WEST COAST MOLLUSC CULTURE:

A Present and Future Perspective

Proceedings of a California
Sea Grant Workshop
in cooperation with the
Pacific Sea Grant College Program

EDITOR,
Rosemary Amidei

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The California Sea Grant College Program is a statewide, multiuniversity program of marine research, advisory services, and educational activities administered by the University of California Institute of Marine Resources. Through the research it sponsors, Sea Grant contributes to the growing body of knowledge about our coastal and oceanic resources and helps solve contemporary problems in the marine sphere. Through its Marine Advisory Program, Sea Grant transfers information and technology developed in its research efforts to a wide community of users in California, the Pacific region, and the nation. Sea Grant also supports a range of educational programs for students, teachers, and the general public to promote the wise use of our coastal and oceanic resources by this and future generations.

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July 9–10, 1987

UNIVERSITY OF CALIFORNIA, BERKELEY

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I. WELCOME

JAMES J. SULLIVAN, Director, California Sea Grant College Program

It is my special pleasure to welcome you all here today. Before beginning, I want to thank the organizing committee that has worked so hard to pull this workshop together. James Lannan, who will provide an overview for our discussions, is a professor of fisheries with Oregon State University in Newport. Donal Manahan is with the Department of Biological Sciences at the University of Southern California in Los Angeles, and Lee Hansen is with the Whiskey Creek Oyster Farm, a major hatchery in Tillamook, Oregon. Lindy Nagata, assistant director of California Sea Grant, also deserves special recognition for her role in organizing this meeting.

Subject area meetings like this one play an increasingly important role in our proposal development process. As many of you know, the last few years have been difficult ones for Sea Grant, which has been essentially level-funded since 1981. In the face of rising costs for everything from salaries to equipment, there has been no option for state programs but to cut all major program areas—research, education, extension activities, and management—and to suspend initiation of many needed new projects.

In the program that I direct, the California Sea Grant College Program, we have found that one way to address our funding difficulties constructively is to work toward closer coordination among Sea Grant programs. In the Pacific states, this is accomplished in large part through our regional network—the Pacific Sea Grant College Program. Another solution is to use highly focused subject area meetings like this one, both to get an overview of the problems facing a particular resource or industry and to see what contributions university researchers and Sea Grant Extension personnel can make to solving those problems.

This particular meeting came about at the suggestion of the California Sea Grant Committee, which was faced last year with a number of preliminary proposals relating to molluscs. The committee suggested that it would be helpful for us to assemble industry representatives and university scientists from the Pacific Northwest to evaluate the status of the shellfish industry in this region, to get a sense of its problems, and to get the perspective of university researchers on what scientific contributions are necessary and feasible.

In addition to our main speakers, each of you in the audience can contribute a great deal to this meeting. I encourage you all to participate fully and thank you again for attending. Ken Chew of the University of Washington had hoped to attend, but he is away, and sends you all his regards.

Let me now introduce our Subject Area Coordinator for Fisheries and Aquaculture, Wallis Clark of Bodega Marine Laboratory, UC Davis.

II. INTRODUCTION

WALLIS H. CLARK, Jr., Bodega Marine Laboratory, University of California, Davis

Let me join Jim in welcoming you to this workshop and take just a minute to describe the subject area meeting we held last year on rockfish because it may suggest some possible courses of action to this group.

In January 1986, California Sea Grant's advisory committee on fisheries and aquaculture met to discuss possible new research directions for the program. One of its recommendations was that the program focus on an important fishery where research could have a significant impact in strengthening the fishery and mitigating impending problems. For a variety of reasons, the advisory committee suggested that rockfish warranted such a concerted, focused approach.

This advisory committee meeting was followed by a subject area meeting on rockfish, much like this one, which involved industry people, university scientists, and government agency representatives. It examined the rockfish fishery from present and future perspectives, examined whether research could make a significant contribution to its health, and identified, in a preliminary way, needed research topics.

As a result of the enthusiasm generated at this workshop, yet another smaller meeting was held at which university scientists worked together to refine ideas for possible research proposals. Subsequently, a number of rockfish proposals were received by Sea Grant, four of which are presently being funded.

I don't know whether this is the course the present meeting will take, but I do know that the very fact that we have assembled such a knowledgeable and diverse group of academicians, industry people, and government representatives from three Western states and Mexico ensures that we will gain significantly broadened perspectives on the mollusc industry.

We will also come away with a much wider circle of contacts who share similar interests and concerns. I always find this one of the most important results of workshops like this one.

You will see from the agenda that the workshop organizers have structured the meeting around three panel presentations--on public policy, implications of waste and environmental quality, and broodstock management and stock improvement. There will be time for questions and discussion after each of these presentations. In addition, there is a discussion period at the end of the meeting, to make sure that all concerns and areas of interest are aired.

To begin, James Lannan of the Hatfield Marine Science Center, Oregon State University, will give us an overview of the oyster fishery in terms of production and consumption.

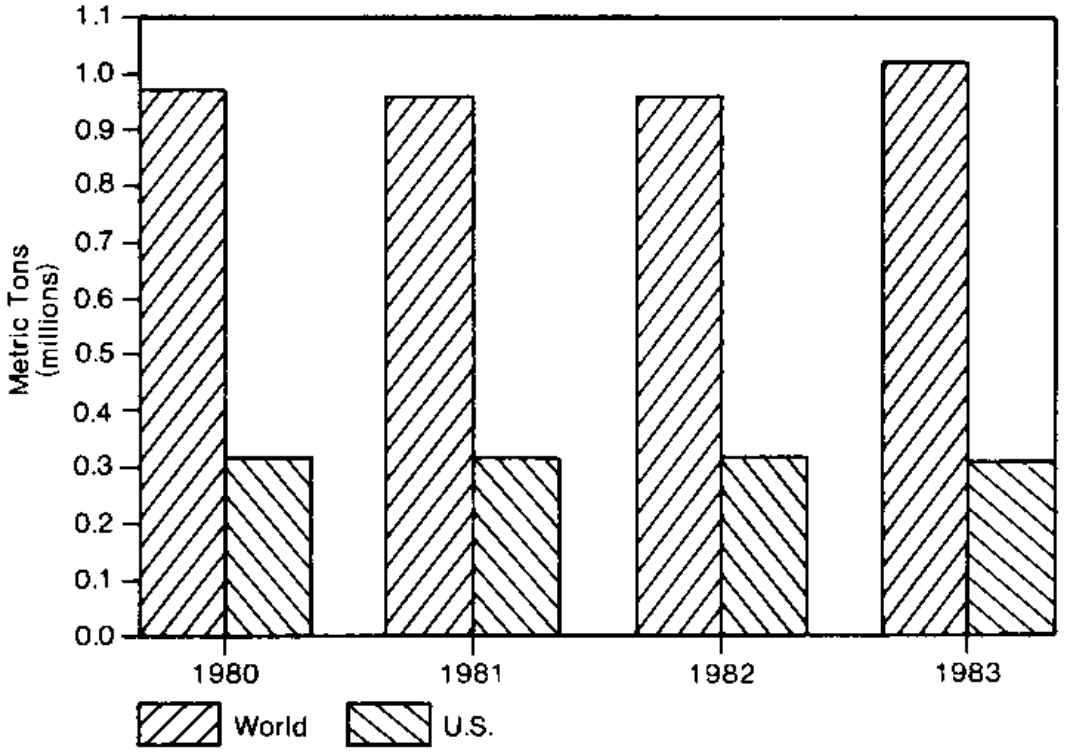
III. OVERVIEW OF WORLDWIDE OYSTER PRODUCTION

JAMES LANNAN, Professor of Fisheries, Hatfield Marine Science Center, Oregon State University, Newport, Oregon

In thinking about how to provide a useful overview for this meeting, I decided that statistics on world oyster production would be a good place to start. Such statistics might help those of us on the West Coast to see where we are relative to other regions, and to see what opportunities for growth are available to us. The figures I will present are from a variety of sources, but many are from the Food and Agriculture Organization (FAO) of the United Nations. I have not adjusted the data, hence it's important to keep an eye on units: some data are reported in metric units while others are in pounds or tons.

Figure 1, from the *FAO Yearbook of Fisheries Statistics*, shows world and U.S. oyster production in millions of metric tons from 1980 to 1983—the most recent year reported by FAO. One can see that world production over this period was relatively constant at about 1 million metric tons of oysters (whole weight).

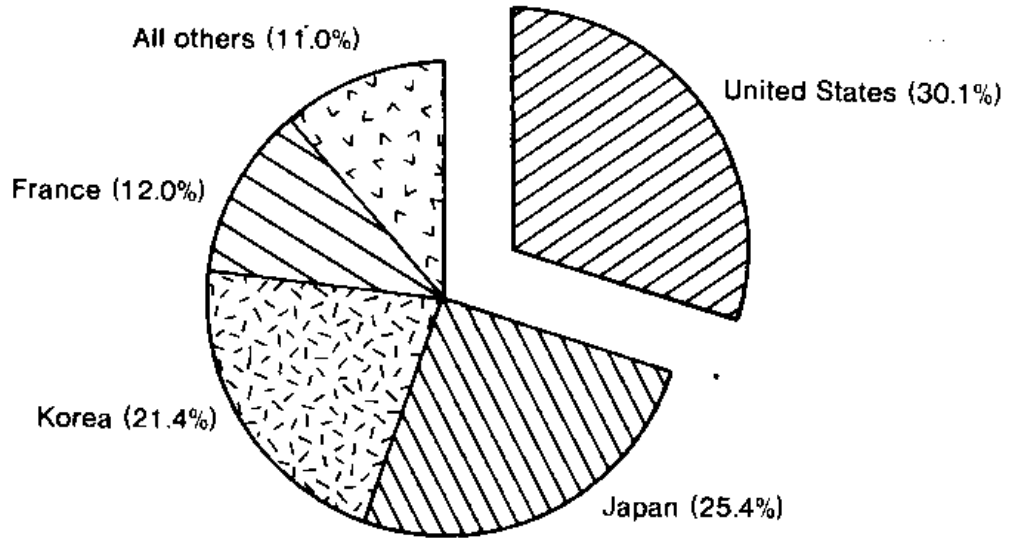
Figure 1. World and U.S. Oyster Production.*



*Source: *1983 Yearbook of Fisheries Statistics*, U.N. Food and Agriculture Organization.

Who is producing all those oysters? The U.S. produced slightly less than one-third of the share in 1983 and that proportion has remained relatively constant to the present time (Figure 2). Japan contributes about one-quarter of the world's oysters, Korea about 20%, and France 12%; all other countries reporting add up to about 11%. Figure 3 lists the countries that produce that remaining 11%. The interesting thing about the list

Figure 2. Major Oyster Producers, 1983.*



*Source: *1983 Yearbook of Fisheries Statistics*, U.N. Food and Agriculture Organization.

of minor producers is that ten years ago there would probably have been only half as many entries. Certainly in Latin America and in Africa there seems to be increasing interest in entering the market.

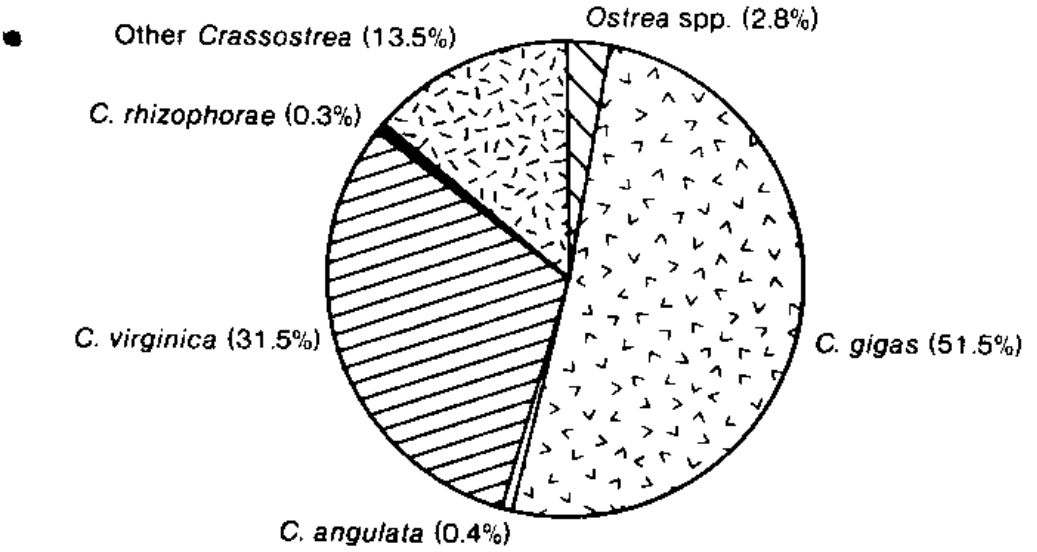
Figure 3. Minor Oyster Producers.*

German Federal Republic	Kenya	Australia
Ireland	South Africa	Indonesia
United Kingdom	Sierra Leone	Thailand
Netherlands	Senegal	Philippines
Spain	Turkey	Malaysia
Portugal	Yugoslavia	Mexico
Sweden	Brazil	Venezuela
Cuba	Colombia	Chile
Dominican Republic	Nicaragua	Jamaica

*Source: *1983 Yearbook of Fisheries Statistics*, U.N. Food and Agriculture Organization.

The term "oysters" includes a variety of molluscs, and Figure 4 shows how the production is distributed. The flat oysters (*Ostrea edulis, O. lurida,* and *O. chilensis* combined) total just under 3%. The Pacific oyster (*Crassostrea gigas*) dominates the world marketing scene with over 50% of production. *Crassostrea angulata* accounts for less than 1% of world production, while the American oyster, *C. virginica*, accounts for 31%; and *C. rhizophorae* less than 1%. All other species (which, in many cases, are varieties of these species that were not identified properly) total about 13%. Comparison of this chart with one made during the 1960s and '70s would illustrate that an increasing proportion of Pacific oysters are being marketed worldwide.

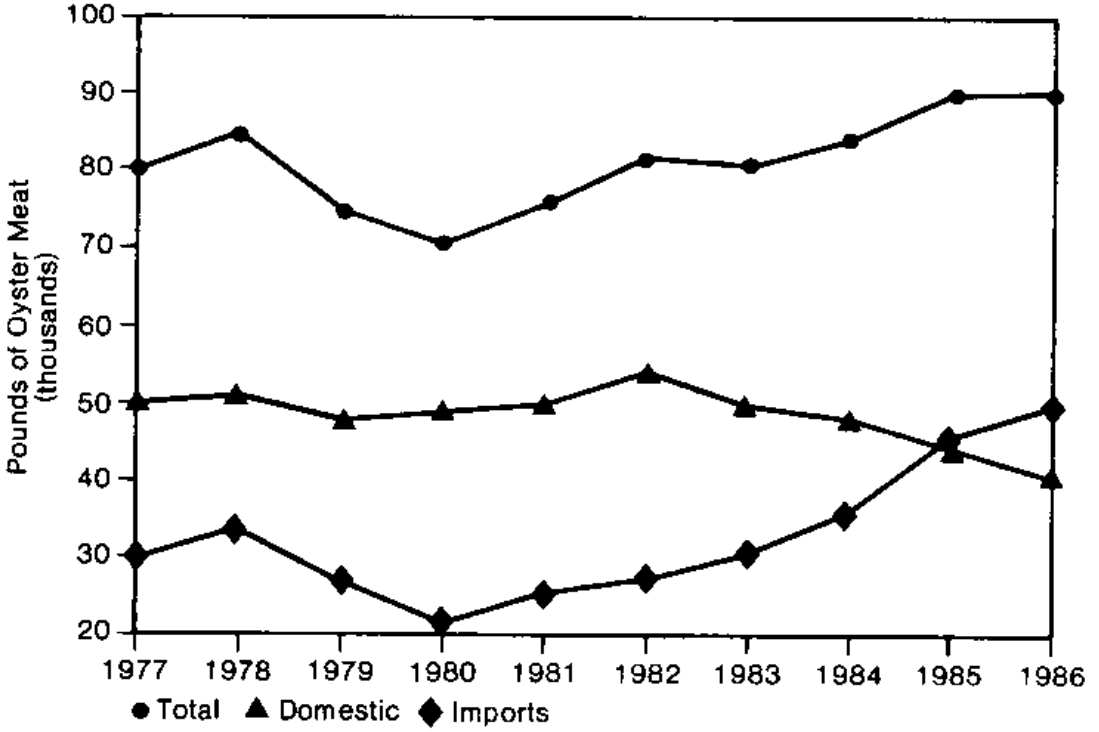
Figure 4. World Oyster Production by Species.*



*Source: *1983 Yearbook of Fisheries Statistics*, U.N. Food and Agriculture Organization.

Figure 5 demonstrates some rather astounding trends in U.S. oyster consumption. Total U.S. consumption has been ranging from about 80,000 to 90,000 pounds of meat annually. Note that since 1980 imports have risen from just over 20,000 pounds per year to their present level of over 50,000 pounds per year. Also

Figure 5. U.S. Oyster Consumption, 1977–86.*

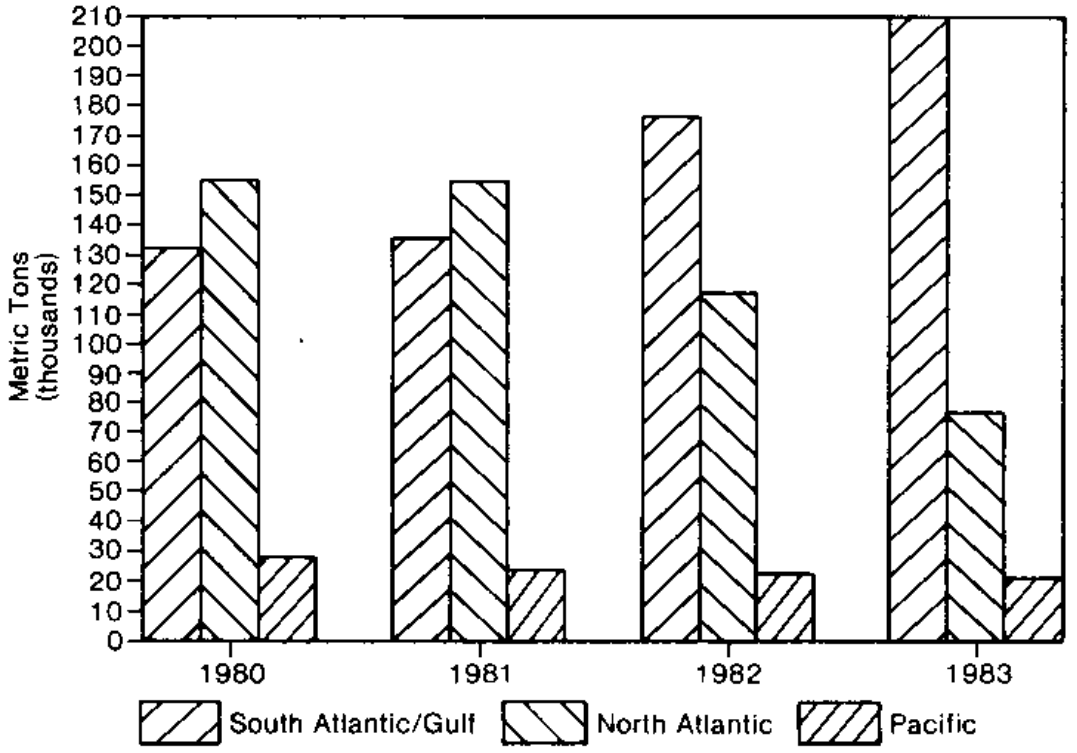


*Source: *Fisheries of the United States*, 1986, Current Fishery Statistics No. 8385, U.S. Department of Commerce, NOAA, National Marine Fisheries Service.

note that since 1985 imports have exceeded domestic production in the United States.

Where does North American production occur? Figure 6 presents U.S. oyster production by region. One can see that the South Atlantic and Gulf states now account for the greatest production, followed by the North Atlantic, where production has been declining rapidly because of deteriorating environmental quality and infectious diseases. The Pacific coast has a relatively small, but significant, proportion of the total U.S. production, hovering at about 20,000 metric tons annually.

Figure 6. U.S. Production by Region.*



*Source: *1983 Yearbook of Fisheries Statistics*, U.N. Food and Agriculture Organization.

