This is to certify that the

thesis entitled

Sociology, Science and Technology: The Case of
Transgenic Fish Research and Development

presented by

Mike Skladany

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Sociology

Major professor

Date February 3, 2000

SOCIOLOGY, SCIENCE AND TECHNOLOGY: THE CASE OF TRANSGENIC FISH RESEARCH AND DEVELOPMENT

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Sociology

2000

Professor Lawrence Busch

ABSTRACT

SOCIOLOGY, SCIENCE AND TECHNOLOGY: THE CASE OF TRANSGENIC FISH RESEARCH AND DEVELOPMENT

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Aquaculture, the controlled cultivation of aquatic organisms, has emerged as a nascent technoscientific based industry of growing global proportions. In accounts of aquaculture research and development, social scientists have avoided problematizing technoscience and aquaculture scientists have avoided problematizing society. In addressing these problematics, actor network theory and methodology offers a fresh approach to questions of how aquaculture scientists go about doing research and development and for evaluating the social effects of technoscience in the making.

A prominent finding from a case study of transgenic fish engineering is that aquacultural technoscience emerges as a heterogeneous network situated within a particular research and development discourse, as part of a broader ordering of the social. In the laboratory, everyday processes of displacing, organizing and constructing a local microworld are filtered and extended by means of inscription devices. These devices serve as the basis for texts which carry ideas, concepts and theories which can be used to extend the laboratory created objects into an ordering of the social.

As transgenic fish extended into social ordering they provoked a controversy concerning outdoor experiments. In following the controversy a public policy process was

initiated which led to the creation of performance standards for conducting this type of research. However, the standards generated new controversies because they rested on the a priori assumption that biological criteria passed for social consent. Unaddressed and a source of further dissent was the social situatedness of standards application within a particular technoscientific context. As a result, new contingency-laden controversies have erupted which are multi-faceted and international in scope.

In conclusion, this work outlines a recasting of the relationships between knowledge and power, agency and structure and an elimination of a priori categorical divides. In particular, a move towards a sociology of objectivity provides an overarching framework to assess and evaluate the effects of technoscience in society and the socially constituted decision making contexts which shape sociotechnical ordering. This volume contributes to a mutually complementary conversation between the sociology of aquaculture and scientific knowledge.

Dedicated to my mother Dorothy T. Skladany, my father Stephen P. Skladany, my sisters JoAnne, Karen and Mary Beth, my daughter Mira K. Skladany and Chavaun, all for the Gift of Life

ACKNOWLEDGEMENTS

To state that a creative and scholarly work is much more than the mere work of the author clearly applies in what follows. Foremost are my committee members Lawrence Busch, Craig Harris, Chris Vanderpool and Ted Batterson. As my chair Larry defined and acted in a manner which exemplified the true meaning of scholarship. His patience, humor, encouragement and support from the inception of this work were instrumental in bringing it to fruition. Through their demonstrated commitments to scholarship, Craig, Chris and Ted each exposed me to new questions, horizons and approaches which are hopefully reflected in the following pages. I also acknowledge the support I received from Gerad Middendorf and Elizabeth Ransom at Michigan State University. At Auburn University, both Rex Dunham and Amy Nichols allowed me access to the study of transgenic fish at the only facility of its kind in North America. Their patience, interest and insight are greatly appreciated and hopefully reflected in the following pages. Finally, I acknowledge the scientists, policymakers, and lab technicians of the "transgenic research community" who took the time and offered insights concerning the field of transgenic fish research and development.

I would be amiss if I did not also acknowledge some earlier influences. George Sekerak, Mike Bacik, and Orin Stecker introduced me to the world of fishing in the lakes and streams of northeastern Ohio. As an undergraduate, S.K Ballal greatly stimulated my interest in biology and ecology. As a graduate student, Conner Bailey not only supported the

undertaking of this work but also encouraged me to further pursue the study of sociology. In learning about aquaculture, my gratitude is extended to former colleagues in Thailand, Amorn and Amphorn Petchawdeerek, Surat Koonphol, Joel Van Eenaameen, Dave Little, the NET Project Staff, Alex Fedoruk, Samran Ritragsa, and Plodprasop Surasawadee.

