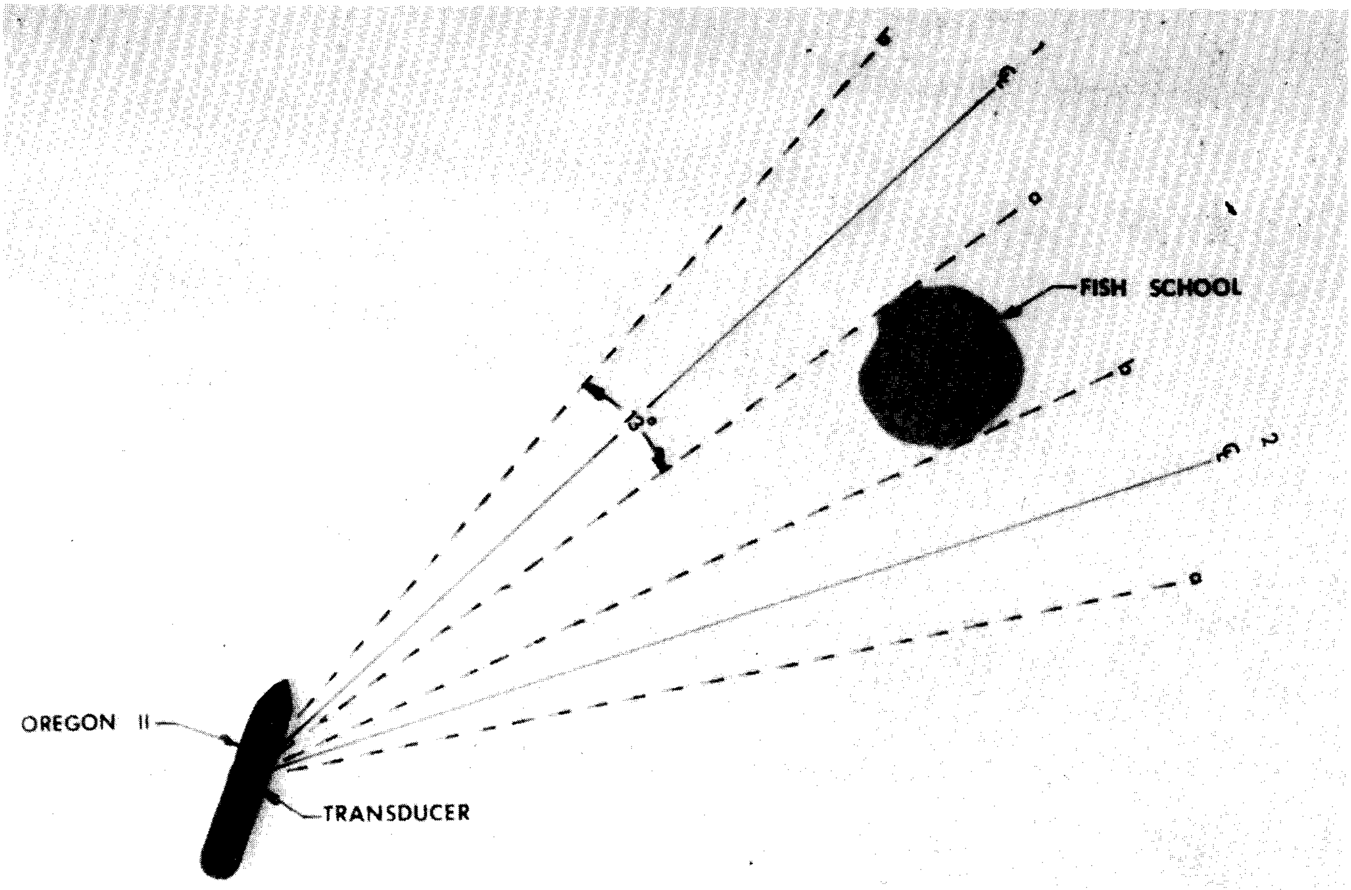

FIGURE 3. Sonar profiling of a fish school with a variety of frequencies and pulse lengths.

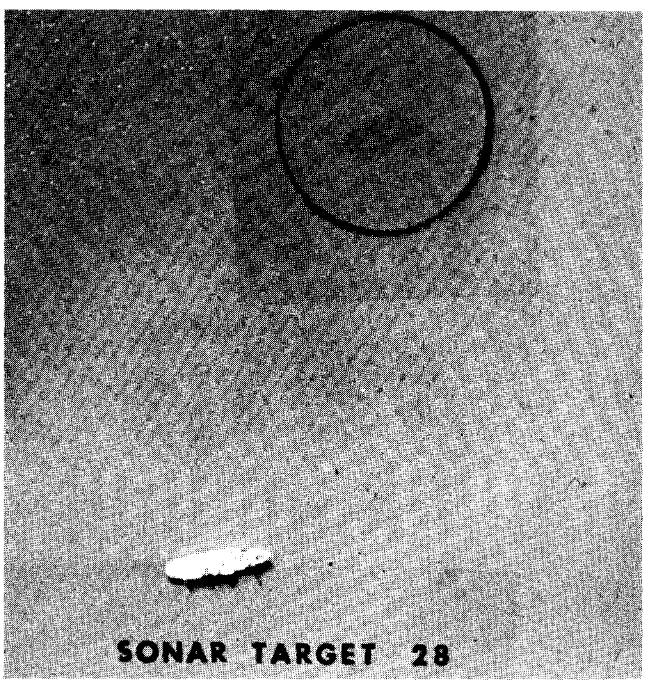

FIGURE 4. Aerial photography associated with sonar profiling target.

Signal penetration studies have been conducted by picking up a fish school on sonar, profiling it with a variety of frequencies and pulse lengths as depicted in Figure 3, and conducting simultaneous aerial photography (Figure 4) to get definitive horizontal profiles of the school.