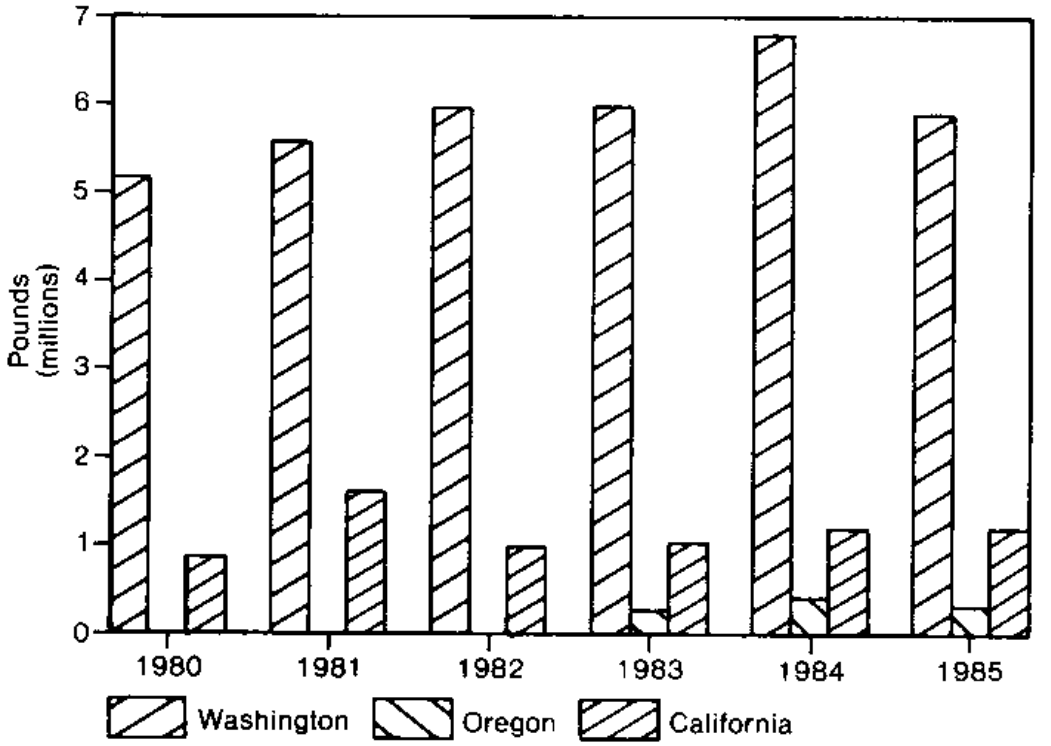
On the West Coast (Figure 7), Washington is the largest producer (80% in 1985), followed by California (16%), and then Oregon (less than 5%).

What can we conclude from this? I think it's clear from import trends that there are opportunities for increased marketing of oysters worldwide, and certainly in the United States. I also think there are opportunities for West Coast growers to expand into Eastern, Midwestern, and Gulf markets if they desire to do so.

Where do we want to go in the future? Do we want to increase production and address new markets? I'm not sure. I know some growers who would like to expand and some who would like to stay just the way they are. I know others who would like to go back to the good old days.

There are a variety of questions that it would be useful for us

Figure 7. U.S. West Coast Production by State, 1980–85.*



*Source 1983 Yearbook of Fisheries Statistics, U.N. Food and Agriculture Organization.

to discuss in this forum on mollusc culture. Lee Hansen, Donal Manahan, and I have proposed three major categories under which we believe that most concerns can be discussed, and we've organized the workshop around these categories: (1) implications of public policy, (2) implications of waste and environmental quality, and (3) broodstock management and stock improvement. We have also reserved a fourth session of uncommitted time and will be making notes on additional questions that might be worth airing in this forum.

The first area, public policy, embraces a number of issues familiar to everyone. For example, the sanitation situation is reaching critical proportions, and all of our futures are going to depend on what happens there. There are other policy issues that are not as obvious, but are worth discussing. For example, we have a good mix of people from the public and private sectors here, and it might be worthwhile to discuss how we should relate to each other in the short- and long-term future. I think it is important to re-evaluate this relationship from time to time because, like a pendulum, it swings back and forth. Sometimes industry seems to drive the public sector. Then the pendulum swings to the other side, and we find people in public positions seeming to suggest that industry exists to support the public sector.

The second area deals with environmental quality. We plan to discuss such technical issues as how to make better use of marginal grounds, how to control pests on grounds, and so on.

The final area we have called "broodstock development and stock management" for lack of a better phrase. We are really thinking of a very broad area encompassing hatchery problems and contemporary situations affecting seed oysters and other molluscs. Opportunities for improvement of stocks through selective breeding and better broodstock management are topics of interest to most of us.

There will necessarily be a great deal of overlap because I doubt that we can discuss broodstock management or environmental quality without touching on policy issues. And when we try to tackle policy issues directly, we are going to have questions arising that relate to seed production and so on.

I would like now to introduce our first panel moderator, who, although not formally a member of our steering committee, put in an extraordinary amount of work on this program. Fred Conte from Cooperative Extension at the University of California, Davis, and California Sea Grant's aquaculture specialist, will moderate the session on public policy.

IV. IMPLICATIONS OF PUBLIC POLICY FOR MOLLUSC CULTURE

FRED CONTE, Moderator, UC Cooperative Extension and California Sea Grant Aquaculture Specialist, University of California, Davis

JOHN PITTS, Washington Department of Agriculture, Olympia, Washington

DOUGLAS PRICE, Shellfish Specialist, California Department of Health Services, Santa Rosa, California

WILLIAM RODRIGUEZ, California Regional Water Control Board, Santa Rosa, California

F. ROBERT STUDDERT, Attorney, San Rafael, California

FRED CONTE

We will begin our discussion of the implications of public policy for mollusc culture with short presentations by four panel members. The first speaker will be John Pitts who is from the aquaculture development section of the Washington Department of Agriculture, Olympia, Washington. The second is Douglas Price from the California Department of Health Services. Doug works closely with the oyster and shellfish industries in California and has been instrumental in encouraging the Department and the industry to work together for a better environment in California. The third speaker is Bill Rodriguez, who is with the California Regional Water Quality Control Board, Northern Region, Santa Rosa, California. Bill has also worked very closely with the shellfish industry. The fourth speaker is Bob Studdert, an attorney, who represents a number of aquaculture companies. Bob has worked closely with the university and with Sea Grant on sanitation and other issues relating to regulation.

Water Quality and Shellfish Aquaculture in Washington State

JOHN PITTS

I'd like to begin by giving you an idea of where we in Washington State stand with regard to improving water quality and developing the aquaculture industry. In 1984 we had a gubernatorial election in which both candidates supported water quality as part of their platforms. In 1985 the legislature established the Puget Sound Water Quality Authority, an agency headed by seven members appointed by the governor. Its charge was to develop a comprehensive plan to protect and enhance the water quality in Puget Sound. That plan is now complete. Then in 1986, the legislature decided to fund the activities of the Puget Sound Water Quality Authority through a cigarette tax.

This year, 1987, the Water Quality Authority introduced and supported four bills. Of those four, only one passed—a centerpiece plan for shellfish protection. But as a result of funding cutbacks in the Department of Ecology, which is in charge of water quality, only about half the funds that were

supposed to be provided for the Water Quality Authority were available. The Authority is presently regrouping, trying to reset priorities.

In the meantime, the Department of Ecology is moving forward with its watershed planning grants. Local governments will identify problems within their own communities and map their watersheds. The Department of Ecology will then oversee those plans over the next several years. This department is also charged to try to open three decertified commercial shellfish beds by 1990. About a third of the commercial beds in the Puget Sound have been closed, eight within the last six years. In addition, the Department of Social and Health Services (DSHS) will use some of the cigarette tax money to double its shellfish staff to twenty people within the next few months. It will increase its monitoring of commercial beds, work with the Department of Ecology to reopen decertified beds, increase its monitoring of processing plants and shipping standards for shellfish, increase patrols of decertified areas, increase and develop a toxics program along with the Environmental Protection Agency, and develop a program for recreational shellfish in our state. (It has been very disconcerting to know that nobody was really responsible for recreational shellfish. Only recently have the Department of Ecology, the Department of Social and Health Services, local Indian tribes, and local health departments met to develop such a program.) DSHS is also developing a position paper in regard to depuration, which should be available within the next few months.

So the shellfish goals for the state through the Water Quality Authority are both to protect the health of the consumer and also to enhance the abundance of shellfish in our state, which is important to both the commercial and recreational industries. But responsibility for meeting aquaculture development goals falls to the newly created Aquaculture Development Section of the State Department of Agriculture.

What are the chances of the Puget Sound Water Quality Authority being effective? I could certainly do an effective job with a couple million dollars a year and a staff—and if we could move about three million people out of western Washington and shut down all the commerce. That's obviously not going to happen, but I do think that some very positive things are going to happen. Water quality was a gubernatorial issue two years ago, and it remains high in the minds of voters in our state. The only thing people have not recognized is that this is going to cost something. When that realization comes, there might be some changes in position.

There's a lot of fingerpointing going on, as there always is. If you are an upland landowner, septic tanks are not the problem; something else is. In many cases, the problem turns out to be the

increasing seal population in Puget Sound—I guess because seals don't vote.

Local governments have a tremendous role to play. They are best able to identify problem areas within their local jurisdiction, and I believe that they have a strong charge to educate local constituents about the importance of water quality. I also believe there must be a local investment, not only in time, but in money. It is important for people to know that they have an important role in maintaining good water quality and passing it on to their children.

What problems do I see in making this work? I do not see much of a problem in regard to public policy, but I do have concerns about private policy within the public sector. I see enervating turf wars going on among agencies to see which is going to be the lead agency and which ultimately is going to get the largest bundle of money. (Part of my job as the Aquaculture Coordinator is to be a facilitator between state agencies.) We are going to have to recognize that as costs go up, we will have to cooperate a lot more to achieve our common goal of water quality.

Cooperation should also include academia. There are certain academics who are extremely aloof in this process, and I would like to encourage them to participate more both with industry and government. I don't want to leave the impression that I want the university to start making policy decisions, but there needs to be a great deal more interaction between academics and our decision-makers. I also believe that government and universities need to become more closely involved with industry. Industry has a tremendous amount to offer to the public sector. There's a great deal of wisdom there and a tradition of on-the-spot problem solving that can be helpful. By developing a close relationship between the universities, industry, and government, we can resolve some of the problems we now face.

Protecting the Public from Environmental Health Hazards

DOUGLAS PRICE

I'm with the California Department of Health Services, Environmental Health Division. It is our general mandate to protect the public from environmental health hazards, and we have a direct involvement with both the commercial shellfishing industry and the sport harvesters.

Shellfish harvested from polluted waters can pose a health risk for several reasons. Shellfish are filter feeders, they are eaten whole, they are often eaten raw or only partially cooked, and they are a very suitable medium for bacterial growth if handled in an

unsanitary manner. My agency, the Environmental Health Division, is concerned primarily with water quality assessment and classification; the Food and Drug Branch makes sure that handling and packaging is done in a proper manner.

My agency is also involved with the program to prevent paralytic shellfish poisoning (PSP) in California. This is a major program that needs considerably more public support and funds. I evaluate and classify all the commercial shellfish growing areas in the state, certify commercial operations, and coordinate the PSP monitoring program.

California's Aquaculture Development Act, passed in 1979 and amended in 1982, gave the Department of Fish and Game a mandate to promote commercial aquaculture, including mariculture. As a consequence of that bill, we have seen a dramatic growth in shellfish mariculture, probably a doubling of the number of growing areas in the state and an easy doubling of operations. This growth of the industry in response to political and public support has created some problems for us as a regulatory agency. Our job is to protect the consumer from health problems known to be associated with shellfish grown in polluted waters or which contain the toxins responsible for paralytic shellfish poisoning. We got no additional funds for these responsibilities through the Aquaculture Development Act; we were simply given the job of health protection in a growing industry. As a result our resources and staff have been spread thinner and thinner over the past several years, and we are not able to do everything that we should to ensure health safety.

The California Shellfish Program is part of the Interstate Shellfish Sanitation Conference (ISSC), a national program composed of states that produce shellfish (i.e., all the coastal states) and a number of receiving states. The U.S. Food and Drug Administration (FDA) evaluates state programs, and it has been telling California for the last several years that we need to be doing more of just about everything: more monitoring, more surveys, more sanitary surveys of growing areas. To put teeth behind their admonitions, FDA has even threatened to decertify interstate shipments of California shellfish.[1]

It's important to understand that threatened decertification of California shellfish by FDA is not based on the argument that our shellfish aren't safe to eat. They are. We have good-quality shellfish. It is based on the fact that our state program has failed to develop a health program on shellfish that is in compliance with the ISSC Manual of Operations.

As a result of this threat, my plea for additional staffing and funds has finally been heard, and we're going to beef up the

[1]Decertification of the California Shellfish Sanitation Program was avoided by a commitment by the State to strengthen the program through additional staffing and funds. New staff members have been hired and comprehensive monitoring and PSP prevention programs are being developed.

program considerably. We're going to see a tightening of the regulatory program and more protection for consumers from the possibility of paralytic shellfish poisoning. And that is good for the industry. There's nothing that would hurt this growing industry more than to have a disease outbreak traced to California shellfish or to have another PSP outbreak such as the one in 1980 in which two people died and about 100 people were hospitalized. It is very important to the industry that health protection be ensured.

Because of the expansion of the industry in California we are getting requests to do mariculture operations in a lot of places that are very difficult and even hazardous to get to, places we cannot adequately control. Open ocean culture, for example, poses a problem with regard to paralytic shellfish poisoning. Santa Catalina Island, as another example, is a beautiful place to grow shellfish, but we can't just drop by to see how things are going. It's a major trip. So as the industry spreads over the state, our job gets more complicated.

And every time a new mariculture project is proposed, we are required to do a sanitary survey, which costs $10,000 to $20,000. We just don't have the funds. I think the Health Department, working closely with Fish and Game, needs to develop a state plan that concentrates maricultural activities in particular areas so that they are not scattered far and wide.

Improving Water Quality in Humboldt Bay

WILLIAM RODRIGUEZ

I work for the California Water Quality Control Board, north coast region, and and have been involved with the shellfish industry for a number of years. The regional board's responsibility is to maintain water quality in the state. We implement a wide variety of policies developed by agencies such as the Department of Health Services, our own agency, and our parent agency, the State Resources Control Board in Sacramento. We also cooperate with a number of federal agencies, including the FDA and EPA. California is a delegated state. We write the NPDS permits for all the wastewater treatment plants in the state.

My discussion today will focus on Humboldt Bay and state policies. With regard to commercially grown molluscs, probably the most important policy is the Bays and Estuaries Policy since most oysters are cultured in these areas. This policy says simply that you shall not discharge wastewater to an enclosed bay or estuary.

In Humboldt Bay, prior to 1986, about eight wastewater

treatment plants discharged to the bay, two of them from major population centers, the cities of Arcata and Eureka. A primary treatment plant that handled all of the wastewater in Eureka had serious problems. There were numerous failures of on-site systems: septic tanks, garbage dumps, and overflowing clarifiers discharged to the bay. Somebody just mentioned the good old days—*those* were the good old days. The bay had closure periods that sometimes lasted for the greater part of the winter, during which no harvesting of shellfish could occur. Dye studies on the outfall from all these treatment plants showed that within any given tidal cycle, wastewater covered the growing areas. FDA studied the conditions and concluded that we shouldn't even be harvesting oysters up there.

As a result, the regional board embarked upon a program to improve wastewater treatment facilities based on regulations from the EPA and our own basin plan. It was proposed that there be a regional wastewater treatment facility: all the wastewater would be collected at one point, treated, and discharged to the ocean. Although this was a good, comprehensive plan, it wasn't politically acceptable. There were too many competing agencies and conflicting community desires. In the end, the regional concept failed miserably and was finally abandoned in 1979.

As a result, the city of Eureka constructed a state-of-the-art secondary wastewater treatment plant to replace the one that was overflowing. And it met the prohibition against discharging to the estuary in a rather creative manner. City officials decided to build their treatment plant near the mouth of the bay, to collect wastewater, treat it, and then to discharge it only on the ebbing tide. Between tides, wastewater is stored in a large pond, and on the ebbing tide it is pumped out and leaves the bay, supposedly never to return. We've done dye studies that show the idea is working. The city also replaced extensive collection systems and leaking pipelines that discharged wastewater to the bay.

The city of Arcata took a different approach. Arcata's wastewater treatment plant sat right on the edge of the bay. Drawing on the resources of Humboldt State University and a grant from the State Water Resources Control Board, the city reconstructed its entire treatment plant. Wastewater is now treated to secondary levels, disinfected, and run through a marsh system. It is then brought back to the plant, disinfected, and discharged to the bay.

We in the Water Quality Control Board maintain a number of ongoing monitoring programs. Although we don't do any bacterial monitoring in the bay related to the shellfish harvesting area, we do have a Mussel Watch program that assists us in assessing other things, such as toxicity problems. With this program we have been able to detect problems with toxic compounds such as penta- and tetrachlorophenols, which are used by the wood

industry, and with metals, discharges, etc. It's given us the opportunity to control some of those things.

We have taken care of the majority of problems caused by municipal wastes in the bay. The bacterial level has improved significantly over what it was just a few short years ago. Our next concern will be the impacts on the bay of dairy farms and agricultural activities. As you may know, agriculture holds a special place in the hearts of Californians, and it is difficult to implement policies to control waste from agricultural uses.

We were talking earlier of costs. This whole program of wastewater treatment plants and collectors at Humboldt Bay, not including closure of disposal sites, cost about $50 million. Most of that was paid for through clean water grant programs, federal and state, but about 20% came from local shares. This demonstrates that there is significant interest at the local level in cleaning up our bays and estuaries.

Public Policy Considerations in Oyster Culture

F. ROBERT STUDDERT

I'm an attorney who represents various members of the saltwater and freshwater aquaculture industry on the West Coast. I have been involved with the legislation that you heard Doug Price speak of earlier, having to do with aquaculture development in California. I am also the bad guy who brought lawsuits against the dischargers in Morro Bay and the Santa Barbara Channel on behalf of the oyster growers there.

The oyster industry is one of the West Coast's oldest aquaculture activities and one of the most heavily regulated industries on the coast. Sanitation laws and regulations regarding shellfish are administered by federal, state, and local agencies. Shellfish beds are often situated on state water bottom allotments and subject to California Department of Fish and Game regulation; harvesting is a coastal dependent use subject to the California Coastal Act and most local coastal planning groups. Shellfish harvesting for human consumption is a priority beneficial use under both federal and state water quality control acts. Add to that a spectrum of agencies such as the Corps of Engineers, Coast Guard, U.S. Fish and Wildlife Service, National Marine Fisheries Service, State Lands Commission, Local Harbor Districts, Tide Land Regulators, etc., and you have an industry that is fraught with public policy implications.

I once counted the federal, state, and local agencies having concurrent jurisdiction over Johnson Oyster Company, located at Drakes Estero, a case that is somewhat complicated by the fact

that the operation is situated in a national park—the Pt. Reyes National Seashore. I found that 32 agencies actively exercise concurrent regulatory jurisdiction over that company. Hard to believe! So, the oyster industry is touched on all four corners by public policy.

Shellfish sanitation and marine pollution probably present the largest areas of public policy concern. In recent years, oyster production in both Morro Bay and the Santa Barbara Channel has been shut down because of marine pollution stemming from point source discharge into those waters. The previously held assumption that "dilution is the solution" regarding ocean outfalls has been seriously questioned as we learn more about how effluent plumes behave in the open ocean.

The Santa Barbara Channel incident, for example, has taught us that undisinfected discharge of sewage may travel in the open ocean much farther than previously thought. The Santa Barbara mariculture site is located five miles downcoast of an ocean outfall receiving primary treatment and five miles upcoast of an ocean outfall receiving secondary treatment. It's hard to say which outfall affects the oyster growing site. With respect to the primary treated outfall, it appears that the die-off rate of coliform bacteria is not what we thought it to be because of their insulation by effluent particulates against seawater contact. On the other hand, prevailing upcoast currents could persistently expose the oysters to the effluent field from the secondary treatment outfall. In short, the effects of current speed, thermoclines, and bottom configuration could result in either effluent plume being transported to much greater distances than predicted. We are presently half way through a study of the downcoast plume, using oysters suspended at the mid-depth contour.

In Morro Bay, we had an undisinfected outfall discharging in 50 feet of water, 3,000 feet offshore and 9,000 feet from the mouth of Morro Bay. Using coliform bacteria testing, dye testing, and drogue studies, we found that large volumes of sewage-contaminated seawater were present daily at the mouth of Morro Bay, available for transport into the bay on flood tides.

Hence, while we have done a lot of pollution-related research, many unanswered questions remain. As I understand it, the coliform bacteria that health regulators use as indicator organisms to manage shellfish growing areas (namely, *E. coli*) simply indicate that they originated in the intestine of a warm-blooded animal, but do not distinguish between human and animal waste. The fecal-strip testing presently employed to make that distinction is said to be unreliable. *E. coli* standards are being looked at on the Gulf and East coasts, but we're told that *E. coli* vs. fecal standards in the colder Pacific waters will make little difference in the test results. Research being conducted by Cabelli et al. on the East Coast with the *enterococci* indicator

organisms holds some promise, but we still have a long way to go in finding an indicator organism that will accurately reflect the health risk to humans associated with eating filter-feeding shellfish.

Nonpoint pollution also impacts the shellfish grower. The tool used by public health regulators to manage nonpoint problems is the "rainfall closure." That is, following *x* amount of rain in a given period, shellfish beds are closed to harvesting operations for *y* days (e.g., 2-day closure following ½ inch rainfall, 3-day closure following 3/4 inch rainfall, and so on depending on the site). There is no "formula" for a rainfall closure, *per se*. It varies from bay to bay, depending on a number of factors—e.g., degree of tidal flushing, initial bacterial concentration, extent and character of the watershed drainage. Basically, health regulators look at the time it takes for *coliform* levels to fall to an acceptable point, add in a safety factor, and arrive at a closure period.

Rainfall closure "formulas" are based, for the most part, on very infrequent sanitary surveys conducted jointly by the FDA and state health authorities. Most state health agencies do not have the resources to conduct frequent comprehensive sanitary surveys of the growing areas. The surveys involve moving fully equipped mobile laboratories on site; the assembly and transportation of a team from the Northeast Technical Services Unit of the FDA at Rhode Island; mustering the boat and technical support staffs; and, in the case of point-source studies, developing dye testing protocols. The last comprehensive sanitary survey on Arcata Bay, for example, was in the late 1970s.

