4. AQUACULTURE AND COASTAL RESOURCE MANAGEMENT

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INTRODUCTION

While general expectations for aquaculture have evolved from the unbounded optimism of the 1960's, e.g., the "feed the world through sea farming" concepts (Ryther 1957, Bardach 1968) to more realistic expectations for a wide range of economically and ecologically important applications (Bardach 1987, Nash 1988), the practice and potential for aquaculture as a tool in managing coastal living resources has a long history. There is nearly a century of experience in the use of aquaculture for augmenting natural finfish populations, notably in the salmon fisheries of the U.S. Pacific Northwest (Malouf 1989).

Intensive aquaculture practices have more recently been applied and evaluated as management tools in invertebrate fisheries (Krantz 1982). While releasing hatchery-produced juvenile finfish (e.g. salmon, *Oncorhynchus* spp.) or shellfish (e.g., hard clams, *Mercenaria* spp.) into wild populations can, at least theoretically, increase abundances of fishable stocks, the practice has rarely been evaluated critically. Yet, in the face of declining landings from overfished fisheries, there usually is strong support for use of public funds to augment public resources through aquaculture. The objective of this paper is to discuss the basic applications and ecological and social impacts of aquaculture as a coastal resource management method.

PUBLIC VS PRIVATE AQUACULTURE

In his definition of aquaculture[1], Glude (1977) implied that there are two types which I will refer to as public and private. These types of aquaculture are easily distinguished on the basis of their overall goals.

[1] "The culture or husbandry of aquatic animals or plants by private industry for commercial purposes or by public agencies for augmenting natural stocks."

The goal of private aquaculture is to provide employment and generate profits while public aquaculture seeks to manage public resources. There are several important relationships between public and private aquaculture (Siddall 1988).

In broad terms, public aquaculture programs use public funds provided through government agencies to increase harvestable stocks of aquatic resources for the benefit of the public, including the fishing community. Public aquaculture generally includes programs to enhance important commercial, subsistence or recreational fisheries. Public programs may be used to augment existing fishable stocks in areas where the fishery is or has been productive. They may serve to establish new fishable stocks in areas where the species, because of natural life history characteristics (e.g., dispersion of larval forms), is not normally found but where it might otherwise flourish. In some instances, agencies charged with natural resource management may promote aquaculture as an economic alternative to traditional fishing. This advocacy of private aquaculture is important, but in the strict sense, it does not represent the application of aquaculture for management of public resources and so is somewhat beyond the scope of the present discussion.

Harvestable stocks enhanced by public aquaculture programs are supposed to be available to all members of the public whose funds underwrote the program. At some point in the organism's life cycle, public aquaculture programs must distribute or make accessible the cultured stocks to the public and thereby relinquish control over the fate of the "crop." The benefits of public aquaculture are obvious when stocks are made available to the public at harvestable sizes (e.g., freshwater lakes stocked with cultured finfish for recreational "fee fishing"). However, for most wild fisheries augmented with very small juveniles, the benefits of public aquaculture are equivocal.

The cost of seed (invertebrate juveniles) or fry (finfish juveniles) increases dramatically with size as a function of the costs incurred in culturing them as they grow and require more space and food. Therefore, public aquaculture programs cannot afford to buy large numbers of large, expensive seed or fry. With limited budgets, public programs can buy or produce a relatively large number of small fry or seed or a small number of large fry or seed.The smaller the size of seed planted, the lower the survival to harvest (Flagg and Malouf 1983). Thus on ecological grounds, the planting of large seed which have grown into a size that is minimally vulnerable to predators is desirable.

However, there often is considerable political pressure from fishermen and public agencies for highly visible programs which release as many seed or fry as possible. As a result, public aquaculture programs tend to plant as large a number as possible of very small seed stock onto public grounds. Once released, these small juveniles face a period of additional growth before reaching harvestable size. After such release, very little is or can be done to assure the growth and survival of this publicly owned crop.