Next, I would like to read a few pages that I have clutched out of a recent talk that explains in some detail one of the perhaps most exciting prospects for future fisheries survey technology. The National Aeronautics and Space Administration has undertaken, as you know, an extensive study to determine the feasibility of developing a satellite system to survey the resources of the earth. The study is now being conducted to determine the feasibility of utilizing remote sensors aboard both aircraft and spacecraft to assess aspects of our minerals, forest, water, agriculture, and other resources. These sensors operate on the principle that each object on earth reflects, absorbs, and emits energy—electro-magnetic radiation—in a manner characteristic of the object's physical and molecular strings, giving each its own special signature. One group of sensors, multispectral cameras, reports the special distribution of electromagnetic radiation from the target over some narrow portion of the spectrum. Other sensors, such as scanning spectrometers, measure intensity and spatial distribution of this radiation as a function of wavelength over the entire spectrum from the ultraviolet through the visible into the non-visible infrared and microwave regions.

Intriguing questions then arise as to the possibility of applying these new technologies to such earth-bound applications as fisheries resources, survey, and assessment. We have initiated a program directed toward the application of remote sensing technology to the problem of pelagic fishery resource assessment —particularly the location, identification, and quantification of surface and near-surface fish stocks. Because of the complexities of the problem and the inherent limitation in each method considered, a number of approaches have been taken. The initial effort of this program was to determine the feasibility of utilizing aerial photography in conjunction with ground crew observations as a means of obtaining quantification and qualification data on known pelagic fish stocks. More than 1,000 schools have been photographed using black-and-white, color, infrared, and various photo combinations. Sixty-five of these schools were sampled to determine size and species composition. Simultaneous sonar soundings were also obtained on a number of schools in an effort to determine subsurface configurations and density. These have shown that the position and surface configuration of fish schools may be obtained in very precise terms from high altitude photography. Selected photographs are now being subjected to color separation and isodensitometric analysis to determine the relationships which may exist between color, tone sensities, species, and school size respectively. The aerial photogrammetric studies are limited in certain respects, due to problems of water penetration and subtle color differences associated with some schools. Multispectral photographic techniques may be used, however, to detect these subtle differences and provide greater depth penetration by excluding those spectral regions which contribute little or nothing to the inclination content of the photograph. Black and white as well as color films are inherently sensitive to large portions of the electromagnetic spectrum.

In case of fish schools in their natural environment, the color differences which may be used to locate and identify certain species may very easily be lost in the background reflectivity of the scene and hence pass undetected upon examination of the photograph.

Multispectral photography separates the reflected radiation into a number of wavelength bands which have been pre-selected to yield maximum differentiation between the target and the background. This is accomplished by using narrow band filters which cover only the area of spectral difference and thus enhance to provide greater contrast between the target and background. A series of multispectral experiments were conducted by Long Island University, under contract to our Laboratory, during the past summer to determine the feasibility of using these techniques to locate and identify surface and near-surface fish schools.

Initially, the wavelength bands for greatest depth penetration were determined for two regions in the northern Gulf area. Special narrow band filters were developed to look at those parts of the spectrum which would give the greatest depth penetration for these waters. A series of test flights were then made over the areas using a 4-lens multispectral camera system in high speed emulsions. 15-x120-foot target areas consisting of red, blue, yellow, and gray scale panels were placed in the scene and served to evaluate the performance of the sensors for underwater penetration and as a control for the analysis on imagery. Schools photographed during these experiments were sampled to provide ground truth data on size and species composition. We have received only a preliminary report on these studies so far but the indications are that we are getting excellent separation of the fish school from the environment and this particular study has indicated that high altitude photography has a potential in survey and assessment projects.

Many pelagic species may be identified on the basis of color or distinctive pattern—the red color of menhaden schools which is identifiable from visual observation, for example. These characteristics are commonly used by commercial spotters to locate schools. The use of colors, or of spectral differences, by the commercial spotter to identify species suggests that spectral analysis of the reflected radiation will reveal characteristic spectral signatures which may then be used to locate and identify fish schools in their environment, at least under special conditions. During September of this year the Pascagoula Laboratory and TRW Systems recorded spectral reflection measurements on 15 schooling species in the north Gulf. Measurements were made on single fish, fish in small groups, and impounded fish schools using TRW spectrometers. The spectral reflectance measurements were obtained under natural lighting conditions from both surface vessels and stationary oceanographic platforms. And again, these data are presently under analysis by TRW. However, we have received a preliminary report from them that shows that this has a possibility for species identification.

Another approach to the problem of locating and measuring pelagic fish stocks which appears to have good potential is the use of low-level light sensors such as image intensifiers which record bioluminescence or "fire" as referred to by fishermen.

The Florida Spanish mackerel fisheries serve to illustrate the potential of this method. In Florida this fishery is carried on chiefly with gill nets and haul seines at night. The fish are sighted by the fire in the water, which is the result of a number of fish schools which cause luminescent organisms in the water to glow momentarily. Rapidly swimming fish cause these organisms to luminesce, outlining their bodies with light and leaving trails of light. Schools of mackerel containing 5–10 tons can be identified by individual flashes of bioluminescence. This fire can be seen with the naked eye on moonless nights; however, it is also possible to pick it up on cloudy nights or, in any circumstance, less than full moonlight. During the past three months a series of tests have been conducted using huge intensifiers on loan from the Night Vision Laboratory at Fort Belvoir. Intensifiers used in these