Timing of the survey is critical. In non-point cases, the survey is always performed during the rainy season. However, the survey does not always coincide with a typical rainfall event. Moreover, other complications arise. For example, we are planning a sanitary survey of Arcata Bay in late January 1988. This coincides with the herring spawn and a period of big tides—high highs and low lows. At low tide, sea birds feeding on the herring eggs on the tidal flats deposit fecal matter, which is flushed into the bay on the next high tide. During the low tides, the water coliform counts are relatively low; however, the intertidal exposure of the shellfish meats may result in high coliform shellfish meat counts. Under such circumstances, there is a big question of interpretation of the data, and coliform counts are far from a precise measurement tool. Timing is also an element in sanitary surveys conducted on deep water or ocean mariculture sites. Santa Barbara Channel is a good case in point. First of all, NETSU has not performed a lot of open ocean surveys. Survey results are subject to many variables, e.g., dilution, up-coast or down-coast currents, whether or not the current is strong, moderate, or sluggish. There is a question as to how adequate our present dye-testing techniques will be in the open ocean.

In any event, between sanitary surveys, the shellfish grower has to live with a closure restriction that may, or may not, reflect actual water quality.

Humboldt Bay is a prime example of the problems with this policy. As you heard from Bill Rodriguez, vast improvements were made in wastewater treatment facilities that discharge into Humboldt and Arcata bays, yet Coast Oyster Company, the principal shellfish grower there, was shut down as many as 125 days per year on rainfall restrictions. The economic impact and operational disruption of such closures is dramatic.

A computerized monitoring program undertaken by UC Cooperative Extension and the Sea Grant marine advisor for the Humboldt Bay area promises to address some of the rainfall closure dilemma. It also verifies the effect of the improvement of point source facilities there. The program takes into consideration rainfall events, tides, water, shellfish meat coliform counts, and necessary elapsed time for the growing waters and shellfish to attain acceptable coliform levels. By adding more data, more samples per station, salinity measurements, watershed rainfall amounts, stream flow rates, and so on, we should achieve an invaluable tool for estabishing rainfall closures in Humboldt Bay. Not only does the program provide ongoing surveillance on how closures are working, but it gives the sanitary survey team a body of translated data, which previously was a jumble of information. The effort is being watched by other states and by FDA's technical service unit. It is a good example of the research community helping to resolve a very difficult problem.

Another problem of concern to West Coast growers is the loss of habitat from ghost and mud shrimp infestation. As shrimp populations on oyster beds increase, they slowly raise the sediment level of the beds, smothering any seed or adult oysters present. The most significant problem occurs in Washington's Grays Harbor and Willapa Bay, but it also threatens California. In Washington, the pesticide Sevin is used to control burrowing shrimp on oyster beds. Today, I understand that about 2,200 acres have been treated with Sevin, of which 1,870 acres are prime oyster fattening beds. I need not tell you that the use of Sevin is an emotionally charged public issue that creates an image problem for the industry. What is needed is the development of a nonpesticide alternative to control burrowing shrimp. Otherwise, the industry will be subjected year after year to preparation of Environmental Impact Statements and to public outcry.

The siting of mollusc culture facilities also presents problems that can be addressed by the research community. Most aquaculture activity is compatible with environmental interests and other marine uses. However, conflicts do arise between aquaculture and environmental interests, between agencies

having responsibility for siting aquaculture facilities, and between aquaculture and commercial fishing interests.

To cite a few examples, some years back at Elkhorn Slough, the Moss Landing Marine Laboratory helped in assessing the environmental impact of aquaculture expansion in that area, which adjoins a U.S. Fish and Wildlife sanctuary. More recently, the siting of an abalone-culture facility on the Santa Barbara/San Luis Obispo border at the Guadalupe River gave rise to an agency conflict between the Department of Fish and Game and local coastal planners in Santa Barbara county, with the abalone growers caught in the middle. The issue: wetland protection. Conflicts often arise between commercial fishing interests and open-ocean siting of aquaculture facilities. Last year in the Santa Barbara Channel, both the commercial fishing and aquaculture interests expressed concern at the loss of gear and indemnification of that gear arising from their competing use of the channel. The problem spawned legislation that was ultimately vetoed by the Governor and resulted in new regulations by the Department of Fish and Game. In some cases, the marine advisor for an area has been able to intervene in an effort to defuse the situation. As aquaculture increases, I think we can expect to see more of these conflicts, and we'll have a greater need for intervention.

Though not connected to any specific policy concern, a very critical research need for the industry relates to the summer mortality losses that have plagued growers over the years. Little seems to be known about summer mortality, except that it affects primarily the adult population. We do know that it has resulted in losses as high as 75% of the crop and that one grower alone sustained a loss in the neighborhood of $400,000. The only way industry can combat summer mortality is by keeping the numbers of adults as low as possible, an awkward and often impractical tactic. The subject deserves more attention.

A later part of this program will address broodstock management and stock improvement in mollusc culture. One would think those areas would be without policy implications. Not so. A bill introduced in the California legislature by Senator Torres, SB 844, concerns biotechnology. It would require both private persons and public agencies to obtain permits before releasing "novel" organisms into the open environment. Organisms subject to the bill are those resulting from any genetic modification—that is, deletion, rearrangement, alteration, or other change in the chromosomal structure. We don't believe that the legislative intent of the bill was to affect the polyploidy work underway at the Bodega Marine Laboratory and are seeking clarification from its author. But bills such as this one have the potential of adding yet another regulatory layer to the mollusc industry.

Conte: We are trying to identify how university research and other resources might be used to address industry problems. Specifically, as Jim Sullivan has said, Sea Grant is looking for input of this type. Are there any questions or comments?

Manahan: It occurs to me that the value of the aquaculture industry around Humboldt Bay must be a small fraction of the $50 million that Bill Rodriguez said was spent to improve wastewater treatment there. How can we justify that kind of expenditure? Wouldn't it be much easier for the federal agencies to shut down the oyster industries in Oregon and California, since they are relatively small? What kind of justification should we be using to make sure that we get as much money as we require for clean water.

Studdert: The concern about water quality is much broader than just the shellfish industry. We're worried about the whole marine environment, recreational uses, etc. As far as I know, the argument for water quality has never been made on the basis of a cost-benefit analysis such as you suggest. Besides that, providing shellfish for human consumption is a mandated beneficial use.

Rodriguez: The nation as a whole and the state in particular have declared that waters should be clean for all kinds of uses, even purely aesthetic uses. You should be able to swim in them, use them recreationally, catch fish—all of those things. The oyster industry's requirements represent just a small part of that argument.

Conte: Although the oyster industry was the first to voice concern about effluent in the Morro Bay and Santa Barbara areas, there was not much progress until people representing the Sierra Club, fishing industries, and recreational industries jumped aboard and made the same demands that we protect the quality of the bay. One reason that the oyster industry figures prominently in debates about water quality is that oysters are excellent indicators of quality—they are one of the first monitoring sentinels we have.

Clark: Is there really some headway being made in water quality? We hear that numerous requests are being made for waivers from Clean Water Act requirements for full secondary treatment of wastewater pumped into the ocean, according to Section 301(h) provisions that allow case-by-case modifications of the requirements.[2] We hear that more and more pollution is being dumped into water legally, that federal monies are drying up, that cities no longer have monies available to clean up sewage.

Price: I'm not sure what the long-term trends will be but the immediate result of the work in the Santa Barbara Channel and Morro Bay was the withdrawal of several 301(h) waiver requests

and the issuance of several waiver denials. Oxnard, for example, decided not to proceed.

Studdert: The clear trend, at least during the past year, was for denial of the 301(h) waiver by EPA. And as mentioned earlier, the involvement of many groups has helped create this trend. It was the the EPA that ordered chlorination of the Goleta and Morro Bay outfalls. The passage of Proposition 65 here in California last year was a clear signal of the importance attached by the public to the whole issue of toxics in the environment.[3]

Price: The concern there was really with recreational uses of those waters when undisinfected effluent was being discharged a mile or less offshore.

Glenn: San Diego, the seventh largest city in the United States, has been dumping up to 200 million gallons of sewage into the ocean every day, 2.5 miles offshore. Right now, there are many days when the kelp bed off Pt. Loma has bacterial counts that exceed maximums established for body contact sports. The City Council finally has decided to drop its 301(h) waiver requests (EPA was ready to deny them anyway) and to undertake what will probably be a billion dollar project to go to secondary treatment. The city is willing to spend a great deal of local money because federal grants are no longer as readily available as they used to be.

Pitts: In Washington, we recognize that it is a lot easier to address the problems of point-source pollution from municipal sewage plant discharge than it is to handle nonpoint source pollution, such as failing septic tanks and agricultural runoff.

Price: That's true of California as well. For example, agricultural runoff is now the major problem in Elkhorn Slough, and it is a problem as well at Arcata Bay, Tomales Bay, and, to some extent, Morro Bay. We are now faced with deciding whether agricultural fecal waste poses a health risk comparable to that of human waste. New standards may have to be developed to deal with a lesser health risk from animal sources. Certainly, I'd rather have cow fecal wastes than human.

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[2]The Federal Water Pollution Control Act amendments of 1972 required all publicly owned treatment works (POTWs) by July 1, 1977, to achieve minimum effluent limits based upon capabilities of secondary treatment. Large municipalities discharging wastes to the ocean maintained that secondary treatment was not necessary in deep oceanic waters where tidal movement and/or swift currents provided high dilutions and rapid dispersion of pollutants. Congress added section 301(h) to the Clean Water Act (CWA) in 1977 (P.L. 95-217) to provide for case-by-case modifications of the secondary treatment requirements for POTWs discharging into marine waters.

[3]California's Proposition 65, entitled the Safe Drinking Water and Toxic Enforcement Act of 1986, is a recently enacted law that remains highly controversial. The new law has two major parts—one dealing with drinking water and the other requiring a warning before exposure to chemicals known to cause cancer or reproductive toxicity.

Rodriguez: Agricultural pollution includes more than just bacteria from cows. Herbicides and pesticides are also of concern. But it is not easy to address policy issues related to agricultural pollution because agriculture in California is very strong politically.

Pitts: In Washington, local governments establish watersheds and identify prime problems. Representatives of agriculture have been involved in the Puget Sound Water Quality Authority from the very beginning, although they haven't been particularly happy about the expensive measures that we have recommended for the future. Agriculture issues are complex. For example, in designing management practices for dairy wastes, dairy products being our state's largest commodity, we must consider lagoons for holding organic wastes, in addition to pesticides. We are working with soil conservation districts, to try to find funds for fencing, animal stockkeeping, and pasture management education through county extension services.

Another difficult area to control is the hobby farm. Backyard farmers who keep a few sheep, goats, and cows often have no idea that they are contributing to a waste problem. Education, especially in elementary and secondary schools, is going to play an extremely important role here.

Glenn: I would like to ask Doug to explain more about what is happening in Texas with regard to the FDA decertification threat.

Price: As I said, the FDA has been very critical of the California program; and it gave us a list of actions to take. We were given a deadline of June 15, 1987 to respond with an action plan, describing how we were going to meet these requirements and demonstrating that we had begun implementation of that plan.

Well, it's very easy to write a plan and describe what we are going to do, but without money, people, and commitment for that plan, it's just something on paper. We did submit our action plan, but the FDA said that it was nonetheless going to proceed with ISSC action because we had not begun appropriate implementation. FDA wants ISSC to discuss California's program and to make some decisions on actions to be taken against the state. Such proceedings typically are held in front of a committee known as the Unresolved Issues Committee of the ISSC.

We are not the only state in this situation; there are several others, such as Oregon, Texas, Louisiana, and Maryland. The states don't like to be told what to do by the federal government. At the meeting that is shortly to be held in Texas, the issue will go before the ISSC Executive Board, which is heavily state-oriented, instead of the Unresolved Issues Committee. I think we'll be able to prevent action for decertification. [See footnote, page 14.]

Studdert: Another recent problem in California was the loss of the shellfish sanitation program's fee exempt status in last year's budget. I am pleased to report that the Governor's budget reinstates the shellfish program.

The "unresolved issue" that Doug has been telling you about raises the fear that the state will be removed from the interstate shipper's list. FDA tried this same tactic back in 1974. It went to ISSC and requested that some states be bumped off the interstate shippers list. But FDA was told that since it doesn't put people on the interstate shippers list, it can't take them off. In effect, FDA doesn't have authority to do that.

There are many steps that ISSC would take before any state was decertified. The ISSC would go to the state, try to bring it into compliance, listen to the reasons why it wasn't in compliance, and then make recommendations to the Unresolved Issues Committee. We're going to have to plead our case before the Executive Board of the ISCC, but the drastic action that FDA has threatened will not come to pass, at least not in Austin.

Lannan: In my introductory comments, I noted that we've become an importer nation of oysters. What regular inspection is there of imports, and do the exporting nations enjoy a more relaxed marketing environment than domestic producers? If so, what needs to be done to rectify this situation?

Price: Importation of shellfish into this country is under the regulatory control of the Food and Drug Administration. In order to be on the interstate shellfish shippers list, companies in exporting countries must be examined and certified by the FDA, which looks at the growing areas, handling plants, and so forth, and gives them approval to ship to the United States. This inspection pertains only to fresh and fresh-frozen shellfish though. If the product is in a can or cooked, it's not covered by the same set of rules. Cooked shellfish from certain countries probably came from waters that are far more polluted than would be allowed here. But if the product is fresh or fresh-frozen, theoretically at least, it's been approved by our federal government.

Conte: Last year in Seattle at the ISSC meeting, a resolution was proposed that the same health standards be applied to exporting countries as are required for domestic producers. This measure has been resisted by the ISSC for about 15 years, based on the argument that it is unenforceable. What we suggested in Seattle is that even if it is unenforceable, the ISSC should adopt it as a matter of principle that might someday be enforceable.

Another issue discussed at that meeting was the FDA's inability to enforce or monitor regulations to the extent people believe it should. The FDA uses the same argument that the states do—it doesn't have the budget or manpower to get the job done.

Studdert: The other recourse is the federal Lacey Act. If a shellfish violates shipment standards in either the shipping or receiving state, the Interstate Commerce Commission can prevent its shipment.

Pitts: This discussion has bearing on an earlier question about how to justify investment in water quality. The United States imported $54 million worth of clams and oysters in 1986. I believe that the investment we are making in water quality to save this renewable resource should be seen as an extremely important economic investment, as well as a public health investment.

Manahan: Do interstate shipping regulations apply to all shellfish, and is "shellfish" defined to include crustaceans as well as molluscs?

Conte: They apply primarily to the bivalve filter-feeding molluscs: oysters, clams, mussels, and in some cases, scallops.

Pitts: The use of pesticides in the water in the state of Washington to control mud shrimp and ghost shrimp was raised earlier. I would like to give you a little background. Washington's Department of Ecology has been issuing permits to apply Sevin (i.e., carbaryl) to water in Willapa and Grays Harbor bays for the past 24 years. And there was an environmental impact statement completed in 1984 by the Department of Ecology and the Department of Fisheries. Fisheries supervises the application of carbaryl in both of those bays and sets maximum poundage limits on its use. Regulations in regard to areas of application are worked out between the industry and the Department of Fisheries.

Last December, the Department of Ecology notified the industry that it would no longer issue permits for the use of Sevin for the control of ghost and mud shrimp unless the pesticide's use was associated with a research project. Since that time, there have been a number of meetings between the Departments of Agriculture, Fisheries, Ecology, and industry, and they have come up with a plan to incorporate the 1987 Sevin spraying effort into a research project. Industry has given $40,000 to look at the incidental crab kill, which is the major political question in Willapa Bay, and also to conduct some benthic studies to determine the persistence of the pesticide in the environment. We will also look at fish kills and other potential environmental problems.

Many questions regarding the use of Sevin have been answered by the environmental impact statement, and studies during the next two years will be used to supplement that impact statement on specific questions, primarily related to crab kill. The research of Dr. David Armstrong at the University of Washington School of Fisheries indicates that Sevin has only a minimal impact on crabs. He feels further that the pesticide actually has some benefit to the crab industry by maintaining habitat and that this benefit may far outweigh the very small number of crabs that

are killed. You should see how an invasion by these shrimps devastates an area.

Certainly, this is a sticky political question from the perspective of environmentalists and the state. We don 't know why the shrimp populations have expanded so rapidly during the last 25 years, though there are some indications that the timber industry, upland activities, siltation, and possibly the El Niño had something to do with this explosion. I'm glad that the Department of Ecology has chosen to allow the industry to participate in this research for the next two years. But when I find the time I would like to look for ways to control shrimp by something other than a pesticide.

Shuman: I am an oyster grower in Willapa Bay, but I don't use Sevin because I have an off-the-bottom operation. The use of Sevin is a very polarizing issue in our bay and in our small town, in which half of the population works in the oyster business and the other half in the fishing industry.

A growing business in our town is harvesting the mud shrimp for bait for recreational fishing. There are probably 20 people there who make their living harvesting shrimp for this purpose and shipping them as far as Oregon and California. They do it by hydraulic pump, using a 10-foot-long PVC pipe which is stuck into the sand and injected with water. A big boil develops, the water comes back up to the surface, and the harvesters stand there and pick the shrimp up as they come out of the boil. After the harvesters have moved through an area, there are almost no shrimp left. And after two or three strong tides, the bottom firms up very well. I'm going to look into having these shrimpers harvest some beds that I am going to start next year.

I think research is needed to investigate harvesting of these pest shrimp. One problem is that the process requires a strong water supply for the pumps. So it's only being used right now on the edges of sloughs. But it is a potentially effective means of control.

Pitts: I talked to a man who supports himself on five acres. He harvests the shrimp, section by section; it takes two or three years for the areas to reinfest with mud shrimp. It's a perpetually yielding investment for him, but one question is whether there is a large enough market for this product as bait. The shrimp taste terrible, so there is no market for human consumption. I talked to a nutritionist about the possibility of using these shrimp as an ingredient for salmon feed or trout culture. Although there's potential, it's not economically feasible at the present time.

Studdert: There really isn't a shrimp problem here in California at the present time. Morro Bay has some ghost shrimpers, and I agree with you that harvesting is a good way of controlling the shrimp population. In Humboldt Bay, there is an added concern that longlining oysters is keeping natural

predators like rays off bottom habitat and that shrimp populations are therefore going to explode. But it is interesting to note that the California Fish and Game Commission last year decided that ghost shrimpers were depleting that resource in Morro Bay and therefore cut the number of permits.

Clark: It is personally heartwarming for me to hear about shrimp having such importance, even though it's negative. Just what do the shrimp do?

Pitts: They burrow into the mud, causing the mud to collapse and cover the shellfish, which can then no longer filter feed. Essentially, the shrimp destroy the habitat for the shellfish.

There are other concerns as well. Willapa Bay and Grays Harbor are extremely important points for migratory water fowl, and these shrimp also destroy eel grass beds and other vegetation that is being fed on by migratory wild fowl. We have a national refuge in Willapa Bay, and there is some feeling that as the shrimp population expands, it will encroach on areas that are extremely valuable habitats for other species.

I think that there is a real opportunity here for the oyster industry to form coalitions with environmental groups such as the Audubon Society. There are a lot of issues in aquaculture and mariculture that could benefit from strong coalitions between environmental groups and industry. That has yet to materialize in Washington, but I am hearing from more and more environmental leaders who are now interested in learning about the oyster industry.

Hollibaugh: Does anyone know whether Manila clams will coexist with shrimp, or do they get buried like the oysters?

Shuman: In our bay the natural substrate for Manila clams is not as muddy as that for shrimp, so the animals don't seem to coexist naturally. It may be more of an issue in the future.

Glenn: I have a question regarding migratory waterfowl. I grow mussels, and the surf scoter comes to Southern California in the winter time and eats my mussels. Can anything be done about it? There are protective regulations regarding migratory waterfowl that prevent normal destructive techniques.

Pitts: With regard to predators, I try to remember one thing. The Hopi Indians always felt that 5% of their sheep were naturally going to be lost as part of the contribution to the coyote population. They saw that as part of the natural balance.

I do not think that a certain percentage of your product should be lost to some predator, but neither can we destroy species that are competing for your product. There has to be some balance in the system—that's just a reality. We are going to have to find some nonlethal ways to prevent predation by waterfowl. You may not have to accept too much loss to your product if you can find a technological means to prevent that loss.

Glenn: I understand your comment, but in the case of the surf

scoters, they'll take any mussel that isn't too big to get in their beaks. A flock existed in the lagoon this past winter, where none have existed before, and they did extensive damage to my farm.

Pitts: You should remember that we're also talking about a political question here. No matter how much we might like to eliminate certain critters, they're here; and there are organizations that support them. In other segments of the aquaculture industry, the problem of predators is just as bad or worse. The U.S. Fish and Wildlife Service has worked to protect aquaculture products from seal predation and has had some limited success. Unfortunately, however, we have not had a lot of research activity in bird predation control in the marine area.

Presently, the salmon culture industry in Puget Sound is employing various techniques to help with bird predation, such as putting cover nets over the tops of the pens or parallel strands of nylon cord about 18 to 20 inches apart to keep the birds from coming down. In addition, nets are being placed around the entire periphery of salmon net pens to prevent attacks by seals and sea lions. An electric fence strung around the pen will prevent river otters from preying on salmon. Technology can obviously be used to help with the problem of predation, but we're lagging behind in the shellfish area.