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LIST OF ABBREVIATIONS

AAES	Alabama Agricultural Experiment Station
ABRAC	Agricultural Biotechnology Research Advisory Committee
ADB	Asian Development Bank
ADCP	Aquaculture Development Coordination Programme
AFS	American Fisheries Society
AIT	Asian Institute of Technology
ANT	Actor Network Theory
APHIS	Animal and Plant Health Inspection Service
BARD	Binational Agriculture Research and Development
CGIAR	Consultative Group on International Agricultural Research
CIDA	Canadian International Development Agency
CSRS	Cooperative State Research Service
CSREES	Cooperative State Research, Education and Extension Service
DANIDA	Danish International Development Agency
DOF	Thai Department of Fisheries
EA	Environmental Assessment
EDF	Environmental Defense Fund
FAO	Food and Agricultural Organization of the United Nations
FDA	Food and Drug Administration
GMO	Genetically Modified Organism
GOR	Government of Rwanda
GTZ	German Agency for Technical Cooperation
hGH	Human Growth Hormone
IBC	Institutional Biosafety Committee
ICA	International Center for Aquaculture
ICLARM	International Center for Living Aquatic Resources Management
IDRC	International Development Research Council
IFDOC	Inland Fisheries Development Operations Center
JICA	Japanese International Cooperation Agency
MTFG	Minnesota Transgenic Fish Group
NEPA	National Environmental Policy Act
NIFI	National Inland Fisheries Institute
NIH	National Institute of Health
NORAD	Norwegian Agency for International Development
OAB	Office of Agricultural Biotechnology

ODA	Overseas Development Administration
OECF	Overseas Economic Cooperation Fund
OSTP	Office of Science and Technology Policy
OTA	Office of Technology Assessment
PCR	Polymerase Chain Reaction Thermal Cycler
PD/A CRSP	Pond Dynamics Aquaculture Collaborative Research Support Program
PI	Principal Investigator
R&D	Research and Development
rDNA	Recombinant Deoxyribonucleic Acid
RNFCP	Rwandan National Fish Culture Project
rGH	Rat Growth Hormone
rtGH	Rainbow Trout Growth Hormone
SIDA	Swedish International Development Agency
SSK	Sociology of Scientific Knowledge
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USOM-AID	United States Overseas Mission - Agency for International Development
VFPP	Village Fish Pond Project

Chapter 1

INTRODUCTION

Aquaculture, the controlled cultivation of aquatic organisms, has emerged from earlier historical associations with capture fisheries and agriculture. In the late twentieth century aquaculture has subsequently grown into a nascent technoscientific based industry of growing global proportions. The mass cultivation and domestication of carps, shrimp, salmon and tilapia among other economically important aquatic organisms are undertaken in diverse ecological regions of the world and currently contribute to about one quarter of human aquatic food consumption (Martinez 1997; Goldberg and Triplett 1997). Given finite marine fisheries resources, modern aquaculture, advanced by the rapid formation of its technoscience, is expected to supplement traditional capture fisheries with much needed aquatic protein for the world's growing population.

So the above story, repeatedly told in aquaculture development circles, would have it. In fact, aquaculture development is at a crossroads. The mythology of "farming the seas" and "feeding the world" through aquaculture speaks little about the complex universe in which the culture of aquatic organisms has recently emerged throughout the world. Questions of how the technoscientific products and practices of aquaculture exert pronounced societal effects have not been posed in a practical, satisfying or intellectually rigorous manner. How did contemporary aquaculture, caught between the nutritional requirement for aquatic protein production, economic development and environmental sustainability, arrive at such a quandary? What unfolds in the following pages are some answers through a sociological inquiry into the hybrid sociotechnical field of aquaculture technoscience and development.

THE EMERGENCE OF AQUACULTURE DEVELOPMENT

Aquaculture, although concurrent with the earlier hunting and gathering of aquatic organisms, has developed out of the very recent industrialization of marine capture fisheries and agriculture. With finite limits evident in capture fisheries, the search for alternative aquatic protein sources has spurred the growth of modern aquaculture. In an effort to domesticate and control the production of aquatic organisms, aquaculture resembles agriculture. However, aquaculture production is relatively recent with cultured species only a few generations removed from wild stocks. As a result, modern aquaculture development presents a series of unique scenarios and problems which are not evident in agriculture.