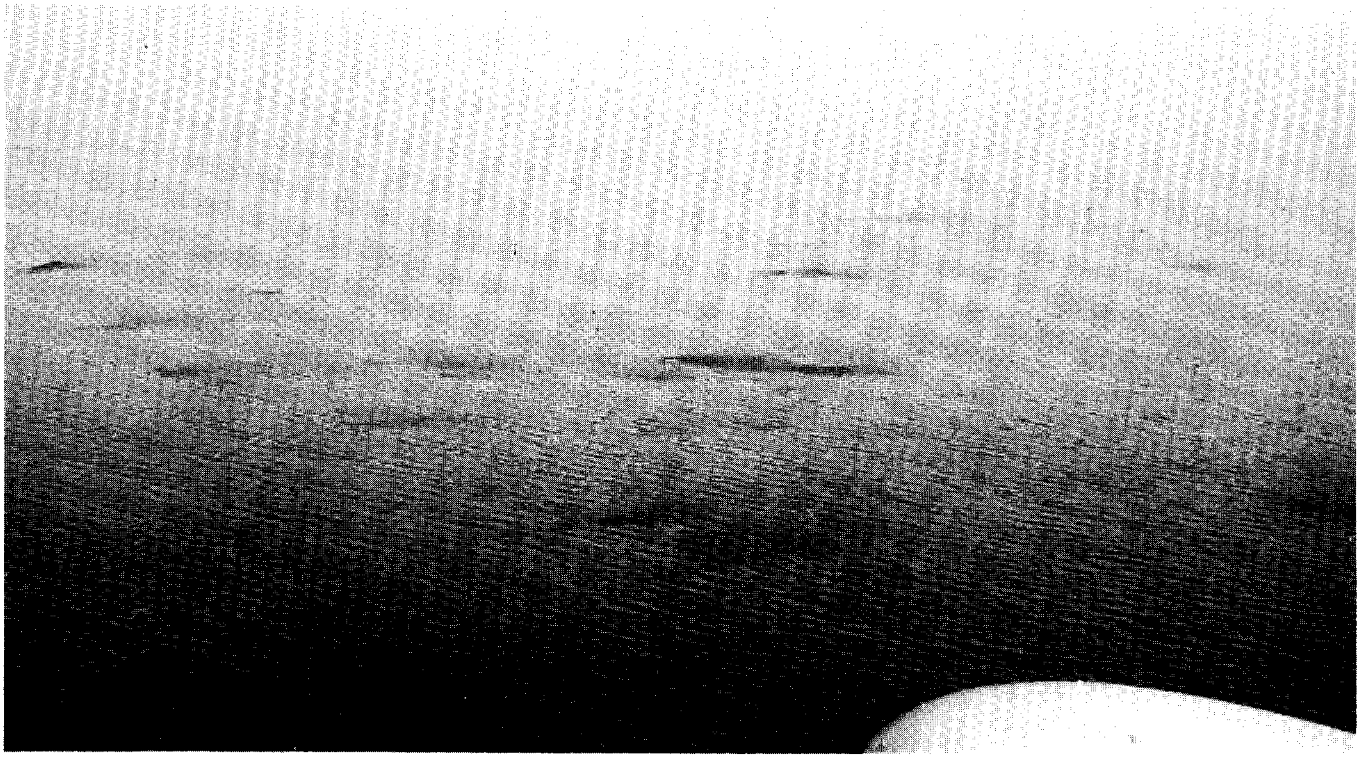

FIGURE 5. Thread herring schools off the west coast of Florida in normal summer.