Public aquaculture is highly intensive (in hatcheries, land-based and field nursery systems) up to the point of seed planting or fry release, at which time it often ceases to be aquaculture at all. This "abandonment" at release is an important feature of public aquaculture. At the time of release, commercial, recreational or subsistence fishermen have derived no benefit from the efforts of the public aquaculture program. Benefits of such an abbreviated form of aquaculture depend on uncertainties of survival and growth of small juveniles released into the natural environment. There are too many uncertainties to forecast the impact of such public aquaculture efforts.

On the other hand, private aquaculture uses private funds and resources to maintain as much control over the crop until such time as the greatest economic benefits may be derived from the sale of products, either as seed, fry or as marketable products. The benefits of private aquaculture, usually cash revenues, accrue to the individuals or corporations whose resources were used to generate the revenues.

Several important relationships between public and private aquaculture programs are summarized in Figure 1. Many public aquaculture programs acquire fry or seed stock from private aquaculture facilities while in some instances the reverse is true: private firms buy juveniles from public programs. Private aquaculturists can profit from sales of seed to public programs (Malinowski 1986), and are able to diversify sources of revenue

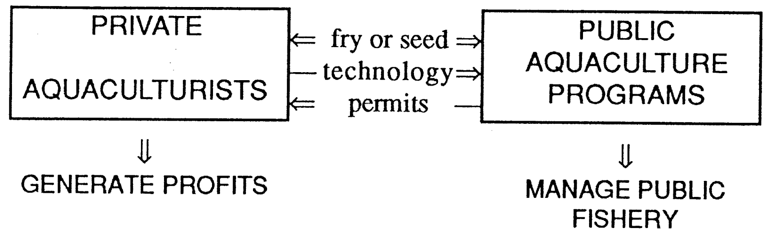

Figure 1. Relationships between public and private aquaculture

while sustaining cash flow required for continued development of methods to culture their species to marketable size. Publicly operated hatcheries may serve as a source of seed stock for sale to private aquaculture interests (*Macrobrachium* facilities in Martinique, for example; D. Lacroix, person communication). Public and private aquaculture enterprises often rely on the expertise of each other to resolve technical problems of production and planting. Finally, many private aquaculturists are dependent upon governmental agencies to permit exclusive use of areas of coastal marine habitats for grow-out of fry or seed stock to marketable size. Thus, the public agencies regulate the space required by the aquaculturist while both sectors rely upon each other for supplies and expertise.

ROLE OF PUBLIC AQUACULTURE IN RESOURCE MANAGEMENT

Based on Glude's (1977) definition of aquaculture, a range of resource management activities fall within the realm of public aquaculture. These include hatchery release programs, some transplant and relaying efforts, and the creation of spawner sanctuaries.

Hatchery Release Programs

One of the most obvious examples of public aquaculture is the production and release of fry or seed to replenish an economically important capture fishery. In some instances, these replenishment efforts are established and directly operated by a governmental unit with responsibility for resource management. Examples of such government-run programs include the U.S. federal salmon hatcheries, some of which were established more than a century ago. Resource management agencies may also procure fry or seed stock from privately operated hatcheries (Malinowski 1986) in an effort to minimize the agencies' involvement in the technical issues of hatchery/nursery production. Public agencies also have sponsored applied research at academic institutions in an effort to develop and refine production methods. However, hatchery operation or even production-oriented research is often perceived to fall outside the mission of academic institutions.

Transplant Programs

Public aquaculture activities need not be based on intensive hatchery production, however. Naturally produced juveniles can simply be transplanted into areas where they grow into harvestable stocks. Such transplant programs represent a manipulation of the species' life cycle for purposes of enhancing production and if the transplanted stocks continue to be manipulated in some fashion, the effort falls within the strict definition of aquaculture. Transplant programs are often undertaken for sessile invertebrates (e.g., oysters), larvae of which may settle in very high densities which limit later growth. Population densities are reduced through the transplantation process; if increased mortalities during and after the transplantation process are compensated for by increases in growth, net production may be enhanced by such transplantation. Thus, one goal of a public transplant program is to enhance production.