In essence, the rise of modern aquaculture development can be traced to two development-oriented themes. First, in the aftermath of the Second World War aquaculture was identified as an international development strategy. Growing development expectations posited that a relatively benign set of small-scale farming practices would enable the world's impoverished tropical populations to meet basic food production needs. Second, by the mid-1980s, international aid agencies, anticipating a new global geopolitical ordering, influenced a shift in thinking about aquaculture development away from subsistence activities towards industrial export-oriented growth strategies. As a result, new industrial forms of aquaculture such as shrimp and salmon culture emerged over the past decade. These industries have increasingly encountered growing environmental problems which threaten their very economic, social and environmental sustainablity. Aquaculture, which was once envisioned as a socially sound way to produce much needed aquatic protein for impoverished people has become oriented toward relatively affluent consumers in developed countries and consequentially a problematic site enmeshed within widespread social conflict.

The controversies and conflicts associated with contemporary aquaculture development show no signs of subsiding. Parallel to terrestrial agriculture, key technoscientific actors in the industrial aquaculture sector are embarking on a new biotechnology driven future. Closely tied to the industrial production of aquatic organisms, the new aquaculture biotechnologies are being developed to increase mass production in order to efficiently "feed the world" and more modestly to establish U.S. dominance in terms of technology advancement. While earlier biotechnology applications in aquaculture can be traced to development of hormone applications in fish breeding in the 1930s, the range, scope and potentialities of the new biotechnologies dwarf these previous advances. Notably, the new aquaculture biotechnologies draw on and incorporate new hybrid associations and scientific fields as diverse as medicine, evolutionary biology, "pharming," aquatic ecology, fish diseases, nutrition, physiology, breeding and the vast field of genetics. Most noteworthy, the genetic engineering of aquatic organisms for commercial cultivation has featured in both popular and scientific accounts of the new aquaculture biotechnologies. A complex mix of predominantly public and to a lesser extent private actors comprise a global network of transgenic researchers and public officials, that is guiding the research and development of the new aquaculture biotechnologies.

In this work, my central focus is to view aquaculture development as problematic. It is made even more so by the advent of aquaculture biotechnology. Against this backdrop, a growing aquaculture development literature has been put forth by social and aquacultural scientists. In these accounts, however, the following central problematics feature: (1) social scientists avoid problematizing technoscience; and (2) aquaculture technoscientists avoid problematizing society. Both social scientists and aquacultural technoscientists each provide highly asymmetrical readings of aquaculture development due to implicit assumptions which rest on an a priori categorical separation between technoscience and society. As a result, aquaculture development is subsequently explained by reductionist social or technoscientific factors.

Against these central problematics, sociologically informed analyses of *aquacultural technoscience "in the making"* are lacking and provide a critical opportunity to mutually contribute to the fields of the sociology of scientific knowledge (SSK) and the sociology of aquaculture. Thus, a study of aquacultural technoscience in the making is novel, challenging and intriguing for a number of reasons. First, as noted above, sociologists do not problematize technoscience. In general, sociologists view technoscience as *a black box* -- as something *made and immutable* which "acts as one piece" no matter how complicated the context (Latour 1987: 131). This "ready made" technoscience is highly evident in the sociological writings about aquaculture development where only inputs and outputs count (Latour 1987).

Absent from these accounts of technoscience are the human and non-human actors, controversies, contingencies, debates and negotiations which underscore that technoscience is an effect of the overall recursive processes of social ordering, captured in this work as technoscience in the making. Pursued further, technoscience, society and nature are *consequences* and *not causes* of the settling of a controversy -- when facts, products and hence "technoscience" are convincingly established and become stable (Latour 1987). Hence, examining technoscience in the making provides a "back door" approach by which to dynamically view how technoscience, society *and* nature take shape and produce effects (Callon 1986; Latour 1987: Law 1994).