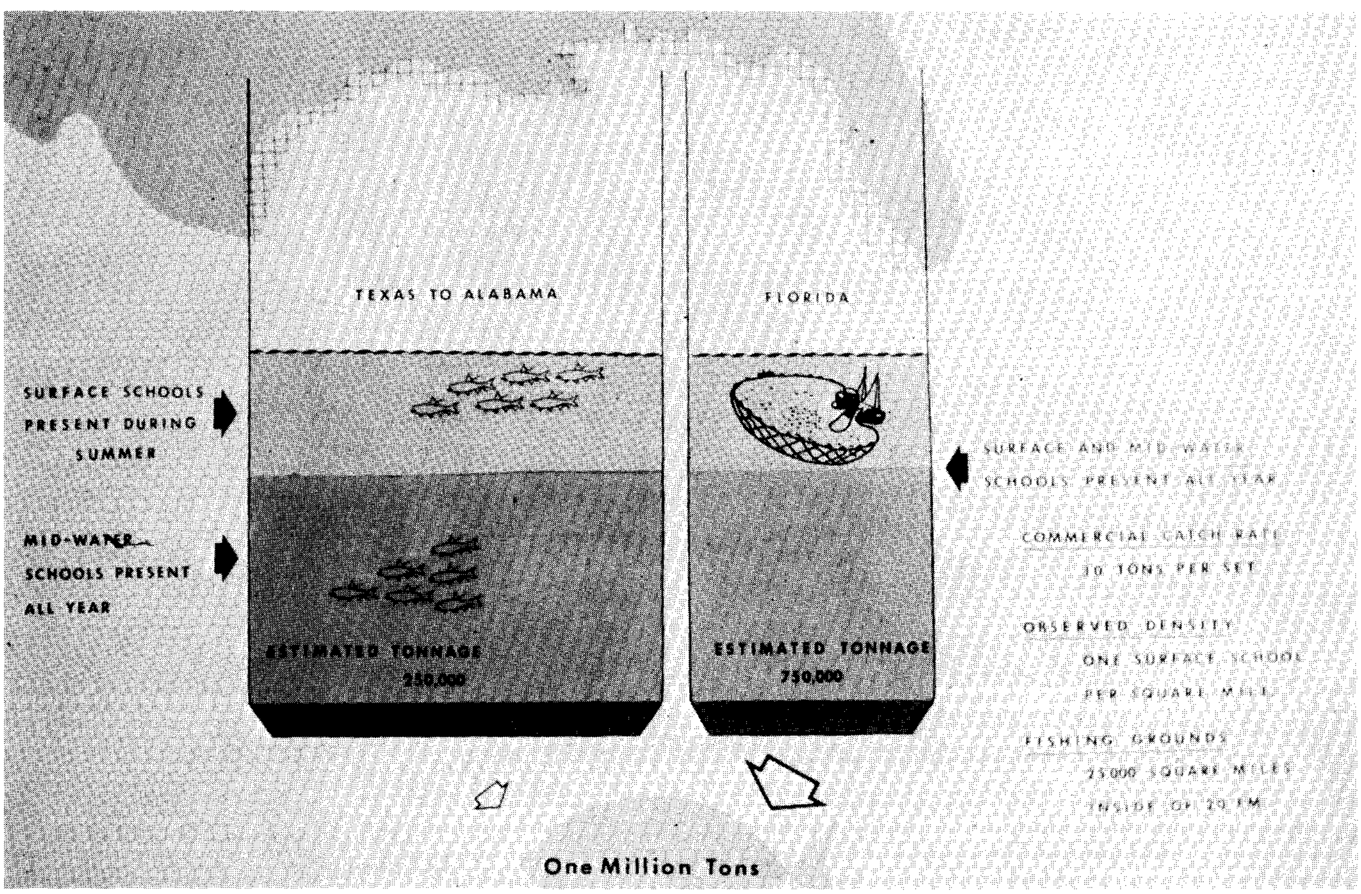

FIGURE 6. Estimate of school count and tonnage of thread herring off Florida's west coast.

initial studies amplify the ambient light and, in the case of bioluminescence, they emit light 40,000 times that seen with the naked eye. Observations have been made using a closed circuit TV system coupled with the intensifier of fish schools, individual fish, and in water masses with low concentration of luminescent organisms. Results of these tests dramatically show that low-level light sensors may be used effectively from high altitudes as a means for locating and possibly identifying pelagic fish stocks over large oceanic areas.

Now let me resume the presentation of my photographs. Figure 5 shows a number of thread herring schools off the west coast of Florida, a very common sight throughout the summer months in that area.

After three years of aerial spotting on the west coast of Florida we came up with an estimated school count and, by sampling estimated school size and simple multiplication, came up with some figures (Figure 6).

Several menhaden schools are visible in Figure 7.

Our first attempt to use aerial infrared film produced this startling image (Figure 8). Here are anchovy schools off the coast of Louisiana, Mississippi, and Alabama.

Later on in the studies when we were working on thread herring stocks off southwest Florida, we happened to have a shallow-water sonar study of fish that were hiding in the sediment clouds. At the time there were a number of vessels in the area fishing for thread herring. It was impossible to see any of the schools from the air. Figure 9 shows these boats being set under sonar direction from our vessel. This particular set hauled about 115 tons of thread herring. None of these schooling phenomena could be observed visually at the time. So again this opens up some intriguing possibilities of analysis of high-altitude photo reconnaissance of the coastal waters.

In Figure 10 a sonar scanning directly ahead of the vessel running through turbid water is reproduced. Each one of these lines is a separate fish school—very heavy concentrations of thread herring schools along the coast here. Very typical of the west coast of Florida in summer months.

We have been announcing that there have been large quantities of fish in this area for many years, but professional fish spotters maintain that the schools (based on menhaden fishing) are too small to set on. They do not show enough color. In Figure 11 is shown a very small school, about 75 feet in diameter. We had to pay a seiner $300 to come over and put his seine around the school and that school yielded 100,000 pounds of thread herring.

The oil slick phenomenon, as perhaps many of you know, has been under investigation by Barringer Corporation in Toronto for the last few years. They managed to interest NASA in the possibility that they could determine spectral signatures in these oils and