Transplant programs also relocate wild stocks from areas where they cannot be harvested legally (for reasons of public access, or water quality, for example) to habitats where they can be fished by the public. Such transplant programs are an important component of public hard clam management programs in the United States (Kassner and Malouf 1982). Adult, legally harvestable clams are taken from waters which are uncertified for shellfish harvests on the basis of bacterial contamination, then transplanted and held in cleaner waters for several weeks until they are fit for market. Such public transplant programs serve two purposes; they seek to increase harvestable stocks in certified waters and they reduce opportunities

and public health risk of harvest and immediate sale from contaminated waters.

Relay Programs

Transplant programs relocate stock for growth and harvest, however adult stocks may also be "relayed" into an area to establish new populations or sustain existing populations through reproduction. Public relay programs differ from transplant programs in that adults are relocated to and protected in new habitats for purposes of spawning. Similar to transplant programs, the relay of mature adults is an example of a minimal aquaculture effort to manipulate a species for enhanced production. Mature adults may be relayed into an area where, for example due to hydrographic conditions, the species' dispersive larval form cannot enter. The goal may be to create a harvestable population or to establish a self-sustaining population in a relatively small area. Relay programs also may be used to bring actively spawning individuals into an area at a time of year when native populations have completed their spawning cycle. The goal here is to extend the local reproductive season for the species.

Spawner Sanctuaries

Spawner sanctuaries (Kassner and Malouf 1982) are sites specifically prepared, stocked with mature adults, and protected on a relatively long-term basis for purposes of enhancing local recruitment. The spawner sanctuary concept is most applicable to sessile invertebrates or non-migratory finfishes. Because the activity involves allocation of publicly-held coastal areas (the water column or underwater lands) and seeks to enhance recruitment in public areas, spawner sanctuaries are inherently a public aquaculture activity. Spawner sanctuaries have been used to reestablish shellfisheries in areas which were historically productive (see Siddall et al. 1986) and to supplement recruitment in existing shellfisheries (McCay 1988).

Regardless of the method used, the general goal of public aquaculture is to enhance public fishing opportunities. There is a great deal of common sense appeal to the concept of adding juveniles to a fished population.

There are several examples in the literature of hatchery programs which have increased the abundance of commercial species (Pillay 1973, McNeil 1980, Scarnecchia and Wagner 1980, Wahle et al. 1979). However, there are important theoretical (ecological) and practical (economic) challenges to any such replenishment effort.

The ecological issues are perhaps best illustrated in a comparison of outcomes in which the attempt is made to augment population abundances in predictable and unpredictable environments.

First, let us consider a public replenishment program that is undertaken for a fishery in which the abundance of the species is controlled largely by unpredictable or random processes, such as meteorological events or pollution accidents. Unpredictable factors usually act independently of the population density of the species. In this instance, juveniles released from the hatchery or relocated to an area will suffer the same fate from the unpredictable event as do the wild stocks. A disastrous storm or spill of chemical contaminants does not discriminate between naturally-produced organisms and those added to the wild population through public aquaculture. If the replenishment program was undertaken during a "bad" year for the species, both wild and hatchery stocks are adversely affected. If the replenishment program was undertaken during a "good" year for the species, natural reproduction in the fishery is likely to exceed that from aquaculture by many orders of magnitude. Thus, in the case where abundances are controlled by unpredictable events, public aquaculture is likely not to have any positive effect on the fishery.

In the case where population abundances are controlled largely by predictable factors, theoretically, it might be possible to restrict replenishment efforts to those seasons which are predicted to be "good" for the population. There are two major problems with this situation.

First, we do not have the information needed to predict "good" and "bad" years. Although we may understand that certain factors, such as competition, predation, emigration or environmental carrying capacity are predictable, we do not have specific information on how these factors vary for each subpopulation in a fishery. We simply do not have the detailed information needed to decide in advance whether to operate a hatchery or not. For example, a replenishment program could add so many hatcheryproduced juveniles to a natural population that the carrying capacity of the habitat (e.g., food, or space for territorial behavior) would be exceeded, and the result of the replenishment program would be little or no gain. Thus, we know that carrying capacity is important, but carrying capacities are "finite, dynamic, and very difficult to measure" (Malouf 1989) so it is not possible to predict the outcome of a replenishment program in the absence of very detailed and specific information on carrying capacity.