Second, the above sociological problematic with aquaculture technoscience is somewhat mirrored in technoscientific accounts. In sum, technoscientists avoid problematizing society. They portray society as a medium of passive resistance. Objects simply diffuse and cause effects (Latour 1987). In order to account for objects moving about by themselves, technoscientists subsequently *invent* a society consisting of discoveries and ideas which are attributed to individual technoscientists (Latour 1987). From this side of aquaculture development, it appears that technoscience made is the arduous unraveling of the secrets of an eternal objective Nature. However, technoscientists exclude technoscience in the making -- the collective work of enrolling allies and the intensive painstaking heterogeneous assembly of human and non-human actors. Similar to backroom politicians, technoscientists move from weaker to stronger positions by building laboratory and non-laboratory associations through representing heterogeneous entities as consisting of one network. As a result of these collective associations or networks, sociotechnical ordering takes shape whereby both nature and society are represented through knowledge, power, agency and structural effects.

Clearly, aquaculture technoscience in the making provides a novel and interesting case study by which to frame a sociological inquiry. Along these lines, it is reasonable to assume that aquaculture technoscience can be characterized as a nascent research and development field which is closely tied to practical applications in commercial cultivation spheres. Moreover, as a technoscience in the making, the rise of aquaculture oriented institutions, organizations, programs, projects and literatures has been relatively recent. In conjunction with the recent institutionalization of aquaculture technoscience, the vast majority of careers in aquaculture technoscience are also still in the making. As a result, the field has shifted rapidly with new actor-entrants bringing to aquaculture research and development practices diverse backgrounds and new interests as well as embarking on hybrid fields of investigation. In a relatively short time, the field of aquaculture has gone through a substantial maturation process where it provides an excellent example of a technoscience in the making.

Third, an analysis of technoscience in the making provides the groundwork for reconceptualizing some fundamental sociological concepts and relations. In particular, the relations between knowledge/power and agency/structure can substantively contribute to an outline for a sociology of objectivity. In short, it is the appeal to "objectivity" which rationalizes, justifies, and legitimates the decisions to extend the objects of aquacultural technoscience in society. However, as my case study of transgenic fish illustrates, the social construction of objectivity is often reduced to a mere "objectivism" where narrow technoscientific criteria alone *act* as a basis for legitimating extensions into the "passive medium of resistance" -- society. Little regard is given to the social consequences of technoscientific choice which often produces unintended effects (see also Middendorf et al. 1998). In contrast, a sociology of objectivity aims to reverse the heady ideological fixation with runaway technoscientific "progress" by putting forth social criteria as the renewed foundation for informing technoscientific choices.

SCOPE OF THIS STUDY

This work applies actor-network theory and methodology in order to examine one instance of aquacultural technoscience in the making: transgenic fish research and development. While an intensive focus on a particular case exhibits specific content embedded in a particular context, this study also reflects a much broader scope framed by the sociology of scientific knowledge (SSK) and the sociology of aquaculture. My aim in this study is to draw on SSK to inform the sociology of aquaculture and to draw on the sociology of aquaculture to inform SSK. The case study of transgenic fish research and development provides the empirical foundation for accomplishing this novel task.

This study is situated against the broader backdrop of three central thematics: aquaculture development, biotechnology and the sociologies of aquaculture and scientific knowledge. First, by critically examining accounts of aquaculture development, I problematize them. The problematization of aquaculture technoscience and development leads to two research questions; (1) How do aquacultural technoscientists go about *doing* research and development? and (2) What are the *effects* of aquacultural research and development? In pursuing these questions the centrality of the laboratory provides a simultaneous point of origin *and* departure. Labs are central knowledge sites for producing aquaculture technoscience but they alone do not answer questions about societal effects traceable to laboratory work. Hence, inquiry *must* go beyond laboratory life and enter into post laboratory "publics" which undergird the sociotechnical choices which situate lab products into wider societal arenas.

Second, aquaculture biotechnology is poised on the cusp of dramatic social changes in the global food system and beyond. While not as pronounced as recent developments in agriculture, aquaculture biotechnology mimics the organizational trajectory of agriculture biotechnology. Notably, there have been no concerted *sociological* studies of aquaculture biotechnology. This may be due to; (1) the previously discussed non-problematization of technoscience by social scientists, and (2) that pending aquaculture biotechnology innovations, such as the genetic engineering of fish, remain "socially invisible" because these activities are "hidden" through a specialized technical language, materials, laboratories, field stations, file cabinets, inscriptions, technical journals and relatively discrete decision and policy making circles. In contrast, policymakers and technoscientists *speak on behalf* of their work, objects, and heterogeneous laboratory ensembles to both the popular press and to a more technically sophisticated group of like minded specialists. One consequence of these *representations* is that technoscientists have a relatively free reign to continue inventing societies around their products.