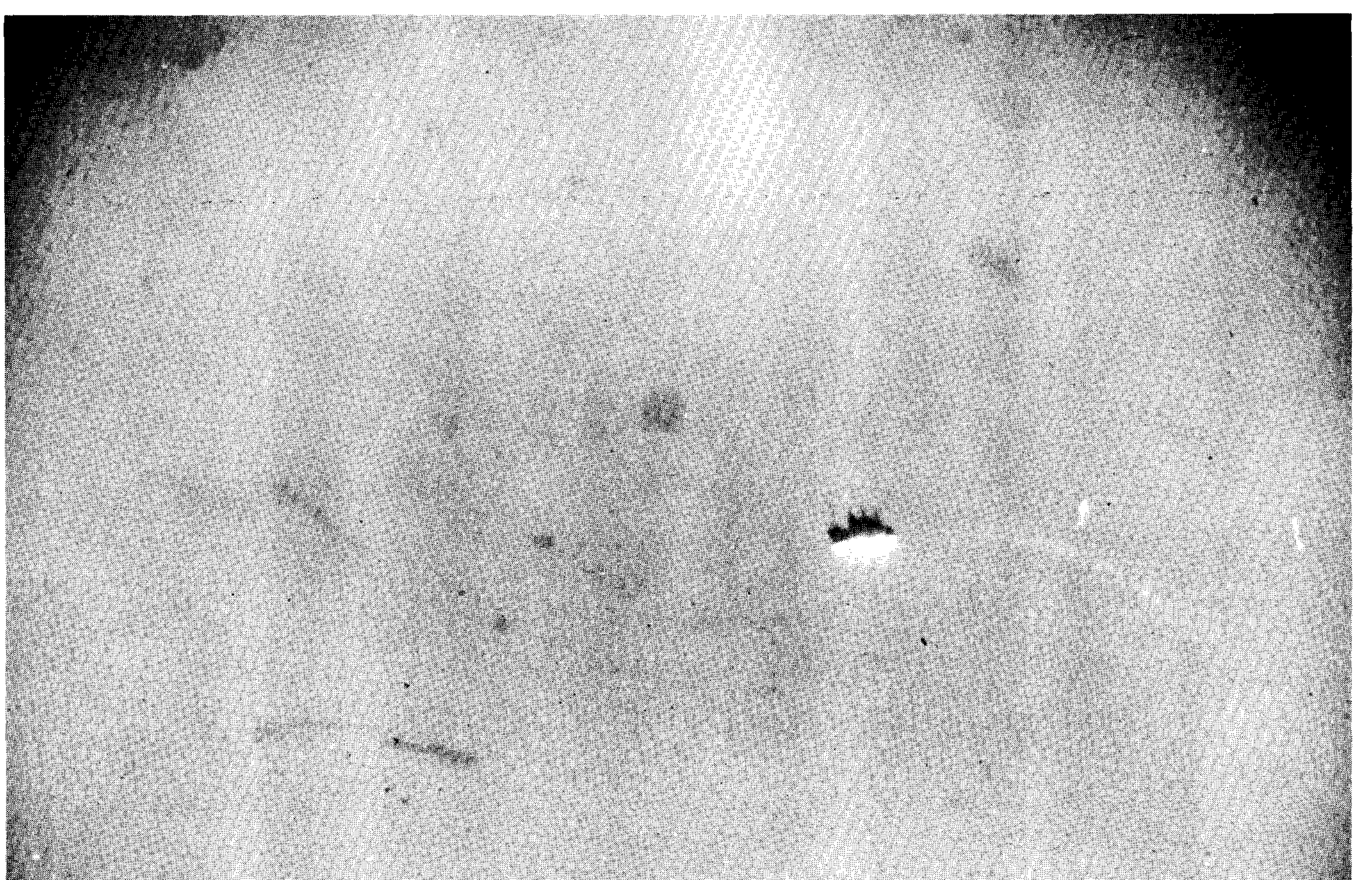

FIGURE 7. Menhaden schools.

were able to do it in the ultraviolet area of the spectrum, only trouble being that ultraviolet has little application for high altitude use because of atmospheric interference problems. Anyway, once it appeared we had a real-time relationship with the surface oil slicks and fish schools, we went back and examined our photographic library, and came up with large numbers of indications of the oil slick phenomenon in association with schools.

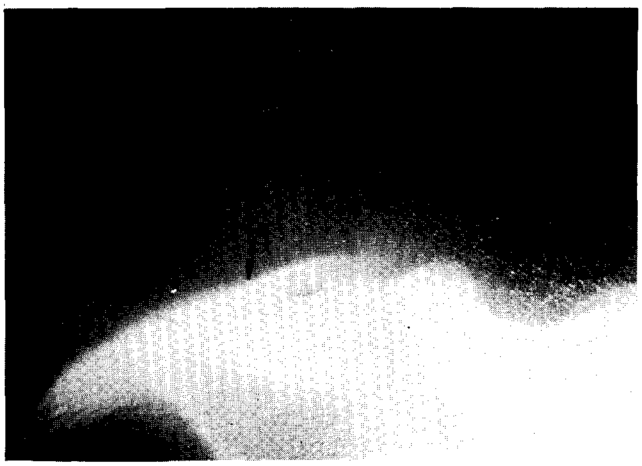

FIGURE 8. Infrared film images of anchovy schools in Gulf of Mexico.

Significantly, Barringer found that fish oil slicks differ from mineral oil slicks in that they have no color. They show (1) an opaque feature as in Figure 12 if you change the angle or (2) a glossy feature as in Figure 13. However, the color was identical to the surrounding environment. Mineral oil slicks have color characteristics and can be easily identified.

We looked at a number of species to see if we could find out which oils in the particular fish created the slicking phenomena. Fish oils apparently have characteristic absorption peaks, and those for mullet are plotted in Figure 14.

We found this immense school of 30-pound king mackerel (Fig. 15). We notified the local fleet of gill netters who extracted more than two million pounds from this single school. Previous year total landings from the west coast of Florida were under 1.2 million pounds.

Figure 16 shows a prototype bioluminescence detector based on equipment developed by the Army. The contract to develop this equipment costs the same as the entire BCF budget this fiscal year.

Here in Figure 17 is one of the first direct photographs of bioluminescence. This is a small school of Spanish mackerel seen from an altitude of about 80 feet. It was just barely visible with the naked eye, and here we are viewing it on a TV screen.