Second, even if our predictions were correct and we operated a replenishment program during a "good" year, the program would face a major quantitative challenge to produce a significant number of juveniles relative to that produced naturally during that "good" year. In a "good" year, it is assumed that recruitment to the fishery would be substantial in terms of sustaining or increasing population abundance, so the public replenishment program must produce and release large numbers of juveniles to have an impact. This is basically an economic challenge to produce huge numbers, perhaps billions (McHugh 1981), of seed or fry at a cost that does not exceed the benefits accruing to the fishery (or related large-scale economies) from the public aquaculture program. While there is some evidence that hatchery programs have had quantitative impacts on some fisheries (McNeil 1980, noted that 20% of all Pacific salmon landings were based on hatchery releases), there is no general consensus that replenishment of public fin- and shellfisheries has been successful. Wahle et al. (1979) showed that a major public U.S. salmon hatchery was returning less than four cents on the dollar ($0.039:1.00) to the fishery. In fact, there are even negative aspects to a quantitative success. Successful hatchery release programs have been implicated in obscuring trends in wild populations. For example, 75% of catches of Oregon coho salmon came from hatchery-reared animals while natural stocks had declined to the lowest levels in history (Scarnecchia and Wagner 1980).

Beyond the quantitative challenge to outproduce Nature, public aquaculture programs face perhaps an even more critical qualitative challenge. There are important qualitative differences between wild and hatchery produced seed or fry derived from "artificial selective pressures" of the hatchery (as opposed to the natural selective pressure of the wild). The hatchery production environment, whether for finfish fry or shellfish seed, is substantially different from the natural environment experienced by larvae in the wild. Critical physical factors such as temperature, salinity, light and photoperiod are maintained at constant and specific levels. The relatively constant hatchery environment sustains many individuals which would not normally survive beyond the larval stage. Foods, often formulated for growth and survival, are abundant. Water quality is monitored and diseased populations discarded before adjacent cultures are affected. The hatchery production process selects for larvae and juveniles adapted for rapid growth in the hatchery environment (Newkirk et al. 1977, Losee 1979), but they are not necessarily adapted for survival and growth in the wild after being released.

Additionally, there are important genetic concerns about hatchery released fin- and shellfishes. Genetic effects of the artificial selective pressures of hatchery production are compounded by unintentional genetic selection resulting from the use of a limited number of broodstock in the hatchery. For example, shellfish hatcheries must invest substantial effort to maintain and condition adult shellfish for production of gametes. To minimize costs associated with this effort, only a limited number of adults are used as broodstock for each season's hatchery production. Often, broodstock are selected from the most rapidly-growing juveniles of prior year's hatchery production, further limiting the gene pool and resulting in inbreeding.The viability of fresh gametes also limits the opportunity for using large numbers of broodstock in finfish hatcheries. Hatchery broodstock may be selected from isolated and genetically different subpopulations on the assumption that better offspring will result, or in an attempt to diversify the genetic information in the hatchery population. However, as Sobel et al. (1987) and Berg et al. (unpublished) point out for the queen conch, there are genetic differences in subpopulations, differences which should be understood and considered in any hatchery release program.

These processes generally reduce the genetic information in hatchery populations and can result in poor performance of the population following release. There are several reports of genetic drift and "founder effects" in

hatchery produced populations of salmon, *Oncorhynchus* (Ryman and Stahl 1980) and prawns, *Macrobrachium* (Hedgecock et al. 1979). However, there may be more important long-term consequences for wild populations into which substantial numbers of genetically similar hatchery-reared animals are introduced. Moav et al. (1980) suggested that hatcheries might be used to effect genetic improvements in wild fish stocks. However, more recently, Kapuscinski and Jacobson (1987) reviewed a range of deleterious effects on replenished wild finfish stocks. Little is known of the long-term genetic impact of replenishment programs on natural shellfish populations.