Third, given the central problematic range, scope and potentials associated with the new agriculture and aquaculture biotechnologies, it makes sound sociological sense to develop new approaches by which to examine them. In critiquing aquaculture development, the adoption and diffusion of innovations (e.g., Rogers 1983) consistently features as the engine of social change (translated as *more* or *less* farmer adoption of aquaculture). Moreover, these accounts as well as political economic and ecology approaches often fall into arbitrary "macro" and "micro" levels of analysis and interpretation. Many authors are unabashedly aquaculture advocates and often assume a priori what they seek to establish (Callon et al. 1986). This asymmetry on the part of both social scientists and aquaculture technoscientists is traceable to fundamental categorical divides between the "macro" and the "micro" and technoscience and society.

In order to address the problematic "dilemma of the divides," fresh theoretical and methodological approaches and resources are imminently required. In casting my net as broadly as possible, I found SSK and in particular actor-network theory and methodology a fertile area for addressing my research questions and subsequently reconstructing an account of aquacultural technoscience and development in the making.

In winnowing the interdisciplinary field of SSK to fit the central problematics and context of this work, Callon's (1986) actor-network account of scallop aquaculture in St. Brieuc Bay, France and Bauin's (1986) depiction of French aquaculture as "bureaucratic intervention" proved provocative, intriguing and resonant with my own interests. Equally influential was the work of Latour (1983: 1987: 1993), Latour and Woolgar (1979) and Law (1992: 1994), all actor-network theorists, which led to the identification of the primary site of scientific knowledge production -- the laboratory. The work of Busch et al., (1991), Middendorf et al. (1998) and de Sousa and Busch (1998) allowed me to contrast aquaculture with agriculture.

Lab studies are points of origin and subsequent departure. First, laboratories are the primary sites of scientific knowledge production. In the everyday work activities of a laboratory, however, much of what takes place does not necessarily enter into the inscription driven realm of ideas, concepts and theories. An observer finds that laboratory life, in the words of one laboratory worker, involves the organizing and ordering processes, trials and tribulations of "making things work." In making things work, lab workers create order out of disorder through tinkering and assembling a range of heterogeneous materials to fit desired interests and to achieve intended effects. Lab workers are social engineers who socially construct objects through organizing a broad array of human and non-human materials into an ordering. They work with instruments and produce inscriptions and thus build networks. When "things *do* work" knowledge claims and corresponding products are extended into the realm of material assertion within a broader sociotechnical ordering (Law 1994).

Second, laboratories are sites or places which powerfully *act* in sociotechnical ordering. Laboratories however, do not act alone but simultaneously *are enmeshed* within a longer network which enables the processes and products to further extend through society. Without mobilization, the objects in the laboratory would simply remain there; without the desired objects, knowledge claims are reduced to mere words (Law 1992; 1994). In this regard, I came to the early conclusion that laboratory studies, which feature in actor-networks and some related areas of SSK, require a simultaneous awareness and pursuit of *associated* matters *outside the laboratory* proper. In particular, a close following of the production of inscriptions provides the central tie in between the inside and outside of technoscience in the making. The focus on a single laboratory has been one of the most pronounced shortcomings of laboratory studies (e.g. Rouse 1987). Going beyond the laboratory further requires incorporating the associated non-laboratory participants in the overall constructing of technoscience, nature *and society*. In this study, I closely followed the associated non-laboratory participants in the decisions and policy formations regarding the movement of transgenic fish into broader societal configurations.

From a laboratory origin and subsequent departure, I found that the divides between the macro and the micro, and technoscience and society are arbitrary and rest on unfounded a priori assumptions. By eliminating a priori divides, a reflexive opening and fresh starting point allows for an actor-network approach to transgenic fish research and development. Moreover, the case study provides an empirical foundation to reconceptualize some conventional sociological relationships between knowledge/power and agency/structure. This recasting of knowledge, power, agency and structure points to a concluding outline towards a sociology of objectivity. The sociology of objectivity prioritizes and calls attention to the social dimensions of values, organizations and practices which are simultaneously evoked by technoscientific choices.