Richards: I'm interested in how the technology of depuration can help a grower when an area has been decertified and the grower is temporarily out of business. What are the policies in California, Washington, and Oregon in regard to depuration technology, and how might the university help in this area?

Pitts: There is no depuration taking place in Washington at present, but the Department of Social and Health Services is preparing position papers.

Price: There is no active depuration in California either. There have been some attempts at depuration in the past few years, but it turns out that the process costs too much. Depuration projects must comply with the guidelines of the national shellfish program and with California's laws. But the problem is that it costs too much.

Conte: Bacterial depuration is economically feasible with clams, but has not yet been demonstrated with oysters, at least in the United States. It is now being tested in many states. The depuration of viruses is starting to appear in the regulations, but the technology for viral depuration has not been developed.

Studdert: The thrust of the effort in California has been directed at cleaning up water quality before looking at depuration, because of the cost issue, primarily. However, not too long ago, water quality in Humboldt Bay was so poor that planners were taking a hard look at depuration. It may be that as aquaculture expands we will find that this technology represents the only solution in certain areas.

Glenn: The technology may represent a two-edged sword because if it is known that you can depurate contaminated shellfish and make them safe to eat, then those who want to continue dumping sewage into the ocean can say there is no necessity to spend millions of dollars on pollution control. We don't want depuration used as an excuse for not cleaning up the waters.

Piedrahita: But depuration is not the answer when water quality is very poor. You can use depuration only when the oysters, or other shellfish, are slightly contaminated. If you let water quality deteriorate too far, depuration will not work in a reasonable period of time. This technique cannot therefore be used as an excuse for not maintaining adequate water quality.

Studdert: What is happening with ozone-enhanced depuration?

Piedrahita: Ozone is just one of the ways you can disinfect the water, and you need to disinfect in order to depurate. It's just part of the technology.

Price: The California Department of Health Services would not allow depuration in badly polluted waters in any case. In fact, we have rules against that. Nor would we allow depuration if there was any question of chemical or metal contamination, which doesn't depurate away. The virus question is something we haven't really covered, but viruses would take longer to depurate than bacteria.

Strain: If oysters were grown in an area where heavy metals were in the sediments on the bottom, would the oysters ingest some of the heavy metals?

Price: They would take up the chemicals or heavy metals that had adhered to the organic particles they were feeding on, or they might absorb these molecules through their respiratory or feeding membranes. If there were any question of heavy metal contamination, we wouldn't allow commercial operations in that area.

Pitts: There is some interesting work, as yet unpublished, that was done in British Columbia by the Ministry of Agriculture and Fisheries in regard to the use of antibiotics in salmon net pens and their accumulation by shellfish. Canadian scientists monitored oysters hung at various levels from the net pens while antibiotics were being used; the nets had been treated with tributyltin (TBT), an antifouling agent. They were not able to detect any antibiotic in the shellfish over the 10-day process of antibody therapy, but they were able to pick up TBT in the shellfish. It took about 45 days for the shellfish to purge themselves of the TBT and other compounds. (The governor of Washington has recently signed a bill limiting the use of TBT in the state.)

Shuman: Where do we stand on the TBT issue in California and Oregon?

Studdert: There were about six TBT bills introduced this past session of the California legislature. At least one bill and an Assembly joint resolution are still viable. I think we'll see a bill that bans the use of TBT in California.

Pitts: The issue has been controversial in Washington because salmon growers in other countries have traditionally used TBT as an antifoulant. Also, the amount of TBT used by salmon operators in our state was infinitesimal compared to what is on the bottoms of commercial and recreational boats. The owners of salmon pens in Washington have voluntarily discontinued the use of TBT. They are moving toward that in British Columbia, and they have discontinued use in Scotland.

Lannan: Oregon had a package of five or six bills regarding TBT in the recent legislative session. One, awaiting the Governor's signature, will put things on hold for two years for further study. Some interesting testimony came out in the course of the hearings. Expert witnesses told the legislature that TBT takes many forms in commercial products. Some anti-fouling paints using TBT have a high initial rate of leaching and these are the ones that cause problems. However, there is another class of high-quality bottom finishes that are used for commercial vessels in which tributyltin is bound in a copolymer, and these paints have a relatively lower rate of leaching. The legislation that is being considered in Oregon is going to continue to allow the use of copolymer finishes but restrict the use of the other types of finishes.

Pitts: It's interesting that you can buy TBT at the hardware store to mix in grout for bathroom showers and paint for bathrooms and other areas where there is a lot of moisture. It's also commonly used as an anti-fungal in underwear in this country. So, it's all around us.

Rodriguez: Even the co-polymer paints release tributyltin, but unlike the other class of paint, they release TBT at a low, steady rate over the life of the paint film. So there is still concern with the copolymer paints, although some people think that they might be tolerable. The question hasn't really been answered yet. And TBT will still be permitted on aluminum boats because of the problem with corrosion.

Glenn: I'd like to bring the discussion back to paralytic shellfish poisoning. PSP seldom, if ever, occurs in Southern California as judged by the ongoing monitoring program. Yet the six-month quarantine is for the entire California coast from Oregon to Mexico. Perhaps the quarantine could be more specific and not include our growing area.

Price: The farther north you go, the greater the hazard. But there's one point I want to make, and it's critical to ocean mariculture. We thought that the Santa Barbara Channel was a safe area with respect to PSP. We went through the records of

our monitoring program for the past 20 years, and we never saw elevated PSP levels in the Santa Barbara Channel. Still, as soon as we allowed the first ocean maricultural operation to get underway, we had a PSP outbreak, which came on fast and was of considerable intensity, enough to kill people. If we had not worked very fast, along with the county health departments, there could have been extremely serious repercussions to the shellfishing industry.

You say there is not much PSP known in Southern California, but the Santa Barbara Channel is not that far from the San Pedro Channel or the Santa Catalina area. We just don't have enough historical data to say it's a safe area. PSP can happen anytime, anywhere, when we least expect it. It's a serious problem and one that has me and others concerned about the general opening up of ocean mariculture in Southern California waters. We would not allow ocean mariculture in Northern California. We would never allow someone to collect mussels or grow them off the Northern California coast.

Pitts: Puget Sound has a PSP problem, too, and there has been some expansion of the areas where PSP has occurred. It has traditionally been a problem in the northern sound, but we are now seeing some blooms in the central sound. We are trying to figure out why this is; whether it has to do with climatic changes, a decrease in rainfall, or other factors. We haven't tied it to mariculture or aquaculture at this time. In developing guidelines for salmon net pen culture, the state of Washington did consider PSP; and we limited salmon production in bays in Puget Sound so as not to increase by more than 1% the present organic loading in that body of water. That's a very conservative approach.

Conte: Several years ago we lost some momentum in PSP research, and just recently I've heard that University of Washington is initiating some programs to get back into it. Where are we now? Where's the HPLC? Where's the fly bioassay? We still need these rapid response mechanisms for detecting PSP.

Price: The fly bioassay is on the shelf. The person who is doing that research is trying to get funds to complete it. I don't know anything about the HPLC. What the grower needs is the ability to test his own product for PSP. If I were a mussel grower I would not want to have to send samples every week up to Berkeley (the only lab in the state that can do the testing) and then wait for the answer to come back. I would want that capability myself. Field testing kits or local private laboratories would be very useful and help protect the industry.

Hollibaugh: I remember seeing, not very long ago, a request from the FDA for state participation in a cross-calibration between the mouse assay and an HPLC method. Do you know if California or Washington participated?

Price: The state of California did not participate because our

laboratory in Berkeley simply did not have either the time and resources.

Pitts: The state of Washington is really very active in its PSP program and probably has a program that's as extensive as any in the country.

Glenn: Are there any states or organizations that are actively promoting aquaculture?

Pitts: That's my primary function in addition to disease regulation, which I co-administer with the Department of Fisheries.

In 1985 Washington produced $35 million worth of aquaculture product, $20 million in shellfish and $15 million in finfish. But the growers felt that they were not getting the marketing support they needed. So aquaculture was taken out of a number of different agencies and put into the Department of Agriculture. Growers are now looking at the possibility of developing a commission, like our state apple commission and our state wine commission. There are commissions for a number of other commodities in the state; industries can make decisions, tax themselves, and control the destiny of tax funds and marketing programs.

My job is primarily political right now. I'm out trying to convince various groups that aquaculture has a positive impact in the state of Washington, not only from an economic perspective, but also from an environmental perspective. I work with local governments very closely. I work with the state legislature and have been in close contact recently with the Governor.

We're on the verge of expanding the industry in finfish and shellfish. I have devoted most of my time to finfish because that is the hot political topic in our state. Our budget, of course, is not anywhere near as much as I'd like. I don't even have a secretary right now, whereas my counterpart in British Columbia has a $3 million budget and seven people working for him. He told me last week that his direction is going to change. British Columbia's finfish industry has gone from 5 farms with about 5,000 fish in the water to 125 farms with 35 million smolts in the water in the last three years. Now they are going to start directing their efforts to shellfish. When I was in Norway, Scotland, Finland, and Sweden last fall, I was asked again and again about shellfish because the Scandinavians are also extremely interested in expanding that industry.

I would like to be doing more; there's room for a lot more activity.

Hollibaugh: Local government officials can have an enormous impact on operations. Within the county you sometimes get a guy who is on your case and sometimes one who is for your case. How do you deal with local government?

Pitts: When I was a county health commissioner, I worked very closely with local governments. Part of the problem was that they

had a lot of misinformation upon which they were making decisions. I worked to bring correct information out in publications in such a way that local government officials could understand it, so that they could make better judgments and evaluations in the permitting process.

Right now four counties in Washington have moratoria on aquaculture. There are citizen groups lobbying hard against aquaculture. I spend a lot of time at hearings correcting misinformation for the commissioners; it falls on deaf ears as far as property owners and commercial fishermen are concerned. I spend time at local, regional, and state meetings with county supervisors. I show them fish, talk to them individually, do whatever it takes to give them the information by which they can make an informed decision.

Conte: When jurisdiction over coastal aquaculture in California was with the State Commission, Sea Grant made excellent headway in promoting the industry, including putting together a coastal zone planning publication that was adopted by that commission as their model for aquaculture. But when jurisdiction switched to the local level, the whole process of education had to begin again. Members of the Inter-agency Committee for Aquaculture Development are stymied right now, hopefully temporarily, because they have no mechanism for influencing county personnel and county planning commissioners. However, there is a bill to establish an aquaculture coordinator in the California Department of Fish and Game, similar to the position in Washington state. The responsibility for educating groups about aquaculture should be an important aspect of that job.

Pitts: The position of aquaculture coordinator in Washington was originally established in 1985, but for over a year it consisted of a part-time person who tried to answer questions. When he retired I took the job. Ultimately I'd like to develop some programs and publications for public information. I'd like to put on a conference for local government and for the economic development councils in Puget Sound. I would like to give some assistance to the Washington Aquaculture Council.

Studdert: You have done a lot better in Washington than we have in California. We have had the California Aquaculture Development Act, which provides for an aquaculture development section, since 1983. It is finally coming to pass. There is a bill pending in the legislature that will give the aquaculture section a coordinator.

Manahan: I'd like the panel to speculate on where you think we are going to be 5 to 10 years down the line on the issues of water quality and mollusc aquaculture. Do you think life will get easier or tougher for the industry?

Studdert: I think things will get a little better. People are a lot

more conscious of ocean pollution, not only bacteria but also toxic waste, and there are more people up in arms than ever before. Proposition 65 should have told us that.

Conte: The progress that has been made reflects recognition of the fact that this is not a shellfish issue but one of maintaining the integrity of a natural resource.

Pitts: I agree. I use aquaculture as a tool to maintain and enhance water quality, and I see it as a very important tool. There's nothing I'd rather see than a $100 million or $200 million aquaculture industry in Washington.

Price: We're heading in the right direction in California, and the industry will continue to grow. We have twice as many operations as we did seven or eight years ago. Total production, however, remains pretty much the same. What we're seeing is a new industry...lots of small operations with great hopes and plans. There are only two things that would pose major problems. One would be a relaxation of current water quality standards. And, of course, disease outbreak or PSP outbreak would be a major blow to the future of aquaculture in California. It is very important for the industry to recognize that fact and to support the health protection agencies in their responsibilities.

Cooper: It was suggested that sewage treatment facilities were upgraded in Eureka because of the oyster industry; I think that is an incorrect perspective. That was really a part of the Clean Water Act. The oyster industry was caught in the middle of a dispute between federal agencies attempting to enforce the Act and municipalities whose discharges from sewage treatment facililties did not meet standards established by the Clean Water Act. I feel an argument could be made that severe restrictions placed on the oyster industry were put into effect primarily as an outgrowth of disputes between regulatory agencies and the cities and were to a much less extent due to immediate health concerns. Many of the issues we've discussed are a mixture of scientific and policy concerns. How do you separate out political considerations from scientific ones?

Rodriguez: I hope I didn't leave the impression that the only reason Humboldt Bay was cleaned up was for Coast Oyster. That certainly wasn't the case. The cleanup was indeed part of the federal Clean Water Act, and it was part of the state's Water Quality Control Act.

Pitts: I don't think you ever separate science and politics. It's just part of the process we go through, and people manipulate the process to meet their goals. But we need to try to do a better job of providing accurate, neutral information.

Lannan: Let's talk about specific recommendations for action. What can we do as a team of individuals interested in promoting mollusc aquaculture? What needs to be done? Who might take it on?

Conte: I think that all the mechanisms needed to address these issues exist. It really is a matter of directing resources. The university, for example, has to do a better job of pinpointing the most critical issues and then put more emphasis on them. One of the things that we in Extension might do is to recognize that sanitation is one of the major issues impacting the shellfish industry in California and devote a greater portion of the program to that issue, working in close cooperation with industry and the agencies.

Lannan: Are the issues really that clearly defined?

Conte: I think they are well enough defined to be able to proceed. This symposium is not the first to address the problems in aquaculture. We've been involved in this process for a number of years now, but we've been working with limited resources.

Sullivan: Where would additional resources come from?

Conte: The most important resource—time—might come from agreement within the advisory community about which issues to concentrate on. We might have to resist responding to public service programs, for example, and focus instead on those issues that are most critical to the industry and have the greatest potential return to the state. I'm not asking for money, but for time and recognition of commitment.

Hollibaugh: Policies that determine what can be applied are not necessarily based on whether a particular treatment works, but rather on whether it is cost-effective or acceptable to somebody else.

Sullivan: What is needed is someone to take the technical, economic, and scientific information and get it into the commonly accepted body of knowledge upon which political decisions are made. All of the great science in the world is not going to do anybody any good unless it gets into the public realm. That means that decision-makers at every level must have the same solid data base to work from so that they can agree and move forward. It's disagreement, or in many cases bad information, that has things stuck right now.

Richards: I want to express the point of view of the University of California's Cooperative Extension Service. Sea Grant's Marine Extension Program has seven field advisors working along the California coast. Our list of clientele includes many sectors, but because my background is in marine fisheries, I've emphasized that area. I work with licensed vessels, charter boat owners, wholesaling facilities, public agencies, and try to resolve conflicts between the oil and gas industry and the commercial fishing industry. As aquaculture develops in the Santa Barbara area, I am giving it more attention. I see this happening in San Diego too. We now have a critical mass of people in both areas who are asking for our assistance in aquaculture.

Pitts: I consider you guys, along with other people in

Cooperative Extension, the universities, and conservation districts, as the ones with the white hats. You can do a lot more in education than any regulator ever can. As soon as a representative of the health department walks on someone's property, a wall goes up. But people will listen to you.

Conte: We in Extension don't look at the agencies as the black hats. One of the most highly leveraged opportunities we have is to sit down with both industry and agency people.

Clark: I'd like to go back to something Jim Lannan said in the beginning. When you look at the statistics, there doesn't appear to be any real growth in the U.S. industry, but imports are increasing tremendously. What is wrong?

Conte: Those statistics do not reflect the growth potential that I see in California. In 1980 there were five bays producing around 900,000 pounds of shucked oyster meat a year. But then we hit sanitation problems, and the R&D companies dropped out of the system. We were cut back to two bays, with a third just coming on, yet we moved production up to well over 1,200,000 pounds per year. We now have three bays in production and a lot of areas we can open up. So this is an industry with growth potential. Numbers from the California Department of Fish and Game put the value of the industry at about $3 million, but Fish and Game computes the value on the shucked gallon not the true market value. We know that half or more of the product is moving as individual shell units at 25 cents each. That would put the value of the product at over $5 million a year, which is $25 million to $30 million since 1981. I think aquaculture has earned its way. We need to reexamine where the University of California is putting its resources in terms of the value of this product.

Lannan: I spent quite a bit of time looking at statistics on the value of production. They honestly did not make any sense to me. I believe that the statistics available through various public agencies seriously undervalue this industry. They tend to compare the gross value of product on the world market, and it doesn't make any sense to evaluate businesses that we have on this coast in that way. When you consider them in terms of their value in local economies, these businesses are pretty important.

Studdert: If the yardstick we use is market value of product, then you have a lot of species that are in big trouble.

Clark: What I guess I'm asking is whether our industry can do something to stop the growth of imports, and if so, what?

Pitts: I can speak for Washington in regard to impediments to growth in the aquaculture industry. Some of the growers are lethargic and want to keep their production where it is. They're comfortable. Some of the younger growers want to expand, but there are political stumbling blocks. There are user conflicts, especially when aquaculture involves putting something on the water surface that was not traditionally there. If you have to water

ski around a salmon net pen or a mussel raft, or even if you have to look at it, you are not likely to be assuaged by arguments about the trade deficit or increased consumption of fish. Commercial fishermen fear that finfish culture will eliminate their industry, though that's not what happened in other parts of the world.

I don't think we Americans yet recognize that we're part of a global economy. We're coming out of the richest period in our history, and it has not yet dawned on us just how competitive this new era is. In terms of opportunity, we should take a look at the technologies being used in Europe that utilize the whole vertical water column.

Glenn: France, Japan and Korea, all major producers of shellfish, raise their oysters through standard off-bottom aquaculture techniques. However, very few of us in the United States do. If we were to use these techniques—to use our water in three dimensions—we could greatly increase production, but this requires changing the way many of us do things.

On another subject, I have found that through a quirk of nature, our mussels in Southern California are in tip-top shape in the summertime, whereas in most of the temperate waters of the world, they are in poor shape. This puts us in an excellent position to penetrate the market in mussels. There's a real opportunity here for the growth of the U.S. mussel industry using standard procedures, but they're off-bottom, and may involve going out in the open ocean. Mussel production in Europe approaches 500,000 tons per year, most off-bottom. Consumption here is growing rapidly, so we've got an exciting opportunity.

Lannan: I think it's fair to say that most of the *prime* grounds in the west are in production, so if you want to increase production, you have to look at developing off-bottom techniques or other methods of putting marginal or inferior grounds into production.

Shuman: I don't know any oyster producer who has enough oysters. We can all sell anything we can produce. My operation is trying to grow oysters as fast as possible. We're limited by land and capital.

Conte: There are additional growing areas available. The process has been delayed because the Department of Fish and Game says that they do not have the time to get the leases open. We need to continue to streamline the process.

V. IMPLICATIONS OF ENVIRONMENTAL QUALITY FOR MOLLUSC CULTURE

DONAL MANAHAN, Moderator, Department of Biological Sciences, University of Southern California, Los Angeles, California
JOHN McMULLEN, President, Ab Lab, Naval Civil Engineering Laboratory, Port Hueneme, California
JAMES T. HOLLIBAUGH, Great American Oyster Company, Marshall, California
DONALD G. CROSBY, Professor, Department of Environmental Toxicology, University of California, Davis

DONAL MANAHAN

This morning we will focus on the technical aspects of water quality. I felt in yesterday's discussion that we somewhat overstated the integration of political and scientific issues. Certainly there are many technical considerations in aquaculture that can be addressed and hopefully solved by science independent of the political process. Those are kinds of issues that we want to highlight this morning.

We had originally planned to have five speakers. Unfortunately, Ralph Ellison had to drop out. So the plan now is to have four presentations—two each from people in industry and the university. Those representing industry are John McMullen, owner of Ab Lab, which is an operation that's been working in Port Hueneme for the past 12 or so years. John is faced constantly with the problem of water quality because he's attempting to run both a hatchery and a grow-out operation in a commercial port. The second speaker, Jim Hollibaugh of the Great American Oyster Company in Tomales Bay, will be talking about the grow-out of oysters. Our third speaker, Donald Crosby, is a professor of environmental toxicology at the University of California, Davis. Don will be discussing the uptake of contaminants by molluscs. And I'll be discussing another element of water quality, namely maintenance of the natural chemistry of water that's essential for optimizing growth.

Water Quality Concerns of a Commercial Abalone Hatchery

JOHN McMULLEN

The concerns of the abalone industry are a little different from those of oyster, clam, and mussel growers. Abalone are not filter feeders, so we are less concerned about (coliform) bacteria, for example.

We are worried about the water quality changing with the growing commercial activity in Port Hueneme. At my facility, we have the capability of raising 600,000 seed abalones a year, which is the quarter-inch (7–8 mm) size. The water is brought in

from the harbor, filtered through anthracite, sand, and then released. We use no substrates in our system; the abalone are raised on the sides of circular tanks, where they eat adventitious forms of diatoms and other algae. After six months we wean them to macrocystis (kelp), which is a standard food, and continue growing them to the two-inch size.