Clearly, public aquaculture replenishment efforts must deal with an imposing suite of quantitative and qualitative concerns. One of the most important failures of public aquaculture programs has been the nearly complete absence of critical evaluations of long- or even short-term benefits. Typically, many agency resources are dedicated to the principal mission of replenishing a fishery. This is usually an open-ended mandate which assumes that the success of the program depends exclusively on the number of animals released. Public demand for large replenishment programs leaves little resources for evaluation of the benefits of the program. Most evaluations are subjective and informal, and usually leave open the possibility that the program is useful. As Malouf (1989) points out in his comparison of clam and salmon hatchery programs, estimates of survival or returns to fisheries often range from 0 to 100%. Evaluations must consider the goal of the public aquaculture program and the impact aquaculture approaches have had on other more traditional management methods from which replenishment programs may divert agency resources. Adequate evaluations should consider all costs of the effort (fixed and variable hatchery costs, administrative expenses) and estimates of economic returns to the fishery (as cost-benefit analyses, or breakeven estimates of survival to harvest) (see Siddall, 1983, for an analysis of the economics of queen conch hatchery production).

ROLE OF PRIVATE AQUACULTURE IN RESOURCE MANAGEMENT

Although the goal of private aquaculture is to generate profits, the activity is not entirely unrelated to issues of public resource management.

There are positive and negative impacts of private aquaculture on public fisheries.

Private aquaculturists often support some level of research and development. There have been a number of private corporations that have shared their positive and negative results with the public sector; many others jealousy guard their successes. Resource management agencies often cannot support fundamental research on management practices but rather rely on the private sector to lead the way in new methodologies. This is an important public benefit from the presence of a healthy, private aquaculture industry.

As noted in Figure 1 above, the private aquaculture industry often secures permits or leases either directly through or with the indirect input of public aquaculture programs. In New York, some local governments require that the private aquaculture industry provide technical assistance to local public aquaculture programs as a condition of such leases (Siddall 1988). Finally, government-sponsored replenishment programs may purchase rather than produce fry or seed from private hatchery operators thus simplifying the technical needs in the public program while providing a source of income to the private culturist.

The incidental recruitment of juveniles to public areas resulting from reproduction of private, mature stocks held in captivity prior to harvest has never been evaluated.Although fecundity of individuals less than harvestable size may be lower than the harvestable adult (Bricelj and Malouf 1981, for hard clams, *Mercenaria mercenaria*), there is little doubt that privately-held aquaculture stocks do produce larvae which are released into public waters. Attempts have been made to evaluate the relative contribution of natural and cultured bivalve populations to recruitment on public grounds (Siddall and Bowman 1989).

There are several negative impacts of private aquaculture on managed resources, including introduction of non-native species, discharge of effluents, over-exploitation of natural sources of seed stock and preemption of ecologically important coastal habitats.

Mann (1978) has reviewed the arguments for and against the introduction of non-native species for purposes of private aquaculture. Non-native species selected for introduction should not compete with local species, should not be accompanied by pathogens or parasites, should not reproduce in the wild, or hybridize with local populations, and must fill a need which cannot be met by endemic species. Public aquaculture programs have attempted to establish fishable stocks of introduced species; however, arguments against any introduction of non-native species are strong.The long-term ecological consequences of a poorly conceived or managed introduction must be considered along with the potential benefits that might accrue from such a program.

Nearly all hatchery facilities are designed as a one-pass, flow-through system. Nitrogenous waste products, dissolved organic compounds and other by-products of the metabolism of cultured stocks are discharged in the effluent. One of the most serious contaminants of hatchery effluent are antibiotics which have been used on a routine basis in the past to prevent or control pathogens. Natural populations clearly are threatened by the proliferation of new or antibiotic-resistant strains of pathogens incidentally released into the environment by aquaculture facilities. Legislation to protect the environment, especially in areas with limited water resources (fresh and marine), often mandate standards for effluent water quality. In jurisdictions where aquaculture is considered an industry, hatchery discharges are regulated as industrial effluents and must meet a number of quality standards and be monitored regularly.