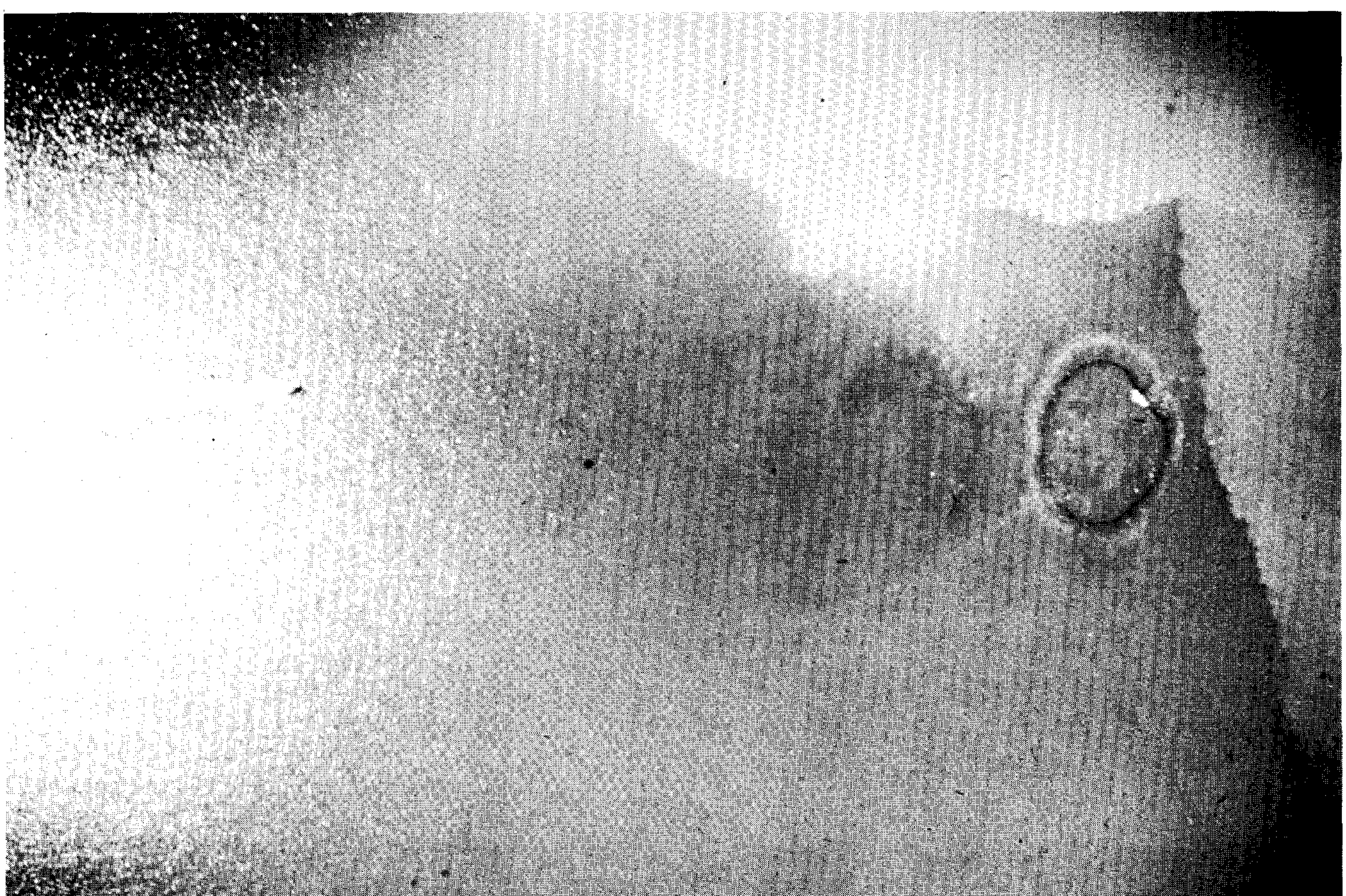

FIGURE 9. Sonar directed set around thread herring schools obscured by sediment cloud.

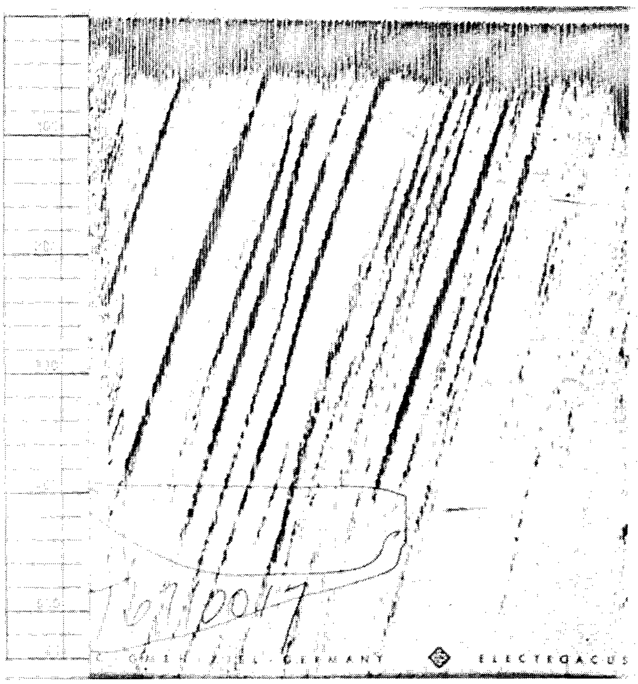

FIGURE 10. A sonar scanning directly ahead of the vessel running through turbid water.

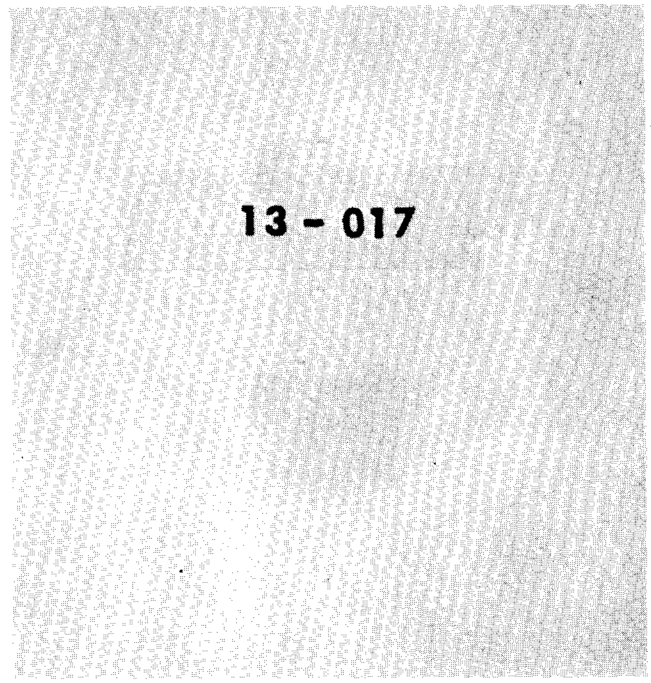

FIGURE 11. A small thread herring school, 75 feet across, that yielded 100,000 pounds.