We have experimented with raising abalone on an oil platform in the Santa Barbara Channel, but there were numerous problems, the biggest being logistics. We did learn though how to raise abalone in 55-gallon drums, a technique that we're using on a Navy pier in Port Hueneme. It's a corrosion pier, however; all those chemicals we've discussed are being tested right there. These abalone are kept at specific densities, fed kelp once a week, and then they're marketed as cocktail abalone at the 2-inch size to white tablecloth restaurants.

I do have some concerns that the research community might address. I want to know what effect TBT is going to have on my abalone if I stay in the harbor. The Navy is considering painting its ships with it. Would a U.S. ban on TBT prohibit foreign ships from coming into U.S. ports? What effect does bottom sediment in a harbor have on the development and growth of abalone and other shellfish? Do the algae that the abalone eats take up toxic material, and what does that do to overall survival of the animal in its early stages? I'm curious to know how these toxic materials are taken up into the muscle of the animal—the only part that is eaten. I don't even know what levels of toxic substances are acceptable. What about sublethal (chronic) doses of toxins? Do they cause disease in the animals or slow their growth? What effects do sublethal or (chronic) periodic episodes of supersaturation in seawater have on these animals? Sometimes our animals lose meat material and shrink up in their shells. We had these animals tested and the only thing we found were *Vibrio* sp. bacteria. Did the bacteria cause the condition or did they just move in on a weakened animal?

Water Quality and Oyster Grow-out

JAMES T. HOLLIBAUGH

I broke the issues related to oyster culture and water quality down into two general areas. The first is the effect of water quality on the product's marketability, an important issue that sometimes gets overlooked. The second is the effect of water quality on production, which is expressed primarily in terms of growth rate and mortality of the organisms through the grow-out stages.

Public health constraints are the most important ones affecting expansion of oyster culture in California. You can grow oysters anywhere—the problem is to find water clean enough to allow you

to produce a product you can sell. Concerns are organic contaminants from pesticides, organic metal compounds, toxic metals, bacteria, and viruses. These factors are usually associated with discharges resulting from human activity. PSP is an exception—it is a problem we have no control over.

Product acceptance is a vague area. Once you have produced the oysters, there are numerous factors that affect their marketability in a free trade market where you are competing with oysters from outside the state and outside the nation, as well as with other shellfish. Both the condition of the product and "plumpness," or fullness of the meat, are important. The reproductive state affects not only the plumpness but also the flavor of the oyster; we have a problem marketing half-shell oysters during the summertime, because both flavor and the consistency of the meat change radically. For this reason, we fully support work being done to control reproduction in oysters during the summertime using genetic manipulation.

You can, of course, raise species that have different constraints over their reproductive metabolism. For example, we grow a subspecies of *Crassostrea* called *kumamoto* that is from warmer water and therefore takes higher temperatures to induce spawning. The problem is that it takes twice as long to grow as a Pacific oyster. I believe it would be better to have a Pacific oyster whose spawning is blocked than to try to develop a *kumamoto* market because of the problems associated with holding these oysters for longer periods of time.

Another factor in marketing is the general appearance of the oyster. In the half-shell market, the appearance of the shell itself is important. Chefs want a nice uniform shell, one with purple striations, as opposed to a shell that's heavily fouled with barnacles or tunicates. Many times it is hard to provide that product because fouling organisms are so ubiquitous in the ocean.

A final factor is the shelf life of the product, which determines how widely you can market it. In general, it takes a week for an oyster to go from the water to the table. Many factors affect shelf life, including hardness of the shell. Harder shells take a bit more banging around during the sorting, cleaning, and distribution process, and unfortunately, a lot of distributors treat oysters like bags of concrete. Another factor is the strength of the adductor. Once the shell starts gaping, shelf life decreases dramatically.

Biological components of water quality as it relates to oyster aquaculture include the quantity of food in the water—that is, the standing crop of phytoplankton and dissolved or usable particulate organic matter. They also include the quality of that food since not all plants provide equal nutrition for oysters. We do not have much control over either of these factors in the standard oyster grow-out operation: it is difficult to imagine how

to manipulate phytoplankton populations in an entire estuary. There have been some attempts in tank culture, but costs are prohibitive.

Suspended particulate material, primarily silt, affects oysters in two ways. Oysters don't like to ingest inorganic particles so they have to spend time and energy sorting them out. More importantly, many water pollutants immediately adsorb onto particles and are deposited on the bottom. When the bottom is stirred up, either by storms or spring tides, a lot of the material is re-introduced into the water column. Some of the adsorbed pollutants are removed from the particles and introduced into the oyster meat. Although you may test water and find that it has low concentrations of nasties, if there is a reservoir of high concentrations of pollutants on the bottom, you still have a potential problem.

Disease is a serious biological constraint in oyster aquaculture, and we are just beginning to understand the extent of the problem for bivalve culture. We don't know the cause of summer mortality incidents in oysters, for example. Another disease with which I had experience lately is the protozoan disease, *Bonamia*. I recently had my crop of *Ostrea edulis* condemned by the state because of *Bonamia*, but oysters growing 50 yards away did not test positive for the disease.

Physical factors such as currents and wave action affect our ability to keep culture structures in place in the intertidal or subtidal zones, and thus can be a problem. But they are generally a positive factor for bivalve growth because they provide a continual supply of food. In an area where water flow is relatively stagnant, oysters can deplete the food supply in their immediate vicinity. Water temperature affects oysters profoundly by influencing their growth rate, and also by controlling their reproductive state, which influences condition, flavor, and appearance. Salinity, too, affects flavor and can limit the kinds of species grown.

Among the other factors that influence oyster growth and need to be studied more carefully are dissolved trace organic materials—vitamins and minerals, if you will. We know that other organisms require such substances so it's likely that oysters do too. Whether or not you can do anything about this in a grow-out system is another question entirely.

Factors unrelated to water quality impinge on the industry and should also be considered. Predators such as rock crabs, sharks, and rays are voracious consumers of oysters. Many of the off-bottom methods that are used to achieve higher densities have the secondary advantage of protecting the crop from some of these predators. Humans are another problem, sometimes engaging in pilferage or even wholesale theft of the product. In

California, we are not allowed to deny access to persons who are digging clams in the midst of our lease. We have to rely on the goodwill of the public.

Pests also affect our industry. Two fouling organisms that I have problems with are mussels and barnacles; these have an effect on product acceptance as well as ease of handling. The rack and bag system that I use provides marvelous settling surfaces for a number of organisms. Mussels that set last winter on my oyster crop are getting big enough to glue all the oysters together into one huge clump. When you are sorting oysters for market, you usually just dump the bag out on a sorting tray, but when they are mixed with mussels into one compact mass, you first have to rip the mass apart and then try to sort the oysters.

Other factors, though less important, deserve mention. Seaweed fouling inhibits your ability to judge the growth of your product and makes it slippery to handle. Rays and humans both are pests because they produce large cavities in the bottom. Nothing is more distressing than to be stumbling around out there in medium tide and all of a sudden fall into a ray hole or a clam hole that somebody hasn't filled.

Other biological communities in the estuary can affect your product. For example, both eel grass and salt marshes are thought to provide a lot of the organic material used by bivalves as food. But it is unclear just how important these are compared to phytoplankton production, and the answer no doubt varies seasonally and from estuary to estuary.

A second and more direct effect of these communities is the result of their perceived value. All the recent leases granted in Tomales Bay have contained a clause that prohibits oyster culture within five feet of a patch of eel grass, the size of that patch being unspecified. A lot of eel grass grows at my end of the bay; if one were to follow this guideline rigorously, the available area for culture in Tomales Bay would be one-quarter what it is now. This new lease restriction stems from a technical report published a number of years ago that showed a relationship between eel grass and herring spawning. The logic is that eel grass is essential for herring spawning, therefore eel grass is essential, therefore anything that provides a threat to eel grass (and there is the assumption that oysters do) is harmful to herring spawning. But the restriction is not based on evidence of any interaction between the eel grass and the oysters. This is, by the way, an excellent example in my opinion of bad policy based on bad, or at least insufficient, science.

I would like to talk a bit about new understandings in marine microbiology that have implications for public health policy, but my time is up so I'll defer that to the final, open session.

Uptake and Fate of Contaminants in Molluscs

DONALD G. CROSBY

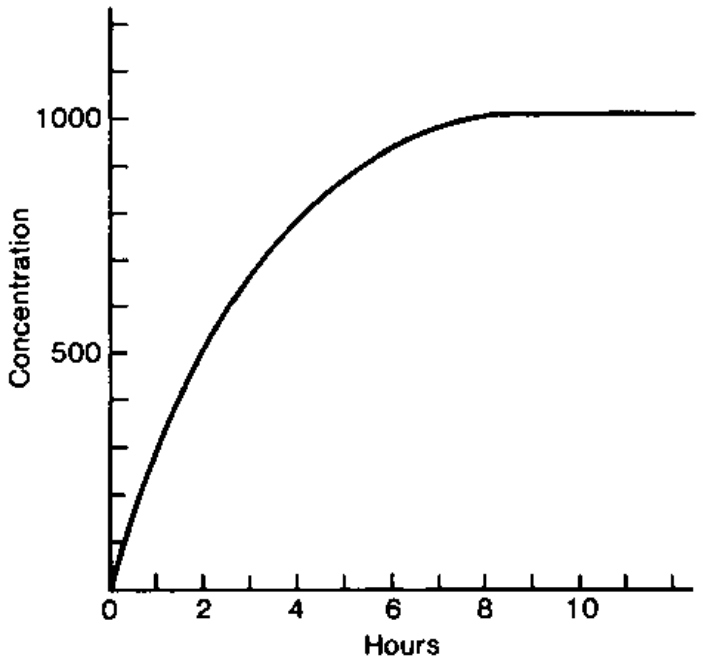
I will talk about some aspects of water quality involving dissolved organic chemicals and then discuss the response of molluscs.

People have been very slow in realizing the extent and variety of water pollutants. In part, this reflects the development of present-day analytical chemistry. When I started off in contaminant analysis, typical measurement units were parts per million, but today we work in parts per trillion. Thus, new technological capabilities allow us to see contaminants that people previously never suspected might be in water.

All water has some dissolved contaminants, which is not surprising given the way contaminants can move through water and through the atmosphere (eventually precipitated into water). And molluscs process a lot of water, particularly the bivalves. An oyster typically processes five or six gallons a day, and a mussel bed has been estimated to process as much as 5 billion gallons in a year. We know now that molluscs take up dissolved organics directly from the water. The older idea of food chain uptake has given way to the realization that most organic contaminants come directly from the water via the respiratory system. Contaminated food is a poor second as a source.

It is inevitable, then, that molluscs are going to be exposed to water-borne chemicals. Once exposed, uptake is very rapid and very easy (see Figure 1). Over a period of 10 or 12 hours, a

Figure 1. Rate of uptake of a typical organic contaminant in a mollusc (ppb).



contaminant that is present at one part per billion in water will be filtered out by a mollusc, and its concentration in the animal will rise rapidly to about one part per million before reaching an equilibrium level. Animals growing in the wild are continually exposed to the chemical, and they are continually bioconcentrating, so they stay at the equilibrium level. Note that if the concentration of the chemical in the water decreases, then the equilibrium point will also decrease.

How much a chemical is bioconcentrated depends on its fat solubility. The greater the fat solubility (and the lower the water solubility), the greater the bioconcentration. Many organic contaminants have a bioconcentration factor of 500 to 1,000; on the other hand, chemicals like DDT have a factor of almost a million. The point here is that the molluscs not only pick up the chemicals in the water directly through their respiratory systems but also can concentrate those chemicals to a rather high degree.

Most aquatic animals seem able to biodegrade chemicals fairly well, but we find that molluscs are among the slowest and least efficient at it. Consequently, more than fish or crustaceans, molluscs tend to build up concentrations of chemicals. State and federal regulators have used this property in their Mussel Watch programs, which essentially use mussels as sentinels for pollutants.

The kinds of organic chemicals that are typically reported by Mussel Watch in San Francisco Bay and Elkhorn Slough are dominated by the stable organochlorine insecticides—the "chlorinated hydrocarbons." This group of chemicals, listed in the first column in Table 1, are all regularly found and were to be expected: benzene hexachloride (BHC), chlordane, DDT and its breakdown product DDE, dieldrin, and toxaphene.

Table 1. Chemicals in California Molluscs*

Usually Present	Sometimes Present	Probably Present
α-BHC	Chlorpyrifos	Phthalates
Chlordane	Endosulfan	PAH
DDT/DDE	HCB	Petroleum
Dieldrin	PCB	Phenols
Toxaphene	PCP	Methyl iodide

*As reported by the State Mussel Watch Program for San Francisco Bay and Elkhorn Slough.

Another class of chemicals found in some samples—the organophosphates such as chlorpyrifos—was unexpected because these compounds are metabolized easily and are unstable in the environment. However, as I said, the molluscs are

not very good at biodegrading. Other compounds found in the mussels (Table 1) include endosulfan, a pesticide previously thought readily biodegradable, as well as some more persistent ones such as hexachlorobenzene (HCB), the polychlorinated biphenyls (PCBs), and, in some locations, the wood preservative pentachlorophenol (PCP).

You might say that you don't use pesticides and that there is no major agricultural area near your culture site, so you are not too concerned. Nonetheless, many other chemicals from everyday living are going to be found in your molluscs; I guarantee it. They just haven't been looked for. Phthalate esters, for example, are very persistent and they are found in a major proportion of commercial plastics. The polynuclear aromatic hydrocarbons (PAHs) are carcinogens found in waste oil and road tar. Every time it rains, they are washed from the roads into the water, where the animals will absorb them. Phenols, too, are very common, as is petroleum. Methyl iodide is a natural compound, but it is bioconcentrated by the animals, so I would expect that one could find it in them. I have included such examples in the third column of Table 1.

Polluting chemicals, then, are extremely widespread and often occur without anyone realizing it. A few years ago, an outfit at Moss Landing was having difficulty rearing oysters indoors. They said they used no chemicals, but when I investigated, I found an amazing variety of common substances around the premises. The air pumps aerating their tanks were in a shed that was filled with oil fumes; a filter in the air line decreased the pollution and solved their problem.

What about the toxic effects of chemicals on molluscs? When pollutants are slowly absorbed over a period of time from low concentrations in the water, molluscs generally do not seem to be particularly affected. There are some exceptions, of course, and the larval or juvenile stages of molluscs seem to be much more sensitive than are adults. There also are a few polluting chemicals being discovered that are peculiar in their high toxicity to molluscs, such as tin compounds like TBTO.

The principal problem actually seems to come from the *perceived* effects on humans. The World Health Organization (WHO) and the EPA have come up with acceptable daily intakes (ADI) of a wide variety of chemicals. A few are shown in Table 2. The WHO estimates that an adult human can acceptably take in each day 525 μg of endosulfan, 70 μg of toxaphene, 350 μg DDT, and 7 μg of dieldrin. From the residues of these compounds found in mussel meat, one can calculate the maximum acceptable daily intake of mussel meat for these substances. So, for example, one would have to eat more than 66 oz. of mussel meat daily to exceed the maximum acceptable daily intake for endosulfan—hardly likely. But to exceed the ADI for dieldrin, one

Table 2. Acceptable Daily Intakes (ADI)

	ADI		Mussel Residue	ADI
	μg/kg	μg/person	ppb	oz. of mollusc
Endosulfan	7.5	525	277	66
Toxaphene	1.0	70	156	16
DDT-R	5.0	350	1640	7
Dieldrin	0.1	7	122	2

would have to ingest only 2 oz. daily. While this still seems unlikely for most people, the point is that, for many chemicals, it is *perceived* that we are approaching the limit of acceptable intake.

Both the public and the regulatory agencies are becoming sensitized to the term "chemicals." California's Proposition 65 is an example of current public unease with chemicals in water and food. To find toxic chemicals in shellfish now seems inevitable, but something needs to be done to control their levels—and to control even their occurrence in products where we can possibly do that. Depuration by exposure to clean water is one possibility. There is some controversy over whether depuration is a good idea, but technically it can be done. I suggest that it is better to avoid exposing the animals to the contaminant in the first place, and that could be a subject for discussion here.

My message, then, is that water pollutants are everywhere—there are no pristine coves—and exposed molluscs will bioconcentrate almost everything right from the water. We often see DDT, but that's because we look specifically for it. If we look for the other substances, we will find them, and with Proposition 65 as a basis, regulatory agencies indeed are going to be looking.

Public and government reaction is becoming a major hazard to producers of shellfish. Let's be clear; I'm talking about reaction to *perceived* problems. Are people falling over dead after eating shellfish? Of course not. But perception is as important as reality in this case. If you don't want a particular chemical in your product, you must contrive to keep it out of the water. Otherwise the molluscs will inevitably pick it up.

Natural Seawater Chemistry: Implications for the Growth of Mollusc Larvae

DONAL MANAHAN

The predominant perspective on water quality is that if we can control the addition of pollutants to the water system, we have

taken care of the problem of water quality. That view of water quality represents what I call a "terrestrial bias" because it is based on our understanding of air quality.

How do we get good air quality? We find the point-source pollutants and stop them. But the chemistry of seawater is much more complicated than that of air. Even if you were to eliminate all pollutants, you still might not have good quality water for your animals. That is because poor water quality for aquaculture can also result from the inadvertent removal of essential chemicals and nutrients through your aquaculture process.

Let me describe some work I've been involved in that demonstrates the potential importance of dissolved organic compounds to juvenile oysters. For about thirty years now, cell biologists have used oyster embryos as models to understand early events of fertilization. We know that about one hour after fertilization, at the time of the first cell division, all of the chemical exchange processes begin. The animals are now taking various gases and ions out of the water by diffusion. And they are also absorbing organic substances, utilizing active transport systems that are similar to the way our digestive systems absorb foods—not passively but actively. As a result, they can concentrate certain organic chemicals against hundred-fold gradients.

We also know from chemical oceanographers that most of the organic material in seawater is in the form of dissolved organic material. Aquaculturists have concentrated primarily on the phytoplankton, but they constitute only a small amount of carbon compared to what is in solution.

I have made a simple graph of the weight over time of oyster larvae, starting as eggs. These are animals that are grown in sterile, filtered, bacteria-free media. As you might expect, the animals depend on inorganic chemicals (like calcium) from the seawater to go from an egg to a larva. Interestingly, they also show a 100% increase in their organic weight during this nonfeeding period. I'm saying that if the water chemistry is good, you can actually double the organic weight of the animal without adding particulate food at all.

That runs counter to how we usually think of these animals growing. We think they begin as a big, fat egg and slowly use up their food reserves to get to the next stage. So the aim of broodstock management is to try to take the lipid level as high as possible in the early egg, because the assumption is that it drops over time. But if you have the correct water quality, you can double the organic content of the egg. So there's a whole lot more to survivorship of these molluscs than simply the condition of the broodstock. Water quality can have a huge effect.

Why don't we see this happening at aquaculture facilities? Because we assume that the only criterion for "good" water is that it be free of pollutants, and we run water over a sand filter to take

out particulate material. As soon as we run it over the sand filter, however, we strip out certain organic nutrients as well, such as amino acids in solution.

What I would like to suggest is that if we observe slow growth rates, or if our animals are dying, we should not automatically assume that we have to go look for a pollutant. It may well be that the problem results from what we took out of the water, not from what we put in. If we have altered the natural chemistry of the seawater, the transport processes that begin when an animal is fertilized might not be able to carry out their normal function.

The session is now open for questions to any of our panelists.

DISCUSSION

Hooker: John McMullen spoke of a supersaturation problem in raising the abalone; could he expand upon that?

McMullen: Recently we expanded our operation to incorporate pressurizing the system. This was done to satisfy the demand for more seawater in the expanded facility. Prior to that expansion, we simply pumped water to a tank on an 18-foot tower and gravity fed seawater to the tanks. We didn't have a significant mortality problem at that time. But when we went to this new system, we saw an increase in mortality. For about a year we couldn't figure out what was going on. We built a desaturation tower out of PVC, put broken bits of PVC in it, pumped water through it and let it splash down into holding/settling tanks and then repressurized it. That seems to have solved the mortality problem.

The reason I brought it up was that I don't know if much is known about chronic or periodic episodes of supersaturation in aquaculture. If you have a situation where a supersaturated condition occurs for an hour per day, or two hours, caused by a small hole or crack on the intake pipe which is exposed to air at low tide, what does that do to the abalone? Does this period of exposure stress the abalone sufficiently to allow an attack of *Vibrio* sp.? (This bacterium is always present in seawater and does not appear to bother healthy abalone.)

I think trying to chase down a problem that occurs sporadically is very difficult. And once identified it is tough to rectify. This problem also arises when chronic levels of some toxins (heavy metal, pesticides, etc.) occur, stressing the abalone, and opening it up to some disease or pathogen.

Manahan: Along those same lines, you mentioned a list of things that are worrying you about water quality—TBT, bottom sediments, and so forth. What is your gut feeling on the hierarchy of problems?

McMullen: I worked on a test with the Navy about 5 years ago using TBT-impregnated pieces of concrete. We submerged the impregnated piece of concrete in a bucket with abalone eggs for a short period of time and pulled it out; we then found that we were unable to develop those eggs into larvae. That is how I know that TBT is extremely toxic stuff. Maybe that is the most important question to be addressed.