Private aquaculturists, facing a shortage or complete lack of seed supplies from hatcheries or those unwilling to pay higher prices demanded for hatchery-reared seed in periods of short supply, have exploited natural seed or fry populations to meet their needs (e.g., in southern United States hard clam populations, *Mercenaria mercenaria*). In some instances, this has led to reductions in year-class strength in capture fisheries, a situation which exacerbates the often adversarial relationship aquaculturists have with commercial capture fishermen. Harvests of wild postlarvae have met much of the needs of coastal aquaculture for milkfish in the Philippines and penaeid shrimp in Ecuador, but the unwanted by-catch of postlarvae of other species caught in fisheries may have reduced landings for the commercial fishermen offshore (MacIntosh 1982, Motoh 1980, Turner 1977).

Finally, as detailed by Clark (1991), private aquaculture practices have often selected sites in ecologically sensitive and important coastal habitats. For example, large areas of mangroves were removed during the construction of shrimp ponds in Ecuador and milkfish ponds in the Philippines (Siddall et al. 1985). Because mangroves are critical nursery grounds for many commercial species, these activities may have led to reduced abundances of shrimp post-larvae and milkfish fry for aquaculturists and catch fishermen alike.

SUPPORT AND OPPOSITION FOR AQUACULTURE

In general, there appears to be widespread public support for any effort, including public aquaculture replenishment programs, to aid public fisheries. In fisheries where even shortterm landings are declining, a sense of urgency prevails. Because public funds are administered by elected officials, replenishment programs for troubled fisheries are susceptible to becoming political tools. The importance of the effort is usually linked to the number of seed or fry; press releases invariably indicate how many hundred thousand seed or how many million fry were released. The lack of critical evaluations of the benefits of such programs does little to change this "blind faith" in replenishment programs. In certain instances, there have been gains in fishery production, but for the most part, especially for invertebrate fisheries, evidence in favor of public aquaculture benefits is not compelling in spite of the "common sense" appeal the concept enjoys.

In contrast, opposition to allocation of open access marine resources for exclusive use in private aquaculture is widespread, especially in areas where aquaculturists confront traditional catch fishermen (Siddall 1988). Traditional fishermen in developed nations often are influential in marine affairs. They are frequently represented on governmental advisory boards which influence management practices and fishery regulation. Their trade supports a traditional lifestyle valued by many members of the maritime community. It is not surprising, therefore, that their vocal opposition to private aquaculture, combined with the economic risks of the aquaculture venture, provides little motivation for governments to accommodate the needs of private aquaculture.

CONCLUSIONS

The effectiveness of public aquaculture in coastal resource management depends on many factors, prominent among which are the objectives of the program, its scale and the ecological conditions under which it is attempted. The true effectiveness of replenishment programs can be evaluated only over the course of many years. The apparent success of a public aquaculture effort in the eyes of the public is likely to depend simply on the numbers of animals released regardless of costs or benefits to the fishery.

There are many examples, notably in finfisheries, in which hatchery-based replenishment programs have had measured effects on the abundance of harvestable stocks. There are few, if any, examples of such success as yet in invertebrate fisheries. Indeed, there are several plant and animal species of proven and potential economic importance in the Caribbean which are being cultured successfully by private aquaculture firms (*Macrobrachium*, *Tilapia*, *Strombus*). Governmental accommodation, promotion and even support of private aquaculture are sound models which should be explored and implemented in the Caribbean. Given the importance of subsistence fisheries throughout the region, government sponsorship of public aquaculture programs to augment, rebuild and establish new fisheries should be considered carefully as a potentially important tool for coastal resource management.

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PANEL DISCUSSION

JIM BURNETT-HERKES: Are there any [public aquaculture] success stories for non-anadromous fishes, strictly marine fishes, and also ones that occur in the tropics that may be applicable to the Gulf and Caribbean regions?