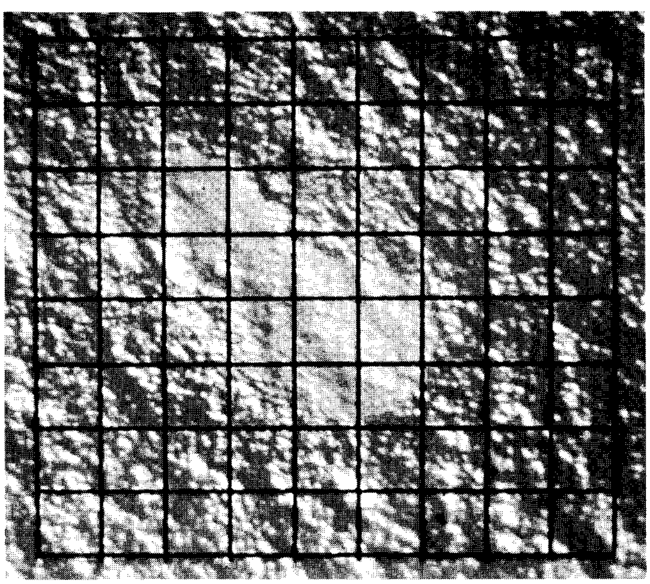

FIGURE 12. Opaque appearing fish oil slick.

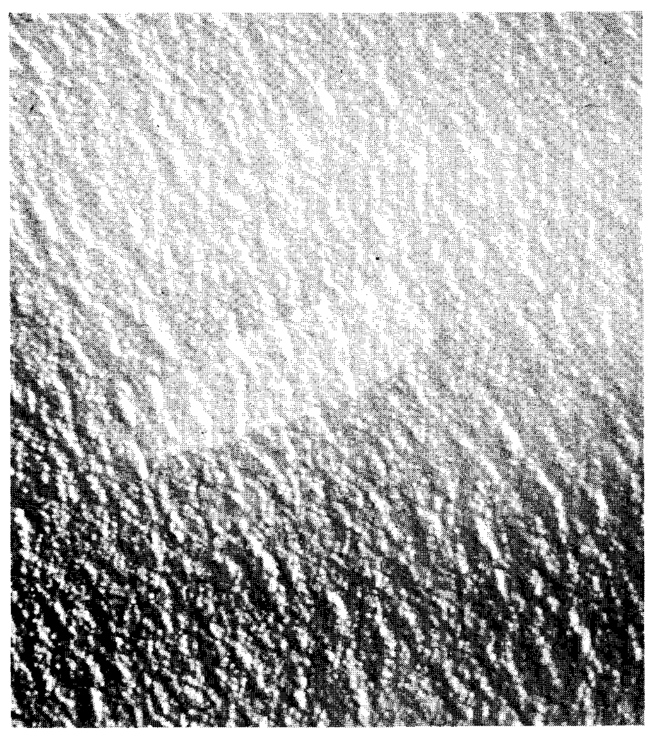

FIGURE 13. Glossy appearing fish oil slick.

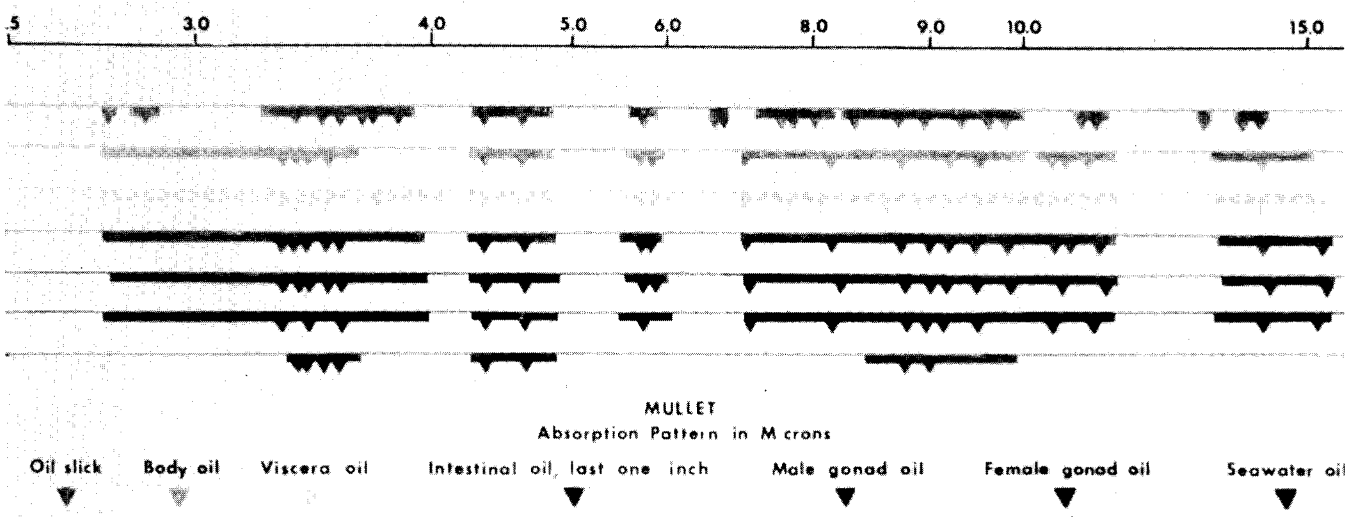

FIGURE 14. Absorption peaks of mullet oils.

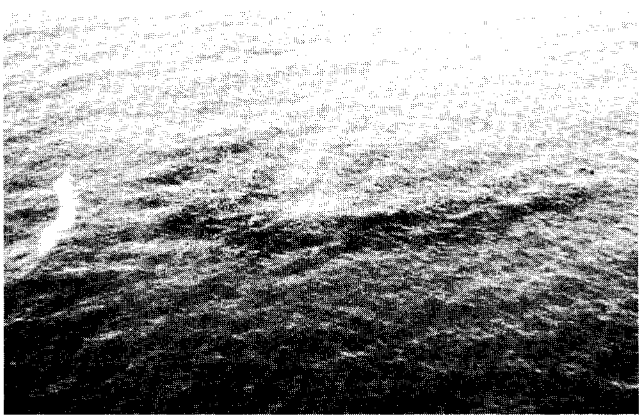

FIGURE 15. King mackerel school that yielded two million pounds.