Crosby: We've had an interest in organotins for a long time, particularly the butyltins, and you're right: they are unusual in their high toxicity. For adult molluscs, other kinds of chemicals, like pesticides, don't seem to have outstanding toxicity, but butyltins do. One-tenth of a part per billion is a lethal dose for most molluscs. No published information is available as to the concentrations of TBTs in mollusc growing areas, but measurements made on the West Coast by Ed Goldberg of Scripps Institution of Oceanography show the highest concentrations to be in marinas. I think most of us would concede that a marina is not an ideal place for a mollusc-rearing operation, but we badly need to find out how much butyltins move and whether they are likely to move into the mollusc-raising areas.

Seeders: In a few weeks freshly painted reef netting rigs will be put out near our mollusc-growing area. All of them have bottom paint of one sort or another. We're going to start taking mud samples this week, just to have them available for analysis sometime in the future. Would proper management be to avoid doing any breeding activities for, say, a one month period? What might be the effect on molluscs of a month's exposure to TBT's.

Crosby: The effect of TBT on your molluscs would have a lot to do with the extent of the movement of the chemical in water and, obviously, the concentration you end up with at your location. We know, however, that even a few hours of exposure to relatively high concentrations of TBTs is lethal. I think that taking water samples rather than mud samples would be more indicative of the situation and easier to do. We don't know much about the rate of breakdown of organotins in mud; we do know that they are lost moderately fast from water. We had some discussion yesterday about differences in bottom paints, and it was pointed out that there is a polymer-based organotin paint and also a paint in which the organotin is simply mixed in. The latter kind is quite dangerous for molluscs and other types of marine life, whereas the polymer paint would not have such an extreme effect. You mention one precaution—avoiding breeding activities when the rigs first go in the water—and that seems like a good idea.

Hansen: I have a shellfish hatchery on the coast of Oregon and every spring after herbicides have been applied, I have problems with my animals dying. One hundred percent mortality usually occurs within days after the herbicides have been applied.

(Here in Oregon there is without exception heavy rainfall in the spring when the defoliants are applied.) We never detect any of these herbicides in the samples we take from the animals, but the problem is most severe three days after application. With each successive rainfall after the application, the problem diminishes, so I'm sure there is a correlation. Would you suspect that we could have problems with these herbicides and yet not be able to detect them in our animals?

Crosby: What is the herbicide, and where is it being applied?

Hansen: The pesticide 2,4-D is being applied to thousands of acres of forest and to roadsides.

Crosby: There have been tests on 2,4-D, and it is not known to have any appreciable toxicity to molluscs. However, the medium in which the pesticide is applied is usually ignored in these studies, and it could be the culprit. If the pesticide is applied in oil, then conceivably the oil is giving you the problem. Is a particular stage of development of your shellfish affected?

Hansen: Yes, the animals start to metamorphose before they reach the usual size. They'll try to metamorphose at 280 μm, for example, instead of 315 or 320 μm.

Crosby: I'm not aware of any research that has looked at 2,4-D or other herbicides in that regard, so conceivably it could be the culprit. But then you should be able to find 2,4-D residues in the mollusc. The fact that you don't leads me to think that the problem is with the carrier, and not the herbicide itself. There are methods to determine that without too much difficulty.

On the other hand, in the case of Sevin (insecticide), it is the breakdown product and not the pesticide itself that is the problem. That's another possibility.

Glenn: Since these toxic compounds are concentrated in lipids, does it follow that the fatter the animal, the more toxic it is?

Crosby: That's approximately true. The proportion of chemical in the fat always stays the same, so if you add more fat, you add more chemical, though the concentration remains constant.

Hollibaugh: Is that true for metals?

Crosby: Metals don't follow the curve I showed you in Figure 1. Metals are taken up by organisms, but not readily released. They bind with protein, and only come out in relation to turnover of protein.

Clutter: What might be the effect of having 50 acres on which there are about a quarter of a million linear feet of 2-inch PVC pipe, used to suspend oysters.

Crosby: Let me congratulate you first for thinking about chemicals. Specifically, with PVC, the principal difficulty is likely to be an organotin compound. Organotins other than TBT are used as catalysts for making PVC. The leaching of organotins out of PVC pipe has never been studied; it would be a good research topic.

Hahn: When I was in New Zealand, I noticed they painted their settling substrates with anti-fouling paint and had no die-off. But they didn't know if the paint contained tin or copper.

Crosby: If I understand this correctly, they had painted a surface with an anti-fouling paint and used it as their settling substrate, and the organisms just went right ahead and settled? It doesn't sound like very good anti-fouling paint to me. The copper-based paints are not nearly as toxic to molluscs as are the tin-based paints, so it sounds as though the paint contained copper or something other than tin. In my experience, anti-fouling paints containing TBT are very effective for all kinds of adhering organisms. In experiments in Hawaii, it was found that paints containing tin even in very low levels, keep everything off; that's why the Navy likes them.

Clutter: Do we know what chemicals come off the plastic Flexar bags that are used to hold shellfish?

Crosby: I was told that these bags are polyethylene. Polyethylene today generally does not contain other chemicals, with the possible exception of phthalate esters to make it flexible.

McCormick: What is the overall state of knowledge on non-point source pollution? Are you starting to look at agricultural residues in California?

Crosby: Yes, we have been looking at that, off and on, for some time. I can't say we have gotten very far. I have a graduate student working on it, and one of the things she is finding is that organic pollutants often break down more readily in seawater than they do in fresh water. One reason why there has been so little success in measuring these chemicals in the marine environment may be that they don't persist for long. We're trying to find out why that is. Again, this is different for metals.

McMullen: What toxics could we expect to find in the edible portion of an abalone? Just metals?

Crosby: Abalones take up contaminants from the water in the same way as do other molluscs, fish, and crustaceans. Toxics get translocated quite rapidly into the muscle, though the highest amounts are in the gills. The chemicals are likely to be wherever there is fat.

Hansen: What about fiberglass resins?

Crosby: Any plastic where you start with a monomer and then polymerize it with catalysts will still have some monomer in it. So if you're using Plexiglas, for example, there will be free acrylate to be absorbed by the animal. On the other hand, acrylate would probably not bioconcentrate a lot.

Participant: What's the most inert plastic. Since plastic works so well in seawater, is there one best suited for aquaculture?

Crosby: Teflon. You can now buy very, very thin Teflon sheet called Tedlar, and you might be able to use that to line things. Or you might be able to use particles of Teflon suspended in a

solvent and sold in a spray can. With any of these chemicals, I'd suggest that you condition the tank—let water run through it for a few days before adding animals.

Lannan: In our laboratory, we've done a lot of bioassays using mollusc larvae as an indicator organism on fiberglass equipment that we constructed. We find that fiberglass is "hot" initially, but the toxicity rapidly leaches out. The catalysts are water soluble, so within a few days, fiberglass structures will easily pass the mollusc larvae bioassay.

Crosby: And any monomer that is left—methyl methacrylate—is water soluble too. I've found the same thing with aquarium tanks.

Seeders: Since abalones are grazers, might they be picking up some of these materials while they graze on the diatoms?

Crosby: Yes, if the diatoms contain pollutants. However, the principal uptake is directly out of the water.

Hollibaugh: Those of us in the industry must weigh possible shellfish mortality associated with PVC pipe or polyethylene structures against the cost of trying to set up an ultraclean situation. I think we are concerning ourselves more than we should with the survival of the animals, when we should be considering other questions, like how pollutants affect the marketing of the product.

Crosby: You are absolutely right. Someone was saying during the break that my presentation really scared you. That was not my intention. Rather, I wanted to present findings that I think are realistic and persuade you to think about what chemicals your animals are exposed to. That doesn't mean you have to make radical changes in your operations. The example I gave of oil fumes being inadvertently mixed in with air shows that some problems can be solved quite easily.

McCormick: We are getting pollutants both from agriculture and shipping. I know that pollutants are adding something bad to the water, but are they also taking something good out? That is, might these pollutants be reacting with organic compounds, like vitamins or amino acids, making them unavailable for the shellfish?

Manahan: A lot of heavy metals will absorb and chelate out various organic compounds in seawater. That's an area of intense study. These chemical interactions do occur, but whether they are pulling out specific chemicals that might be of benefit to molluscs is unknown. Very likely they are.

Crosby: The organic pollutants, as opposed to the metals, probably do not do that. Further, they are usually present in the parts-per-trillion range, whereas the nutrients are in the parts-per-billion range and even up to parts per million. So the amount of contaminant, even if it did interact, would be very small.

Richards: Does anybody know exactly what chemicals the

Mussel Watch program is testing for? Does it include organics? Can one correlate their stations with growing areas?

Crosby: California's State Mussel Watch Program puts out reports regularly, though they do run behind. The reports list all of the stations on the California coast and give an account of the 25 or so substances that the program analyzes for, both in wet and dry weight. I think aquaculturists would find them instructive and valuable reading. I took the statistics for my talk from that. I chose high values, but not the highest. The reports can be obtained at nominal cost from the Department of Fish and Game.[4]

Pitts: If someone here was scared by Dr. Crosby's comments, you can imagine the response of decisionmakers and elected officials, who are usually laypersons. Oftentimes, this type of information is presented to commissioners or legislators without expert interpretation, and it results in a negative decision. Information on toxic substances has to be framed in a perspective that the lay population can understand.

Piedrahita: Is there something that the aquaculture industry should do to prepare for widespread publicity on the pollution issue? Are there preferred culture methods? Should the industry plan for depuration of organic toxins?

Crosby: One important thing that we have been working on is a master list of chemicals that aquaculturists might have to deal with and levels that they are likely to encounter.

As a long-term matter, depuration should at least be looked at as a possibility. There also will have to be greater regulation of chemicals onshore before they can get into the seawater. For example, I had a quick look at a data bank on the distribution of pesticides in California and found that the Salinas area river valley is the major user of Dacthal (herbicide) in the state. There seems to be a connection between the chemicals used in that drainage and molluscs being contaminated on the Monterey coast. In that case, we may need further regulation of Dacthal to lower the possibility of it polluting seawater.

Hollibaugh: We're dealing with bad press already. A year ago a study by the New York Department of Health concerning an outbreak of virus in shellfish on the East Coast was reported in the *New England Journal of Medicine* and was picked up by a number of news services. A UC Berkeley faculty member, who writes health articles for the *San Francisco Chronicle* and other papers, used that report as the basis for an article for the food page, the gist of which was "eat oysters and die." A number of people in the industry tried to reply to the article with letters to the editor, but it didn't do any good. The editor published some of the replies, but the writer's next column simply ignored the points they had raised concerning differences between shellfish culture

[4]Mussel Watch reports are available from: Publications Office, State Water Resources Control Board, P.O. Box 100, Sacramento, CA 95801.

practices of the West and East coasts. (For example, the East Coast industry is based on a fishery. Regulators have poor control over where the shellfish comes from, and there is poaching and illegal transfer of shellfish harvested from polluted beds into approved beds.) The local health services were very supportive. They presented our position to the media, but we still were up against a syndicated columnist.

Pitts: We had a similar problem in Washington State. We approached it by having the Department of Agriculture issue a press release—more effective, I think, than letters to the editor. When I was a politician, I learned that you should never get into a fight with someone who buys ink in barrels.

Price: When you are talking about pollution, there are two effects to distinguish. One is the effect on the growth of the animal and its metabolism, and the other is the effect on people, including whether they find the product acceptable. One thing that industry can do is to encourage the FDA to determine human tolerance levels for these materials in edible shellfish. They have not done that. Even where FDA has set levels (like mercury at one part per million; PCBs, two parts per million; DDT, five parts per million), the figures are one or even two orders of magnitude above Mussel Watch figures. As Dr. Crosby says, you can always find these chemicals, but from a public health point of view they may be insignificant. And, of course, tolerance levels take into account how frequently people eat a particular food.

Another aspect of the pollution problem came up in the Elkhorn Slough when we tried to determine just how contaminated the shellfish are. The mussels in the harbor area did indeed have fairly high levels of toxins, but out in the slough away from the boats and the Salinas River, the levels were very, very low—parts per billion at least. So there is a distinction between what you can find in the worst part of a waterway and in the parts in which shellfish are growing.

Conte: In the past, commercial growers have requested that we establish what the toxin levels are in the natural mollusc fisheries that are being harvested, not just study levels in the commercially cultured shellfish.

Glenn: One thing we must do is to develop some perspective. For instance, what are the levels of these different chemicals in chicken eggs? Or in beef? Or in lettuce?

Lannan: I'd also like more talk about depuration because it allows us to hold our animals during periods of heavy rainfall when we are not allowed to harvest. By harvesting before a rainfall and holding the animals in clean facilities, we could continue to market them over a period of a week or two until the bay water is clean.

Seeders: Another concern is pharmaceutical pollution. A salmonid pen operation was proposed within a few miles of our

bay. In the public hearings it came out that the owner was proposing to feed the salmon a new artificial food, which sometimes has to be mixed with antibiotics. I got into sea farming because I saw chicken and beef farmers using chemicals that jeopardize people's health. I'm concerned that we in aquaculture may start trying to get too much yield out of small spaces and have to begin relying on antibiotics. Is anything being done to see if there is a problem with pharmaceuticals in seawater?

Crosby: As far as I know, there have been no studies of antibiotics in seawater, and I agree that we must look into all kinds of chemicals, including commercial feeds. Since we are far from the ocean in Davis, we rely on commercial chow for our aquaculture operations. A few years ago, an article reported that badly contaminated waste feed materials had been incorporated into the chow. We analyzed some of our own, and although it wasn't as bad as the published values suggested, the chow we were using was contaminated. If you are going to be using aquaculture, particularly onshore, chow will have to be watched as a source of contamination.

Manahan: It is my understanding that mammalian antibiotics have a half life of only 20 to 30 minutes in seawater, which is one reason why they are extremely ineffective in controlling marine microbial communities.

Pitts: There is much misinformation rampant in the community in regard to salmon aquaculture. For example, the feeds that are being used with salmon aren't artificial feeds; they come from fish meal and are produced in pellet form, which is more economical and environmentally sound because pellets result in less waste.

With regard to antibiotics, we often hear that tetracycline is going to be used as a growth stimulant for salmon, as it is in the beef, pork, and chicken industries. But studies on salmonids show that tetracycline does not stimulate growth, so therefore you'd be throwing the antibiotic away. If it has to be used for disease, tetracycline is probably the drug of choice. In Washington, we use it on two organisms *Vibrio anguillarum* (vibriosis) and also *Aeromonas* (furunculosis). The antibiotic is used two or three times a summer for a ten-day period. (Tetracycline is a water-soluble compound, the sulfonamides are fat soluble.) In the marine environment in summer temperatures the half life of tetracycline is probably less than 20 days. There is no evidence, either here or in Europe, that these antibiotics are being picked up in molluscs.

Lannon: Fish culturists have a lot of experience dealing with pharmaceuticals, both for preventing and controlling outbreak of disease. The Japanese have the best documented histories.

Turning to the question of feed ingredients, fish culturists have a long history of formulating artificial rations. These rations include ingredients available on the commercial market: fish

meals, oils, vitamins, etc. Some feed mills are very good about controlling the quality of the formulated ration, but there is still virtually no quality control of ingredients. Things like cotton seed meal may be of high quality, or low quality because of poor storage. Similarly, most of the lipid fraction of fish rations comes from fish oils, which are highly prone to auto-oxidation. A barrel of salmon oil from Seattle, for example, may be very different in quality from menhaden oil shipped from the East Coast through Yuma, Arizona.

Hahn: Dr. Manahan, after you have filtered the water through your system, do you recommend having amino acids leach back into the water? What is your solution to the problem you have found?

Manahan: I do not recommend adding chemicals to seawater. Microbes will take over your whole system. At present, we don't know the chemical requirements of any animal we grow in the sea. When we know exactly what chemicals an oyster needs, then we can start our manipulation. At this stage my recommendation is simply to try as hard as possible to disturb nature as little as possible. Use the chemistry of the water in as natural a form as possible. Maybe if we use an inert biological filter instead of sand to get rid of the particles, this will have a good effect, but maybe not.

Pitts: Industry representatives in our state are always asking me how we can better use the university, Sea Grant, and public funds to enhance knowledge and improve the dissemination of correct information. Are there any suggestions?

Crosby: Apparently, the general public and even some regulators are not able to interpret the kind of data they are likely to find, for example, in the Fish and Game reports. Maybe the University of California, through the Marine Extension Program, could provide more interpretation for the public on toxicity issues. Maybe we need to put more effort into educating the public as to what various concentrations of things mean.

Hollibaugh: California does not yet have an aquaculture coordinator in state government. While we in industry do have a lot of interaction with the university, it is on more of an ad hoc basis, not channelled in the same way as in Washington. So if we have a problem, we have to call the aquaculture specialist, or one of the marine advisors, or go to Bodega Lab and ask them to let us set up an experiment on our own. The relationships work on a less formal basis than in Washington.

McMullen: My experience is similar. Scientists who are interested in doing research find me and ask me questions. But when I want to present a research problem to be worked on, I do not generally get any response. That is not to say I don't get any help—but not necessarily the research help I need.

Hollibaugh: The questions industry ask get lost somewhere

along the line, perhaps because they are applied and practical...not the kinds of questions that interest a scientist focusing on a research project.

Lannan: I have to come to the defense of the professors here. We academics have something of a black eye right now, and maybe we deserve it in part. There have been lots of meetings, not unlike this one, designed to stimulate dialogue between producers and researchers and agency people, with the aim of outlining research needs. But the outcome is often that academic people just continue to do what they had intended to anyway. Maybe that's not completely bad, and what really broke down was the process.

When I look over a list of the concerns that have been aired today, I see that the topics fall rather neatly into two categories: art and science. Shellfish culture is really a highly developed art form. By understanding the underlying science, one can improve the reproducibility and the application of the art, but aquaculture will always continue to be an art form. There is a good deal of information and practical knowledge floating around, and many topics can be dealt with by simply sharing information—one example would be gas supersaturation. On the other hand, there are legitimate research questions, where the information available is very limited. For example, what are the nutritional requirements of bivalve and gastropod molluscs? Virtually nothing is known. The basic biochemical and nutritional studies that have been done with mammals and microorganisms just havn't been done for shellfish. What are the allowable levels of pollutants (organic pollutants especially and heavy metals)? We must keep the dialogue going and improve the communications.

Hollibaugh: I would not place the issue of toxic pollutants on a list of research priorities—except for issues of public perception, which I see as a public relations problem as much as anything else. I am more interested in questions that affect my operation directly, such as summer mortality and the fact that I can't sell halfshell oysters in the summer. Since I cannot sell them, I am looking for other kinds of oysters to grow in the summer or for a genetic method of improving my stocks. I am also interested in differences in culture methods and in genetic studies aimed at producing an oyster that has better shelf life.

Conte: I'm glad you said that, but I have to agree with Jim Lannan as well. As a UC Cooperative Extension person I've been waiting to hear industry people articulate their needs here today. I've listened for years to questions from industry about research in shellfish sanitation, but I have heard nothing today. I have to conclude that Extension should deemphasize that area. But I don't want to walk out of this meeting and later be beset by industry because the university is not working on sanitation issues. I don't understand why shellfish sanitation hasn't come up.

Sullivan: I really don't see that it's the university's responsibility to clean up industry's image. That should be done by the industry association. The association should turn to a specialist, like Fred Conte, or to a researcher, like Don Crosby, and then put out its own informative press releases. A good model would be the California Seafood Institute, an industry association that deals with bad publicity very rapidly. That group does call on university and agency experts for information, but they see it as their job to take care of public perception.

Hollibaugh: I agree with your point that the university is not responsible for cleaning up industry's image, but I want to make the point that because of the direction the meeting here has taken, the needs of the industry have not adequately come out.

Glenn: Despite the fact that the University of California has an immense amount of talent, that talent is pursuing basic research, which often is very esoteric and has nothing to do with my needs today or tomorrow. So essentially that talent is unavailable. Depuration, mentioned earlier, provides one example. Virtually all the countries of Europe require depuration for everything. We in the United States must find the optimal way of using that technology before we need it.

Lannan: As important, or more important, than working on depuration, is understanding better what happens to growing areas when they are adjacent to sources of pollution, especially bacterial pollutants. What is the residence time of these organisms in the water? What are their dynamics? Do zero plate counts mean that there are no bacteria or are they there in some other form?

Hollibaugh: There's a lot of room for work in the area of the indicator organisms. There are studies by the EPA and one from Florida State University that show little or no correlation between fecal coliform counts and health risk. Yet coliform counts are the universally applied standard for water quality. What can we do to get a more meaningful indicator for the true health risk of the product? Suspending harvesting operations for two or more months each year is not a particularly happy situation for me as a grower in Tomales Bay. If there is a real health risk, I am happy to stop harvesting; but if not, I want to be able to harvest during those periods. It's a great economic burden to be closed during the prime halfshell season for the oysters I'm growing.

Lannan: I have some serious personal questions about the relative values of basic and applied research and how to weight them. But it is really rather naive and incorrect to write basic research off. Solutions to so many problems in agriculture and aquaculture resulted from basic research. I question whether it is good use of a scientist's time to get deeply involved in plumbing problems. But somewhere between the extremes, we should be able to achieve a balance and respond better to industry's needs.