SCOTT SIDDALL: [There is] important potential for public aquaculture replenishment in the subsistence fisheries in the Caribbean. Subsistence fisheries are of small geographic scale. These stocks [can] be looked at at a more or less micro-geographic basis.

I know of no critical evaluations that would tell us that there are success stories. When we define a success, we have got to include break-even cost and cost/benefit analyses.

ROBERT SIEGAL: Why do you really need aquaculture? Is it because the domestic fishery managers or the domestic fishery regulations are such that they've allowed certain stocks to be overfished or depleted and you need aquaculture as another possibility to enhance the domestic stocks? Should the resource managers be held more accountable for the fact that certain stocks have gone under? If the fisherman is a direct beneficiary, should the fisherman be required to pay some of the cost of the aquaculture program? Should it be paid from public tax dollars? Should there be certain kinds of user fees?

ED JOYCE: When half the legislature and every recreational fisherman in the state [Florida] wants these programs, it is [difficult] to say no. We compromised in the funding of a [redfish] hatchery on the basis that the major goal and direction would be to produce the large numbers, to determine what was present in the natural environment, to release only animals that could be tagged and would be certain that we had produced. We can not only show what our survival rate was, but how many of those natural animals we displaced with our hatchery-reared stock, if indeed we displaced any. The ultimate goal of the project was to say: "It is going to cost you $150 for that one snook to be caught by that one visitor from Ohio when he comes down." I don't think folks want to pay those kind of prices.

Since the emphasis so much on: "Hey, don't say no, you're not being innovative. We need to have new things to solve these fisheries problems," many of these [hatcheries] are being strongly emphasized not to come out with negative [research] results.

In Texas, one publication quotes 13 million animals released and 132 returned, of which they doubt the verification of 60 of those. They have been most successful in raising and releasing, but they are not tagging and they do not know what is coming up.

It is a real complex issue and one that is fraught with danger for research on several fronts.

CARL BERG: The conch research program in the State of Florida had the exact same goals as [were] just explained for the snook. We need the research to show that this was necessary, effective and cost-effective. The State of Florida is doing snook, redfish, conch, clams and scallops, all with the same idea. Before any government gets into this, they really have to show that it is going to do something.

SCOTT SIDDALL: We concluded that we need evaluation, that they are politically difficult to get. They are hard to do accurately; even the science is affected. My lack of including Caribbean examples was because there aren't any that we can say, conclusively, here is a positive program, one that has been evaluated to work.

BISESSAR CHAKALALL: If a replenishment program is successful, then I would say we can destroy the wetlands because we can use them for other purposes and have replenishment programs when we maintain our stocks. How would the panel react to this?

CARL BERG: Every attempt [to replenish stocks from hatcheries] has been a total failure and the best example is the Ecuadorian shrimp industry where they promised to release all the baby shrimps to keep the stocks going and in fact they have wiped out that industry.

JOHN HARGREAVES: Some work was done on the Gulf Coast (see Turner 1977) where they compared the value of mangroves for nursery of shrimps versus the potential aquaculture gain if you doze those mangroves down to form fish ponds. [They] found it was better off to use the mangrove as a nursery. The wild catch, as a result of that nursery, was equal to or exceeding the potential gain from aquaculture.

KARL AIKEN: The coastal regimes in the smaller islands are very critical, very important and very small. In developing any coastal aquaculture activity, one has to build in the stops, and the checks, and the safeguards to protect the coastal environment.

BISESSAR CHAKALALL: I would like to look, from the conservationist's point-of-view, at marine parks and marine reserves in terms of one of the objectives of replenishing stocks: protecting nursery areas and critical habitats. How does that relate in terms of the cost effectiveness of an aquaculture replenishment program?