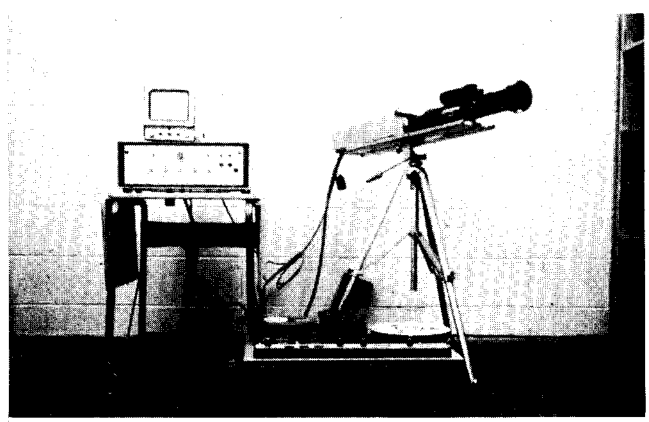

FIGURE 16. Prototype of newly developed bioluminescence detector.

DISCUSSION: Harvey Bullis—WORLD FISHERY TECHNOLOGY

Discussant: Phil M. Roedel

Roedel: A couple of comments before we get to the questions.

It has been interesting to me that in the last year or two all of our discussions with industry in California, and we have had many of them, have homed in on the need for exploratory fishing, gear development, and economic surveys as the most important things that Government can do today for the California fishing industry. Not that they regard what we are doing as unimportant—just that they feel that we, for a variety of reasons, are not carrying out work in these areas that the industry feels could result in a great deal of help to them.

With respect to sea surveys of pelagic fish, we in the Department of Fish and Game are at least guardedly optimistic that the techniques that are now being developed with our research vessel, the ALASKA, will pay off. The preliminary results in population size estimates for anchovies have been gratifyingly close to those developed by Dr. Ahlstrom through his egg and larva study.

With that, I think I will throw it open to general questions. Perhaps Dr. Chapman, from the initial remark, has first priority.

Chapman: No question.

——*:* Would the image intensifier work in the water that doesn't have phosphorescence?

Bullis: Yes. The point is that it amplifies light. This particular unit amplifies this light 40,000 times. We are now testing a unit that amplifies 90,000 times with much better optics. The capability exists to go farther with this. The difficulty is that we are operating this as a charity case. If it were not for the goodwill of other governmental agencies turning over this equipment to us, we couldn't afford to buy the off-on switch.

Chapman: Another thing is that water without luminescence in it hasn't much fish in it, ordinarily.

Bullis: Actually, this is a very preliminary estimate of what this equipment can do. We think that the equipment is so sensitive that you might be better off in areas of low bioluminescence. Most of the luminescent organisms we are dealing with are dinoflagellates and these have a very short period to their phenomenon. You can see that in the last two figures. The fish outlines very nicely. When it is frightened and takes off at a rapid swimming rate, it leaves a trail of fire behind it. If you had heavy bioluminescence in an area, then you could tune your instrument down and compensate for it, but the point is, even at very, very low levels, well below what you can see with the naked eye, the equipment is still able to record it.

——*:* Have you identified the source of the particular oils on the surface?

Bullis: No. We examined the stomach contents and the last inches of the gut, fecal matter, head oil, tissue oil, liver oil, and gonad oil. The spectral characteristics of each were very different. The testes, the ovaries, the stomach contents, the fecal matter, and body oils each had definable characteristics.

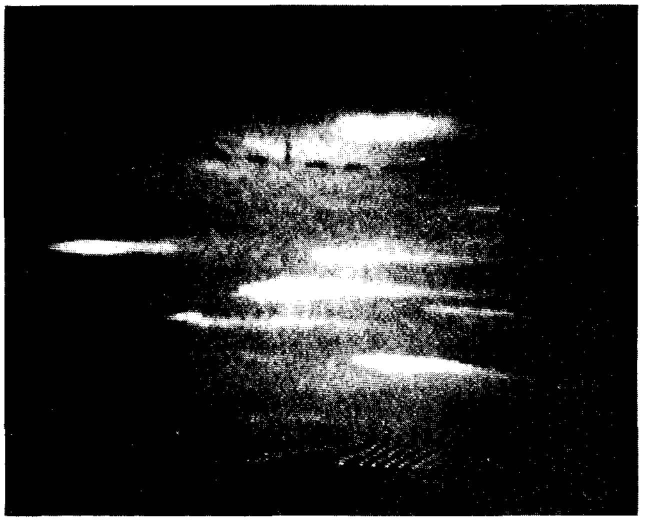

FIGURE 17. Bioluminescence associated with small school of Spanish mackerel.

——*:* Is it the same for all species of fish?

Bullis: No.

——*:* Stomach contents must vary depending on what it's been eating?

Bullis: The stomach content, yes. This is a hodgepodge and we examined a few of these and it didn't seem to be a very important consideration.

Isaacs: This oil phenomenon is an interesting one and I am delighted that you are working on it. I have read several times that fishermen could detect these oil films on the surface and also that the petrels are adapted to picking up oil droplets on the surface over fish that are being fed on by predators. At least one book also has referred to oil produced by the predators on these fish.

Bullis: One of the intriguing things about these oil slicks: Barringer found out that they had a very short duration, break up into small lenses very quickly, and then emulsification takes place rapidly. I suppose you could compare this to the joke about alligator eggs.

Isaacs: May I make a comment that goes back quite a bit in these discussions? I was rather astonished—no, not astonished, it sounded quite realistic—at this tendency of fishermen not wanting to accept greatly improved fisheries. This is an interesting matter because it tends, of course, to keep the poor, poor. How do you account for this? Is it that if a more effective fishery is developed that they will not be a part of it because they don't have the capital or because their boats are not adaptable to it? What is it?

Bullis: I think there are too many things that are acting here to pick out why this condition exists.

Chapman: Oh Harvey, it's the same thing with fishermen as it is with scientists, they don't want to think and they don't want to change.