Richards: Dick Glenn suggested that the University of California does pure science work almost exclusively, but that varies from campus to campus. Those of us who have had Land Grant experience at the Davis, Riverside, and Berkeley campuses understand applied research much better. What *has* been missing in the system, however, is the idea of an experiment station for aquaculture, though I think that Bodega Marine Lab is working toward that.

Cooper: To make interactions between industry and the university work best, we, as industry, have to find researchers working on projects of mutual interest. For example, we have interacted to a great extent with the University of Washington during the development of our triploid oyster program. And we have recently begun working with Dennis Hedgecock of UC Davis to obtain help in developing a breeding program. What has not, in general, been successful is for industry to ask the universities to work on a problem where no existing research program is established.

Conte: The issue of basic vs. applied research has not been a problem for the growers in California. In fact, it's been the policy of the board of directors of the California Aquaculture Association to support the basic research efforts of the University of California. Industry does, however, wish that some of that basic research could use aquaculture animals as the vehicle. I have found strong regional, national, and state support for basic research throughout the industry.

Sullivan: I think it's nice that the industry supports basic research, but I don't like the fact that industry might want to deny funding to basic research projects if it does not like the species the researcher has chosen. That hinders the development of science. Howard Bern's work on salmon is science of the most basic kind, yet it is likely to have broad applicability.

Hollibaugh: But sometimes an organism is chosen for study just because the researcher has an interest in that organism, not because it is the ideal organism for answering some particular question.

Manahan: I'd like to close this session by giving my own reactions to some of the issues that have been raised. The question keeps coming up of how to present measurements of toxins once we have made them. The issue of public reaction to reported contaminants seems to be a serious concern for the industry. But if the public is all that concerned, I can't understand why people keep buying more and more oysters...why does the import figure (given by Jim Lannan earlier) keep increasing? Could it be that we're exaggerating public perception of the pollution issue?

The question of how to measure water quality also came up. That was an extremely complicated issue for many years. During

the 1980s, however, there has been an explosive growth in analytical chemistry of highly saline solutions that allows us to work with many organic contaminants, naturally occurring dissolved material in seawater, and a lot of the inorganics. With that analytical capability applied to some of the empirical approaches we work with in industry, I'm quite optimistic that empirically we can cope with a lot of these water quality issues.

There are very few laboratories in the world, maybe two or three, that are studying the basic biochemistry of nutrition of molluscs. What amino acids do they need? What fatty acids do they need? What vitamins? What are the ratios of all these things? We haven't even started to apply the basic lessons of agriculture to mariculture.

VI. BROODSTOCK MANAGEMENT AND STOCK IMPROVEMENT

LEE HANSEN, Moderator, Whiskey Creek Oyster Farm, Tillamook, Oregon
RICHARD GLENN, Owner and Manager, Seafarms West, Carlsbad, California
ALPHONSO AGUIRRE, Partner, Cooperativa Bahia Falsa, Ensenada, Baja California
RANDY SHUMAN, President, Applied Marine Research, Inc., Seattle, Washington
DENNIS HEDGECOCK, Geneticist, Bodega Marine Laboratory, University of California, Davis
WILLIAM HERSHBERGER, Associate Professor of Fisheries, School of Fisheries, University of Washington, Seattle, Washington

LEE HANSEN

We will have five speakers in this session on broodstock management and stock improvement.

Our first speaker, Richard Glenn, operates Seafarms West, a shellfish farm in Carlsbad, that uses off-bottom growing techniques that are identical to those used in France for oysters and molluscs. Our second speaker, Alphonso Aguirre, is a partner in a cooperative in Ensenada, which is the largest shellfish producer in Mexico. He will discuss a number of research needs in abalone culture. Randy Schuman, president of Applied Marine Research, Inc., manages an off-bottom oyster farm in Willapa Bay. He has a number of practical problems in broodstock management and marketing to share with us. Finally Dennis Hedgecock, a geneticist with the University of California, Davis, will discuss exactly what the process of domesticating oysters will entail, and William Hershberger of the University of Washington will elaborate on the requirements for genetic improvement of molluscs.

Before we start I would like to give my pie-in-the-sky wishes for future research. I believe what we in industry can take care of our own short-term problems. But I'd like to see someone collecting and holding exotic species in quarantine for us to experiment with. Genetic studies are important, but they could take years. I think one thing that we desperately need now is the ability to manipulate water quality.

European Techniques of Oyster and Mussel Farming Applied to a Southern California Coastal Lagoon

RICHARD GLENN

I'll start by telling you a little bit about growing mussels and oysters so you'll have an idea that farms actually exist. The techniques that we use are totally off bottom, and are quite different from those used by the large growers in Northern California and Puget Sound. The stock we get from Whiskey

Creek Oyster Farm is only a few generations removed from wild stock—three at most—and we get great variations in growth rates and everything else. There has been essentially no genetic selection, so we've got a long way to go in stock improvement.

We are leasing 5 acres of water from San Diego Gas & Electric, which owns the entire Carlsbad lagoon complex. In addition to a shore facility, we have tanks that are used to hold marketable product after harvesting so that when we get an order we don't have to go out into the lagoon for oysters.

Our oysters are grown using a tray culture technique that I developed in Baja, California. Growing oysters in trays creates fouling problems. So when the oysters reach 4 or 5 cm, they are put in bags and grown in the intertidal region, where fouling is not a problem. The oysters have to be shaken up, like popcorn, so they don't stick together. These techniques are identical to those used throughout France. When the oysters are of marketable size—when they fill about half the bag—we bring them in and wash them off in the bag. We have a mechanical cleaning gadget, but these oysters have rather fragile shells because of fast growth, and we have to handle them more gently.

We grow three types of oysters, Pacifics, French (or Bélon), and Kumamotos. All reach marketable size in one year or less.

Our mussel growing operation follows Italian long-line techniques. Unlike oysters, we obtain mussel seed from natural spatfalls in our lagoon and nearby. The seed is placed in a tubular net "stocking" designed specifically for mussel growing. The stocking or "reste" that we use comes from Italy and, originally, we imported it. Now it's available in the United States from dealers who do the importing themselves; NORPLEX is now manufacturing the same item in Washington. The mussels are put inside the stocking and suspended from the longlines, each one of which is some fifty yards long.

Let me conclude by listing some things that could help us in our operation. (1) There's a gastropod (*Pteropurpura festiva*) in the lagoon that will drill almost any bivalve, but it has certain definite preferences—for oysters over mussels and Bélons over Pacifics, for example. Research is needed to find a way to control this drill. (2) We have quite a problem getting small mussels to stay put. They move around like snails when they are small, so they have a tendency to be knocked off the rope or other substrate on which they are growing. It would be nice to know what substrate, if any, will encourage them to set and stay put. (3) Also, someone should figure out what disease is afflicting *Ostrea edulis* and what to do about it. The French have been working on the problem for quite some time. But they look to the United States as the leader in technology, so maybe the University of California can come up with the answer.

Abalone Culture: A Perspective from Mexico

ALPHONSO AGUIRRE

I would like first to make some general observations about the close economic relationship between our two countries, which suggests that it may be possible to think about developing shellfish culture on a coordinated basis between the Baja California peninsula and the West Coast of the United States.

Some weeks ago, the U.S. Congress approved a measure to promote the integration of a common market between Canada, Mexico, and the United States. Five days ago, on July 4th, 520,000 Americans crossed the border to Mexico and spent $31 million in Baja California over the weekend. Each day, between 200 and 400 trucks move between Baja and the United States, transporting all sorts of merchandise. On the other side, most of the cars in Baja were made in the United States. One hundred tuna boats made in the U.S. or by U.S. companies, and costing $5 million to $10 million each, fish in Mexico with Mexican flags.

Regarding mariculture, you have technological know-how on the U.S. West Coast that allows commercial scale production. In Baja, we have very clean, rich, unusually virgin waters that are not facing competitive uses. Baja has almost no fresh water, no industry, no agriculture. We do have natural resources for mariculture development, but we need technology and capital. We both have good markets.

In the three northwest Mexican states of Sonora, Baja California, and Baja California Sur, Japanese oysters and mussels are now being grown successfully. In Sonora, 400 metric tons of Pacific oysters are harvested each year by 27 co-ops. In Baja California Sur, three co-ops produce 150 metric tons per year in Magdalena Bay. In Baja, our co-op produces 1,000 metric tons of oysters per year, 95% of which are consumed in the regional national market that we developed for the product and 5% of which are exported to the U.S. One private company whose main market is Mexico City, produces 350 metric tons of mussels per year.

Abalone culture in Mexico has had an interesting history. Two decades ago, Mexico contributed 60% of the world's abalone catch. Now, our production represents less than 6%. This great reduction has resulted from both overfishing and an increase in Australian catches. From a peak of 6,000 metric tons per year in 1950, production last year dropped to its lowest level, less than 500 metric tons. Nonetheless, abalone remains important to the economy of the Baja peninsula and to the Mexican fisheries economy; almost all of the product is exported, contributing to the foreign currency needs of the country.

Between 10 and 15 years ago, the Mexican government recognized the overfishing problem. Results of research on

techniques of raising abalone done cooperatively with Japanese researchers, were promising, so ten years ago, two juvenile production laboratories were built by the Ministry of Fisheries. Since then the production laboratories have been run erratically, mainly because of financial difficulties.

Our cooperative, the largest cultivated shellfish producer in Mexico, started the first abalone culture in Mexico at the pilot commercial level 3 years ago, using red and black abalones. Some of the juveniles were produced in the Erendira laboratory, others in the United States, and still others were obtained from the natural environment. The growing area is located in the San Martín Island area. Our growing yards are floating PVC 50-gallon drums linked together; the food is natural fresh kelp.

Our first results are good. In 30 months, the juveniles grew to the harvest size of 8 to 10 cm. The observed mortality, related mainly to handling, has been between 20% and 30% over this growth period. Financial results are satisfactory, but would be improved by lowering the mortalities and integrating the juvenile production phase.

Japan had 28 juvenile abalone production centers in 1981, with an annual production of 20 million 2.5-cm juveniles, and the Japanese have been expanding continuously. Our need is at least in that order of magnitude in the short term. Juvenile production should be allowed to grow under protected conditions. Restocking of natural populations is also attractive, though it is not clear yet how restocking with laboratory juveniles affects natural populations.

We can divide the technical needs of abalone culturists into two phases. The first is juvenile production, which is sophisticated and technically complicated. The other is the growing of juveniles to commercial sizes. Both phases can be done by the same producer; however, it is easier to specialize first and later to evolve an integrated system.

Research needs from our standpoint for the production of juveniles are: (1) Development of techniques for inducing sexual maturity, so we can have a continuous production of juveniles; (2) Design of commercial, large-scale juvenile production facilities. Optimal commercial scale and location should be considered; (3) Genetic improvement in the growth rate and food conversion efficiencies of juveniles; and (4) Financial projections on the commercial production of juveniles.

Research needs for growing juveniles to harvest size are: (1) Design of commercially viable growing yards (floating, middle water, and bottom), including artificial and concrete reefs or structures; (2) Development of alternative diets, including, possibly, land vegetables; and (3) Design of handling techniques and operating systems to reduce mortality during the growing phase.

A special effort should be made to disseminate information about advances in a clear and condensed way, emphasizing financial and economic aspects. It is also essential that the producer have detailed knowledge of the market. Good market studies tell management the production levels that will satisfy the market, as well as optimal presentation size.

Research Needs from an Oyster Producer's Perspective

RANDY SHUMAN

The problem of obtaining oyster broodstock is a very practical one for our industry, which often operates in a crisis mode. If a hatchery facility needs broodstock, it has to find a source that is in spawning condition and bring it to the facility, usually within a week. If a state boundary happens to be between the source and the facility, then there are always pathology problems to be dealt with. It would, therefore, be extremely helpful if there were central coordination of broodstock handling. Perhaps a central facility could handle broodstock lines, exporting them to any hatchery, and making sure they're in the right condition at the right time.

Another problem is that oysters are such a plastic species—that is, environmental conditions have a large effect on the expression of genetic traits. Therefore, a big problem in talking about selecting genetic lines for particular traits is the fact that animals sharing exact genotypes but found in different environments will be completely different animals from a grower's point of view. And it is difficult to control the organisms' environment because natural conditions and culture apparatus vary.

We in industry are very interested in the polyploid research that is now underway. If we could extend our selling season from 9 to 12 months, we would be elated for three reasons. First, consumer confidence in our product is undermined when we have to admit that oysters are not in prime condition, even for a short period. Second, that three-month gap allows producers from other parts of the world to move in. Our niche in the market is being filled during the summer season by Canadian and New Zealand growers—they have their foot in the door so to speak, and the only thing limiting them from being a larger factor in the market is the expense of their product. If they got down to our price, we would have a difficult time getting our customers back in the fall. Third, seafood consumption is high during the summer months, especially on the West Coast, as a result of increased tourism. And that's exactly the time of year we are out of production. It's a big opportunity missed. Also, for small and

medium-sized companies, it is a major problem to have your cash flow change by 80%; banks don't like to see that.

Another question that growers would like to see addressed relates to appearance. In many cases, we actually sell our oysters on their outside appearance, so it would be nice to have oysters of uniform size and shape. The ideal would be an oyster that grew quickly when small, and slowed down when larger.

One of my major responsibilities is marketing, and I've seen a positive change in how oysters are marketed. Some restaurants now have oyster menus...like wine lists. We would see an even greater improvement in marketing if we knew why the appearance and flavor of oysters change both seasonally and geographically. Winemakers have a fair amount of control over how their product tastes—they understand enough of the chemistry to produce a certain taste. I would like to see some research as to why the taste of oysters varies the way it does. It's a long-noted phenomenon that's not understood.

I'm also interested in the development of new aquaculture species. At present, many species are not utilized that might be. Innovative marketing ideas are needed. Our company now has a grant to study the culturing of the geoduck clam, and one of our ideas is to market that species differently. The animal is large, and it is sold now as one large piece of raw meat. Our idea is to sell it at a small size, perhaps 2 to 3 inches long, and have it eaten almost as it is sold. We should not underestimate the food service people. They like to try out almost any new product.

We in industry have one other serious concern that is not directly related to broodstock management but to the relationship between universities and the private sector. My background is in university research, and now I'm a manager in the private sector, so I have a keen interest in this relationship.

We're having a problem in Washington State that has been brought about by the polyploid work being done by the University of Washington. You may know that the University of Washington has tried to patent the triploid oyster and the process it takes to produce that oyster. Yet it is continuing to try to get oyster growers to help in this research with both money and in facilities. At the last board meeting of the Pacific Coast Oyster Growers Association, I was appointed chairman of a committee to ask the university to clarify its policy on patents because there obviously is a lot more research on the horizon. We were told by the university's Office of Technological Transfer that prior to 1981 there was no coordinated federal policy on patent rights for research advances made with federal funds. But in 1981, a new federal law gave those rights completely to the university.

Because this is a time of financial hardship for universities, our university and many others have become more aggressive in looking for patenting opportunities and pursuing them in the

individual departments. Last year the University of Washington received $1 million in royalty fees, hardly small potatoes. The first $10,000 in royalties goes to the inventor, and then the next $30,000 is divided through a complicated formula between the department and the university.

The next step—the one that concerns us the most—is to license that invention. The policy at the University of Washington is to identify the company that will bring an invention to the marketplace as quickly as possible, thus generating the fastest royalty flow into the university. Licensing will not be done on an open bid basis, but "in house" by the university.

I think this is a major threat to the relationship between industry and the university. The feeling in Washington State is that if there is not a strong written agreement between the university and the oyster growers in the future, then the university is not going to get any help from us. Why should we help the university with our facilities if it is going to turn around and sell an important technology to the highest bidder?

Also, in all of the research I have done, the contracts have stipulated that all results be published. But now, if there is patent potential, publication will be delayed until patent rights have been obtained and licensing agreements signed. I think the situation is potentially serious and one you should all be aware of.

Can the Pacific Oyster Be Domesticated?

DENNIS HEDGECOCK

I want to concentrate less on technical matters, like the genetics of bivalves, and more on a philosophical matter that surrounds the process of domestication. The issue we are confronted with when considering the West Coast oyster industry is, "Can the Pacific oyster be domesticated?"

This definition of domestication was written by a British geneticist, Helen Spurway (*J. Genet.* 53:325–362), in 1955; it is a bit cynical but makes a point I'd like to stress.

> To call a population, or species, domestic seems to mean no more than that, dead or alive, its members have widely accepted economic value as a source of raw materials or labour, and their slaughter, and if necessary castration, and if possible copulation, is organized by human society. The adjective domestic describes human behavior to the commensal.

It is quite clear that Pacific oysters, both dead and alive, have economic value as food for human consumption. It is also quite clear that commercial culturists now completely control the spawning, distribution, and harvest of these organisms on our coast. The Pacific oyster is an introduced species, an exotic, and

would probably not occur here except for a few localities where natural spat set does occur sporadically. So the industry really controls the future of this species on our coast. At present, production of triploid oysters—that is, animals with an extra set of chromosomes—is being considered as a way of "castrating" oysters. So in these respects we seem to be falling in line with Spurway's definition as to what is domestic.

There are some areas, though, in which society and even the concerned parties at this workshop have not really begun to treat oyters as a domestic species. I suggest that the answer to the question of whether Pacific oysters can be domesticated is *no, not yet.* There is not yet sufficient commitment and determination to make oysters domestic.

The West Coast industry now relies almost exclusively on hatchery production of eyed larvae. The development of the techniques for producing these larvae and their recent application from 1980 onwards are real milestones in this industry, because they mean that this oyster population is now in closed-life-cycle culture. It is this closure of the life cycle that creates the opportunity for stock improvement as well as the responsibility for safeguarding the genetic resources found in those stocks.

Selective breeding does appear to be possible. There is plenty of genetic variation to work with, so why don't we get on with it? The answer is that we can't get on with it because we don't have pedigreed populations. We don't know who is the offspring of whom or the genetic relationships among individuals.

Before written history, when humankind first domesticated our terrestrial stocks, the pedigree of a particular dog, for example, was known because the whole family was reared in plain view, around the campfire. With oysters that's not possible. Because of the enormous number of offspring and the fact that they're mixing in the environment at all stages of the life cycle, pedigree information is exceedingly difficult to obtain. Nevertheless, this knowledge is absolutely essential in order to quantify the variation in traits and to separate what part of the variation may be genetic and what part environmental.

Furthermore, it is difficult to determine the economic value of certain traits, for example, increased growth rate, without pedigree information on individuals. How important is it to alter shell shape? Disease resistance? Genetic trade-offs need to be assessed against hard figures on the economic value of traits and the costs of altering those traits. Thus, it is only by developing pedigreed populations that we can begin to design breeding programs and to treat this animal as a domestic species whose reproduction is completely controlled.

At the same time, we have the responsibility to guard against erosion of genetic variability resulting from inbreeding and to avoid the negative effects of *indirect* and *domestication selection.*

These forms of selection are occurring now as a result of the fact that these populations have a closed life cycle. Domestication selection operates naturally upon the animals in culture. Some oysters are genetically adapted to this strange environment, and will leave, on average, more offspring than oysters not so adapted. Genetic changes are occurring in a cultured population all the time, whether we know it or not. We have to understand those changes, but presently we have no knowledge of them whatsoever.

Indirect selection is the effect upon other traits when one is selecting for some particular trait. Suppose industry people decide that they want faster growing oysters, so they start keeping track of growth rates and take the fastest growing oysters back to the hatchery for reproduction. Because of unknown correlations in basic genetic traits, it could be that while selecting for growth they are actually creating negative effects on other important traits.

The brief history of western aquaculture provides good examples of broodstock mismanagement and failures of ill-conceived selection programs. For example, a study of Indian carp (which are grown in centralized hatchery facilities and distributed to farms) showed that by selecting big fish for breeding, growers were also inadvertently selecting for slower growing fish. The larger broodstock fish had gotten large precisely because they were slow growing in early life and had delayed reproduction. These are the kinds of negative effects that can occur through broodstock mismanagement or ignorance of biology.

In another example, managers of a commercial penaeid shrimp farming operation in Italy believed that their stock was being maintained by several hundred breeding animals each year. But a genetic analysis showed that this population was actually being maintained by only two to four reproductive individuals, and that the resulting inbreeding was responsible for a decline in hatching rate from 60% to 10%. Clearly, we need to have information on the genetics of cultured oysters. You can't assume from a head count of broodstock in the hatchery that you have got a large population and that you are protected from the consequences of inbreeding.

What behaviors do we need to develop to treat Pacific oysters as a domesticated species? Again, I'm putting the emphasis on us, not the oyster. The oyster is not going to domesticate itself. First, the industry has got to know who the parents are and to keep track of progeny from generation to generation. It's the only way we are going to understand the genetic basis for improvement. Second, individual producers in the industry must learn to work with each other and with academic aquaculturalists and to form the kinds of cooperatives that have been so helpful

with terrestrial species—the dairy herd concept if you will. No one company or university laboratory can shoulder the burden.

Third, on the academic side, we must extend fundamental knowledge in physiology, reproductive development, nutrition, and pathology, as well as genetics. And we need to make a much greater effort to apply this knowledge to the improvement of production.

Fourth, there should also be a bioeconomic description of this industry, a precise mathematical model of the whole process of producing and selling oysters. This type of model is invaluable in identifying research priorities so that our efforts will yield the biggest return by lowering the cost of production.