LEROY CRESWELL: Maybe a cost-effective way to augment the capture fishery is to promote the private sector so that it takes some of the pressure off of the private fishery. This is particularly true in the case of mangrove oysters, where the areal extent of the fishery is limited or on small islands where there is limited coastal area. If government is going to develop a private sector aquaculture program or promote it with the goal of being able to take some of the fishing pressure off of the capture fishery, it is very important that they target the fishing community to develop aquaculture. Often times, the people that show interest in aquaculture is not the fishing sector. Many times, they actually conflict with the fishing community. If this is going to be a viable method to help augment the capture fishery, we [need to] bring into the program and target the fishing community to get involved in the aquaculture aspect of that species, so that [the program] does, in fact, serve the goals that were originally intended. Then it can be a cost-effective method of bringing back depleted stocks in the case of mangrove oysters.

SCOTT SIDDALL: The most qualified group to practice small-scale aquaculture is the fishing community. They have the skills. In my area, we confront extreme oppositions to the involvement of the commercial fishing community in aquaculture because of the implication that aquaculture, in its private form, requires the allocation of common marine resources. There is a real friction there. [Do] other panel members see that here in Caribbean fishing communities when they try to promote aquaculture?

KARL AIKEN: In the oyster culture project in Jamaica, we have indeed directly targeted the commercial fishermen to get involved at the commercial level and to switch from artisanal fisheries for scale fish and lobster to becoming aquaculturists. They have responded not as readily as we thought they would. One of the main problems is getting suitable coastal property to lease to them. The severe storms that we have had recently have done a lot to take people away from getting into oyster culture. Another problem in the Caribbean because of unemployment and all the various social problems, is theft of the oysters from the growth rafts.

BISESSAR CHAKALALL: One of the objectives [of the seamoss cultivation project in St. Lucia] was to reduce fishing pressure and to target fishermen to get into seamoss cultivation during the off season. Fishermen did not want to get involved in seamoss cultivation. They changed their objective and decided to target unemployed persons within the fishing village. The unemployed persons did not want to get involved as well, because it was something very new, and it was a small village, and they did not know much about it. They did not want to take the risk because they did not want to become the laughing stock in case it fails. Now they are targeting fishing families, so that you have the fisherman as well as his wife and children involved in the venture.

CARL BERG: Hard clams are a good example where both the private sector aquaculture has been developing for 50 years or more and has had major impact on the public sectors. On [Cape Cod] there are a number of hatcheries which provide seed of the hard clam, *Merceneria merceneria.* That group [ARC] has selected a genetic marker, which is a little brown mark in the shell, that identifies their stock. Over the past number of years they have been very successful at picking out broods, breeding them, getting fast growing ones and then supplying both their own commercial venture and the public sector on a number of the islands offshore. What has developed, in effect, is a put-and-take fishery to augment existing fisheries and establish new fishable stocks of exploited species. In this case, the townships in the islands and on Cape Cod each year buy seed stock, throw them out and take a tax from the tourists who want to fish them. In so doing, they have been able to manage stocks, they have been able to continually assure that there are clams for people to collect each year when they come up there.

Initially the brown marks on the shell were in less than 1% of the population. Now they are in approximately 10% of the population. They unintentionally have been able to augment or increase the native stocks. For the short term, like the coho [salmon], this aquaculture stock, a genetic strain in this case, has been effective in increasing its proportionality of the wild stocks.

SCOTT SIDDALL: The classic definition of a put-and-take fishery is one where the stock that is being put out by the public aquaculture program or even private aquaculturists is very close to harvestable size. The definition relies on nearly 100% harvest on an annual basis and is a very small component of aquaculture's role in coastal management. What I describe is more or less a put-and-lose fishery and put-and-we-don't-know-what-happens situation where very small seed stock are being released that face a substantial portion of their life in the wild before they reach harvestable size.

The scallop fishery on Long Island is a perfect example of a habitat that has historically been very productive of an important invertebrate, but has none in it now. Aquaculture has been used to attempt to rebuild these fisheries, [but] even with what amounts to 50 to 75 years experience in this fishery, [there is still a] lack of fundamental information about the factors controlling the success of this public program. To date it has not been successful. One of the things that public aquaculture must do is to sustain itself over many years at perhaps a lower level than what might be otherwise done before it may have an effect.