Objectives

There are three objectives which guide this volume. First, I seek to advance a mutually complementary and sensible conversation between the sociologies of aquaculture and scientific knowledge. The sociology of aquaculture has achieved growing recognition as a legitimate and applied area of inquiry. This is all the more remarkable considering that a mere decade ago, sociologically oriented literature on aquaculture development was sparse, fugitive and when published, often marginalized. This status reflects a corresponding "urban bias" by which academic developmentalists "assigned a residual status to agriculture and rural life" McMichael 1995:ix). As the sociology of aquaculture crystallizes, a growing number of accounts are consistently constrained by a number of shortcomings. In particular, a general lack of theoretical development is often conflated with an over wrought empiricism which heavily leans on exclusive social categories to account for aquaculture development.

In contrast, aquaculture technoscientists have been acting as development sociologists for decades. Callon's (1987: 84) analysis of engineer-sociologists in the development of the electric car in France, demonstrated how engineers not only envisioned the mechanics of the vehicle itself but also conjectured a "social universe in which the vehicle would function." As I illustrate in Chapters 2 and 3, aquaculture technoscientists exhibit a similar orientation by envisioning a social world in which fish culture would function in society. No matter how "technical" the claims, aquaculture technoscientists play on several social contexts and themes at the same time. For example, not only did Swingle (1957) provide "technical assistance" to the Royal Thai Department of Fisheries by identifying suitable native Thai fish species for culture. He also identified elements of "institutional strengthening" in terms of appropriate research organization and design. As I demonstrate in Chapter 2, Swingle (1957) also situated this "turn towards aquaculture" against an implicit societal backdrop of rapid economic development, environmental degradation and declines in traditional capture fisheries. At this analytical juncture a problematic impasse becomes evident between social scientists and aquaculture technoscientists. Both parties address the same phenomena but their analyses are predicated on a priori assumptions which lead them to separate and reduce the phenomena to disciplinary divides. As a result, their conclusions often seem arbitrary and partial. In Chapter 4, I trace these assumptions to the epistemological foundations of diffusion theory.

Given these problematics, I advance fresh theoretical and methodological resources from SSK to re-examine aquaculture development. At the same time, SSK practitioners have rarely ventured into the field of aquaculture with the lone exceptions being the work of Callon (1986) and Bauin (1987). In the field of agriculture however, Busch and Juska (1994), Busch and Tanaka (1996), Kloppenberg (1992), Murdoch (1994), and de Sousa and Busch (1998) have produced stimulating SSK oriented breakthrough studies with far reaching implications. It is against these influences that the present volume is situated and seeks to advance a SSK approach into the field of aquaculture development.

Second, I apply actor-network theory and methodology to address the above stated problematics in aquaculture development discourse. In studying transgenic fish research and development at a leading facility in the world, I found that by "following the actors" (the methodological principle of ANT) it was impossible to remain confined to an immediate laboratory environment. While conducting our daily work of organizing and ordering a microworld around transgenic fish, I gradually became aware of the laboratories' situatedness in a much larger "transgenic community" or network. While at the laboratory, phones rang with collaborating PI's from all over North America on the other end inquiring about the incorporation of their gene constructs in the transgenic fish genome; postal express orders of critically needed supplies arrived which alleviated bottlenecks in moving forward with work tasks; potential funders and visiting scientists from around the world toured of the facility. I also traced the social history of the laboratory to past and present day controversies over the emplacement of transgenic fish in wider societal settings. While in the lab I had to simultaneously go beyond it.

By "following the actors" one must go beyond the immediate lab environs. Coupled with the tracing of the lab's social history a distinct analytical nexus takes shape which is crystallized in decision making moments and broader policy contexts. Both within the lab and outside it, the extension of the social positioning of transgenic fish was predicated on decisions made in both local and nationally diverse contexts. As I show in Chapter 6, the decision to move transgenic fish to outdoor facilities entailed input, debate and controversy involving a diverse set of actors. The anticipated consequences of mobilizing the non-humans (the fish) by proposing to move them a few hundred feet, sparked the forming of a scientific advisory group to create national performance standards for the “safe" conduct of this research.