Finally, government granting agencies must help sustain the long-term commitment necessary to improve the Pacific oyster as a domestic, commensal species. This is difficult because granting agencies tend to operate on 1-, 2-, and 3-year cycles. It's easy to see why it is difficult for agencies to make a 5- to 10-year commitment, but nevertheless, that is what will be necessary if we are going to domesticate the species.

Designing Genetic Improvement Programs for Pacific Oyster Culture

WILLIAM HERSHBERGER

Prior to embarking on the best approach for genetic improvement in any mollusc, you have to ask youself what it will take and what the likely results will be. You also have to consider the requirements of that program for measuring, reproducing, and maintaining the stocks you are going to produce.

The first requirement is a thorough system of recordkeeping and strain identification. Without that ability to define a pedigree, as Dennis Hedgecock has stressed, we're dead in the water. Recordkeeping and strain identification are admittedly not very exciting, but they are absolutely necessary.

Second, we need to define the goals of the program. What do we want to do? We want to make better oysters. But what does "better" mean? Each producer must define what "better" is on an individual basis, guided by economics. I as a geneticist cannot set the goals; the producer must.

Adequate genetic variability is the third factor. Fortunately, with the molluscs looked at so far, this seems to be no problem.

Just behind these top three requirements are a couple of other considerations. Because of the plasticity of the organisms we're dealing with, the variety of grow-out systems in which the improved stocks will be used must be kept in mind. There are only about three commercial hatcheries on the West Coast, and

they are providing seed stock to grow-out areas up and down the coast. Needless to say, these areas vary tremendously in variety and requirements. Unless we keep environmental variability in mind, we're not going to make any progress. Finally we have to keep in mind the requirements for the maintenance, reproduction, and monitoring of the broodstock.

I'd like to evaluate these factors against three genetic approaches we can use: selection; hybridization (not in the sense of crossing two different species, but rather two different strains of the same species); and chromosome set manipulation.

First, selection. Selection involves choosing the animals you want to reproduce on the basis of phenotypes—that is, on what they look like. In order for selection to be effective, there must be a lot of variability in the traits that have been defined as important. In selection, the expression of traits will be specific to the environment in which the organisms are grown. That is, the shell shape of an oyster in a bed in Oregon will differ quite dramatically from the shape of that same oyster in a bed in Washington—or right next door for that matter. Shape depends on a large number of factors that we have not been able to identify or quantify. So general application *may not* be possible with selection. We don't have enough information to know. In one experiment at the University of Washington we found that greater than 60% of the variability in adult oyster traits resulted from differences in growing beds, and only 40% resulted from other factors, including genetics. This does not mean that we cannot make progress, it only means that we must first determine how much of the variability in a trait is due to genetics and how much is due to environment.

Selection is good for long-term stock improvement. We have been working on the problem of summer mortality for 6 years, and have selected strains that do perform better, at least in Washington. Another positive aspect of selection is that you don't need a large variety of broodstock, but the process does require constant monitoring. I've been working on a domestication program for coho salmon for the net pen industry for 8 years, and when I get out of it, the industry will take the program over and run it indefinitely because it has to be continued year after year after year. One problem with selection that must be noted is that eventually you will have to address inbreeding; there's a lot of discussion about how important that is with the Pacific oyster, but few conclusions have been reached.

Hybridization, or cross breeding between different strains of the same species, is another means of achieving genetic improvement. The U.S. corn industry, for example, is based on the concept of "hybrid vigor." Best results are obtained by mating strains that are genetically very different. We can use naturally occurring divergent strains or we can enhance divergence by

inbreeding different lines over five or ten generations.

Chromosome set manipulation, which I'll talk about later, offers the *potential* of decreasing the time necessary to get a high degree of inbreeding. We have gotten the procedure to work in fish, where we can produce totally inbred groups in one generation, but oysters are a bit more difficult.

Another positive effect of hybridization is that it does allow us to maintain high levels of genetic variability, which is very important in oysters. But hybridization requires the maintenance, testing, and recording of many crosses—it's like looking for a needle in a haystack—and you have to maintain at least two different stocks. However, the results are genetically identical offspring, thereby potentially giving you a more homogeneous product.

Chromosome set manipulation (or "polyploidy") centers, at present, around the production of triploids; that is, animals with three sets of chromosomes instead of the normal complement of two sets. Triploid oysters are sterile and thus do not expend energy producing gametes. Production of improved stocks by triploidy is immediate—within a generation—and is generally applicable to most grow-out areas. By eliminating sexual maturation and gamete production, triploidy can eliminate the deterioration of oyster meat during the summer months and allow growth to continue, undiminished by reproductive effort.

However, as the process now stands, you have to make new triploids for every production group. Also, the fact that the animal is sterile precludes any further genetic improvement in the species. It is a single-step process giving immediate benefits. Some recent work with fish suggests that we can make some improvements in triploids by selectively choosing different stocks. Also, we are trying to eliminate having to make new triploids for each production run. We've had some success with this in fish by producing triploids from crossing diploids with tetraploids. The other benefit of chromosome set manipulation is that you do not need to maintain a large variety of broodstock. We obviously need a lot of work if this approach to mollusc stock improvement is to reach its long-term potential.

In summary, each approach has positive and negative aspects, both practical and theoretical. Selection will probably turn out to have the most consistent and the most broadly applicable long-term genetic effects on the cultured mollusc population, but we have a long way to go. Each of the approaches could result in the development of genetically improved stock for specific needs of industry.

Manahan: When I was working in the oyster business in England, the word was that the entire *C. gigas* industry was based on gametes originally obtained from less than six oysters. I am curious about what degree of variation now exists here in the United States. Are there major differences, for example, between the animals in two bays that are closely associated. Is there a huge variance in the genetic pool? Or is it more limited?

Hedgecock: There is no evidence for differentiation, and I wouldn't expect any because the seed used up and down the West Coast comes from the same few hatcheries. Each individual site has a lot of variation, but I don't really believe there are different stocks. There is a West Coast stock of *C. gigas* at this point, and there are stocks of the Kumamoto variety, which really is a different species.

Hershberger: I agree with Dennis, though a recent study suggested that the Pendrell Sound spawning group of *C. gigas* can be separated from those in Washington. But within Washington and the populations we've studied, it's one big homogeneous population.

Hansen: Some industry growers report that natural, reproducing stocks from Willapa Bay are different from those natural reproducing stocks of Pacific oysters in the Hood Canal and Pendrell Sound. Have you heard this?

Hershberger: There is electrophoretic evidence that they are slightly different. I can't give you exact figures.

Cooper: Genetics is one area that we as a company have to move into because our hatchery and our grow-outs constitute a closed system. Genetics is also an area where we can interact in a reasonable and effective manner with the universities. We can do the animal rearing if the university can do the things that we are not equipped to do: extensive data collection and electrophoretic work, for example. We'd really like to see Sea Grant get involved along these lines.

McMullen: How do you go about setting up a broodstock management program? In the case of abalone, we have a group of perhaps a million eggs, but we are not sure how they are going to turn out. So we mix them together with other eggs from different parents. Obviously, we lose track of who the parents are. How would you envision handling that?

Hershberger: If you are going to start a broodstock management program, you have to keep records. You have to be able to identify the genetic background of the animals you are working with. I don't have a good way to go about it but one of the things we do when working with Coast Oyster is to set aside some tanks for broodstock maintenance and reproduction.

Lannan: There are some biochemical markers that can be

used to trace lineage. You can look at the Mendelian inheritance of those biochemical factors and work backwards to figure out who the parents were, but that's a complex process and very expensive. A more reasonable approach is to use the agricultural method of setting up replicates and using statistics to partition out the tank effect from other factors influencing performance. The people in poultry and corn have struggled with all of these same problems over the years. It takes a commitment of time and money, and there is no guarantee of immediate payoff. Until you make that commitment, though, there's not much opportunity for progress.

Hollibaugh: I don't think it would be a problem for us growers to put the seed stock in the field in the final grow-out and keep varieties separate. The problem that John McMullen described is more likely in hatcheries. I would be willing to participate in a program where I was given seed with different properties. It would be easy to keep them separate by rack and bag.

Incidentally, the *kumamoto* is a really good oyster for the halfshell market: it has a good shape; and that shape is much less plastic than in *C. gigas*. The flavor is better, and the color is nice; but the oyster grows very slowly. I would like to see someone develop a *kumamoto* oyster that grows at the same speed as *C. gigas* but maintains all its other properties.

Clutter: I have been doing a little bit of growth study work in Tomales Bay. I do not know of any other growth studies being done. Does anybody care about detailed growth curves? Or details of differences in growth rates with height in the intertidal?

Shuman: There has been some work done on that in British Columbia and the United Kingdom, and there are some publications. People care, but I think the results are site-specific.

Lannan: We had an interesting discussion with a group of growers in Oregon about how to set up a recordkeeping system. One of the things that came up was the complexity of determining and monitoring growth during production. It is fairly complicated to randomize a sampling process to be sure of pulling a statistical sample from your grounds. It's very easy to bias the statistics by improper sampling. For example, on longlines one often finds a gradient in growth. It is much easier to maintain good growth records in a small-scale experimental setup.

Glenn: Any interest on part of agencies in regional seed banks?

Sullivan: This sounds as though it would be an appropriate activity for the U.S. Department of Agriculture (USDA).

Lannan: I don't think it's out of the question that we could establish some kind of a center, perhaps through agricultural experiment stations. But it would be highly unusual in the present political climate for any agency to make a long-term funding commitment. Administrators become gun shy about the kind of

long-term commitment that we would be talking about.

We had a Sea Grant selective breeding project in Oregon that lasted eight years. But when the Sea Grant project was terminated, we had no means of continuing to propagate the selected lines, so they were lost.

Clark: I know you can cryopreserve oyster sperm, but I don't know whether anyone has tried to preserve the eggs of oysters. They are nice little cells, and would probably be susceptible to preservation. How long did you hold those sperm?

Lannan: A year. My methods were very crude. It certainly would be possible with contemporary technology to preserve them for extended periods of time.

Clark: It is sure cheaper than holding the animals.

Lannan: I know from my own experience that one of the problems is to match selected stock with growing areas. The first step in establishing a center would be to establish an information base and get the recordkeeping underway. I'm embarrassed to say that I'm not completely up to speed on the status of the system that we are trying to get underway in Oregon and Washington.

Hansen: Oregon State University is attempting to start a broodstock program from hatchery to grow-out and back to hatchery. I think they are looking for a computer program in order to get rolling.

Hershberger: I am ambivalent about the concept of stock centers for a number of reasons, one of which relates to ownership of stocks. If a federally funded or state public agency takes over a stock center, the stocks become public property. If industry members were to develop stock, would they be willing to put their pet projects into a stock center that is available to the rest of the industry? I doubt it, unless what you're developing is a real gene bank.

Lannan: That is in fact the reason for the loss of popularity of stock centers in other commodities. Some producers contributed germ plasm in which they felt they had a proprietary interest, and as good small businessmen, they wanted to use that germ plasm to their own competitive advantage. When that proved impossible, they eventually went off independently. This was not necessarily bad, however, because competition fuels progress. The ultimate objective should be a degree of cooperation that allows the worthwhile exchange of materials but still gives one the opportunity to back off.

Hansen: In the last two years *Ostrea edulis* has come under fire in a number of areas in the world for disease problems. At the moment I am reluctant to bring any stocks into my hatchery, even those that have been approved by Battelle Northwest. I think we are going to lose that particular animal unless some agency takes responsibility for holding stocks that do not have

Bonamia. The other thing is that recently there has been a lot of interest in raising *Crassostrea virginica* for use on the East Coast. But no state agency is going to allow me to bring that oyster into Oregon, even with the blessing of a pathologist. We need a place where the oysters, clams, and abalone can be held and examined for disease, or we are not going to be able to move them. I believe that over time it is going to get harder and harder to move exotic species of shellfish.

I'd like now, if I may, to ask Jim Lannan to sum up this session.

Lannan: The concerns of this session fall into three categories. Some deal with broodstock management and don't involve genetics. Others relate to the genetic improvement of broodstock. The third area stands alone and includes ethical questions. Who owns these processes? Should universities patent research developments that could help the industry?

Under the first category, broodstock management, one suggestion was that it would be advantageous to the growers in our region to have a central source of exotic species that had been imported and reproduced in quarantine.

Abalone growers, in particular, seem to want assistance in the development of facilities, both for producing juveniles and for grow-out. Also, we need better understanding of the processes necessary to condition abalone and to have sexually mature individuals throughout the season. In addition, there's a need to investigate alternative diets for abalone, perhaps using some ingredients from land-based agriculture.

For molluscs in general, the problem of securing broodstock year round needs to be addressed, as does the possibility of establishing a centralized facility to maintain and distribute broodstock. And we need a system of recordkeeping to better understand genetic and environmental interactions.

Under the category of genetic improvement of stocks, the discussion emphasized that while we typically talk about growth and survival as desirable traits, there are other factors that should be studied, such as improved shell appearance and taste. Within a single estuary, flavor can vary between growing grounds, yet we have no idea what factors regulate that variability in flavor.

We have to develop pedigreed populations and implement a recordkeeping system to monitor genetic work. Until that's done, there's simply nothing that can be accomplished in terms of genetic improvement. The question is, who is going to do that? Perhaps growers are going to have to increase their level of cooperation or form some type of cooperative in order to make this happen. We certainly have a long way to go. Cooperative efforts would involve changing attitudes and that is a slow process. And it is difficult for a small business person to take on additional labor and recordkeeping expense when there is no immediate payoff. However, the technical information now

available indicates that substantial gains can be made. The technology is there and the outlook for genetic stock improvement is favorable if we can muster the commitment.

Once we have pedigreed populations, we must develop criteria for assigning economic weights to different traits. Then we have to understand the phenotypic and genetic correlations among these traits to understand what gains are realistic. We need to decide what we are trying to accomplish. We have to understand genetic and environmental variances and co-variances so that we can use statistical methods to direct our breeding efforts. We have to understand the statistical patterns reflected in the mating system to direct the breeding program; otherwise it is purely a hit-or-miss program.

Finally, there appears to be substantial genetic variation in most molluscs that have been studied; this is true of oysters. It is important to conserve that genetic variation. If we lose it and then find a trait to be valuable in the future, that trait will no longer be retrievable. We don't have seed banks as the cereal growers do (and which they use quite often, by the way). So we are dependent on present genetic variation to make improvements. We clearly have a moral and ethical responsibility in addition to a practical responsibility to manage our broodstocks in such a way that we maintain that diversity of genetic information over the long-term.

VII. OPEN SESSION

Lannan: The idea of creating an open session to take care of topics that did not come up in previous ones was a stroke of brilliance, for indeed there are a few things we should spend a little time discussing.

Jim Hollibaugh had some interesting information on microbial biology, but was cut off in the interest of time. This general area is now recognized as having been overlooked for too long. In the area of warm water farm pond management, for example, studies have shown that our previous paradigm of a process driven by primary productivity is a gross oversimplification, if not out-and-out wrong. We now know that energy-flow through the heterotrophic organisms (i.e., bacteria) is every bit as important, and at times more important, than primary productivity. So let's begin by letting Jim bring us up to date on this important topic.

Hollibaugh: I'd like to review briefly how our understanding of what bacteria do in the ocean has changed over the past 10 years. The classical picture of marine food chains was that the chain started with phytoplankton, which used simple nutrients and light to create complex organic molecules; phytoplankton, then, are considered the "primary producers." They in turn were fed upon by zooplankton and filter feeders of different kinds, which were themselves eaten by fish.

Recent work has shown the existence of a microbial loop, a sort of side branch of this whole pathway. It has been demonstrated that a large fraction of the organic matter produced by phytoplankton, instead of going directly to zooplankton and other filter feeders, is released into the water and cycles through another group of organisms—the bacteria—which are primarily responsible for taking this dissolved material back up to a particulate form. The bacteria are then fed upon by flagellates, ciliates, and in some cases directly by filter feeders, among which oysters and other bivalves are prominent.

In terms of their numbers and importance, we now know that bacteria are very abundant in the sea—typical numbers are on the order of 10^6 to 10^7 cells per milliliter. We know also that at least 10% of these bacteria (and usually much higher percentages) are living, in the sense that they have some measurable biochemical activity. I did a back-of-envelope calculation that suggested that the biomass of bacteria in San Francisco Bay is on the order of 5,000 Humphrey units (Humphrey, you remember was the humpback whale who sailed up San Francisco Bay). That's a lot of bacteria.

The methods used by public health people for identifying bacteria in the ocean and estimating their abundance are plate count methods or "most probable number" (MPN) methods. But the numbers you come up with using these procedures are

several orders of magnitude lower: perhaps 10^3 or 10^4 cells per milliliter. So the methods presently used for judging water quality yield estimates that are in fact a small fraction of the total number of cells there.

Bacterial cells in the ocean are undergoing very dynamic population changes. Population doubling times are on the order of hours to days and yet the cell numbers don't change, which means that something is eating the bacteria. And the predators do not discriminate between naturally occurring bacteria and those introduced from runoff.

My point is that because we usually isolate only a small portion of the cells from seawater, we can determine the taxonomy of only a small portion of those cells. So the taxonomy of marine bacteria is largely unknown. We don't know how many bacteria react like fecal coliforms if properly stimulated (we don't know what the right ways to stimulate them are). Fecal coliform bacteria disappear after a while in seawater, but we don't know if they die, are eaten, or become dormant. And if they do become dormant, can they become reactivated, thereby indicating the presence of a pollution source when none exists in fact.

There has been a little bit of work done on these questions but not nearly enough. What evidence we have suggests that our indicator organisms are not doing their job. We need to learn more about microbial ecology and be sure that new information gets into the hands of the public health agencies.

Glenn: Are there many marine microbiologists?

Hollibaugh: There are about 50 in the United States, and a number of other specialties touch on the area. Most of the work is offshore though; estuaries are more complicated because of the proximity of the bottom and terrestrial and freshwater inputs.

Hansen: I've read that in France they use ponds for oysters for greening and flavor. Would you think that bacteria play a part as well as phytoplankton?

Glenn: The end result in those ponds is definitely due to the phytoplankton.

Lannan: Are there any other topics that people want to raise?

Glenn: Aquaculture is labor intensive. Thus any mechanical devices would be very handy. For example, we use a device to handle our mussels that is patterned after an oyster washing machine used in the East. There is also a handling device from Holland that is very effective, but it is expensive.

Shuman: Our major labor cost—perhaps 40%—is the hand sorting of half-shell oysters. So we've explored a numnber of possible technologies. We're now looking at machines for sorting apples and bulbs from Washington State—they sort by weight using a rotating pan system. Some agricultural engineering would help us. A second-hand mechanical apple sorter costs about $8,000—we could pay for it in saved labor costs in about 3

months—and there are new computerized apple sorters costing $50,000.

Conte: In designing equipment, you have to be able to show that there's potentially a market or wide distribution.

Lannan: I'd like to get back to the issue of policy. In most public agencies, there is a requirement that policy decisions be made on the *best* available scientific evidence. Basically it requires bureaucrats to go to the library and pull together figures to justify, or serve as guidelines for, the development of public policy.

The key word is *best*. The literature, however, contains examples of atrocious science as well as good science, and the agency people can't always distinguish between the two. Is there some way we could get involved here to help the process operate better?

Pitts: It's important to understand that policy is not determined by the majority of people. Those who speak out on any issue are those who have a vested interest: either their seals are going to be impacted or their view is going to be affected or their favorite water-skiing site is going to be eliminated. People who are not opposed to a proposal, or who are even in favor of it, do not speak up. What I'd suggest as an action plan is that you mount an effort to educate your politicians in the 60 days or so prior to an election day. Elected officials are more attuned to learning and hearing at that time than at any other. Collect everyone in your community, in your county, who has anything to do with aquaculture—including those who manufacture boxes or crates for transport, processors, ice makers, net makers, boat builders—and have a "candidates night." I guarantee that if you can get 50 people there, you'll have candidates. Listen to what they have to say, and then take the opportunity to educate them.

In addition, as an industry, go to the university, to Sea Grant, to Cooperative Extension and ask if they will provide neutral expert testimony at hearings; get knowledgeable people who can explain information in plain English and work to counter the misinformation that is rampant. You have to find those people who are your supporters and support them. Be sure to give them the economic facts, because economics is about the only argument these days that justifies displacing some other use. Put politics on your work plan.

Lannan: That's good advice, but elected officials are only one part of the equation. In Oregon, we have citizen's commissions that make policy decisions on agency recommendations. Unfortunately, the agencies frequently do not know much about molluscs and do only superficial literature reviews on which to base their recommendations. There must be some role here for academics that we're not playing.

Also, in both legislative and administrative proceedings, it's

often hard to find neutral, credible witnesses; university people can come into those forums and project a relatively unbiased viewpoint.

Studdert: I agree, Jim. University people are always considered neutral, and hence more credible, witnesses, in both legislative and administrative forums. Obviously, scientific objectivity is given more weight than what is often considered the biased testimony of industry with the attendant vested interest. In the legislative situation, the opportunity for university testimony exists during Policy Committee hearings in both houses of the California legislature. In the administrative situation, the California Administrative Procedure Act affords an opportunity to be heard during the promulgation of regulations by a state administrative agency. Again, the rulemaking body will treat university testimony as less biased and more credible.

Sullivan: If there are no more questions or comments, we will bring this workshop to a close. Again, my sincere thanks to each of you for your time and contributions.

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