Third, by going beyond the lab and entering into multi-sited decision making arenas, assessment of the effects of research and development further opens us to re-examine some critical sociological concepts and relations. Rather than making a priori assumptions about Power/Knowledge and Structure/Agency, the empirical basis of this volume demonstrates that these concepts and relations are intertwined with a "recursive sociology of process" (Law 1994: 100). I advance the argument that power-knowledge and structure-agency are material relational effects which arise from the jostling and machinations of sociotechnical ordering.

Finally, the address of these objectives translates into examining the decision making processes which affect both the minute laboratory microworlds and broader public spheres. We need to ask: How are decisions concerning transgenic fish research and development made? By whom? And for what end? In Chapter 7, I pursue this question by assessing the decision making contexts and by outlining a sociology of objectivity. This work demonstrates that the decision making context concerning transgenic fish research and development is restricted to biologically defined expert systems and discourses. Much like agricultural biotechnology development, justification for aquaculture biotechnology relies on a set of narrowly defined biological criteria which is further reduced to commodity forms of production (Middendorf et al. 1998). From the scientific and associated policymaker standpoint, biological criteria alone act as a representation of social desirability.

At this juncture, it becomes apparent that the restricted criteria which dominate decisions regarding the extension of transgenic fish research and development may lead to favorable, nebulous and at times highly contested societal impacts (See Sagoff 1989). At present, the aura of a scientific "objectivism" is no substitute however, for a more concerted socially defined sense of objectivity regarding the extending of transgenic fish into social ordering. As a consequence, the call is for readdress of decision making contexts which shape the social-technoscientific-natural world. A turn toward a sociology of objectivity which is constituted by socially defined values, organizations and the kinds of societies we want would offer greater clarification and a fuller direction for human advancement.

Transgenic Fish: A Case Study

I have always been interested in fisheries and later, aquaculture. Trained as a biologist and influenced by the New Alchemists (1976) and Schumacherian (1973) vision, I have participated in and have observed the growth of aquaculture into an industrial technoscience. Given this background, I undertook field work at Auburn University's Fisheries and Aquaculture Genetics laboratory and field station. Initially, I was confronted with obstacles such as research topic selection and direct access to working aquacultural scientists. As a former aquaculture trainee (1977) and resource economics graduate student (1987-1989), I held recognition with the Department of Fisheries and Allied Aquaculture but did not directly study in the Department.

As one who was seeking to enter into the world of aquaculture technoscience, I began to conduct extensive background investigations of the aquaculture field through an assessment of Auburn's Department of Fisheries and Allied Aquaculture. At the same time, I read extensively in the field of SSK and in particular concentrated on laboratory studies. Highly influential in shaping my initial research proposal was the work of Busch and Lacy (1983) who undertook a pathbreaking study of public agricultural research in the United States. Consequentially, I modified a survey conducted by them in order to elicit a general overview of influences on Departmental aquacultural scientists, their activities and their views of science (Appendix A).

When the survey format was ready, I formally met with the recently appointed Chair of the Department. Accompanying me was a well respected professor of rural sociology. As a result of this meeting, the chair mentioned the survey at his first departmental meeting which gave instant credibility to my intentions. I felt that a survey would prove to be more comprehensible and non-threatening to the faculty and provide me with a rough composite of departmental scope and activities.

Fifteen of eighteen tenured faculty responded to the survey questionnaire. These responses provided the background which filtered into my selection of the transgenic fish laboratory/station. The results from this survey are insightful as they provide a glimpse of technoscience in the making. Briefly, Auburn scientists overwhelmingly mentioned that more effort be devoted to "basic" research defined as:

> increases of knowledge in science with the primary aim of the investigator a fuller knowledge or understanding of the subject under study, rather than a practical application thereof.

One survey respondent, a leading figure in the field, offered the following assessment:

> I try to work on "real" problems and I often must conduct basic research in order to have a basic understanding of the processes involved... the big problem in aquaculture research is that there are few "first rate" researchers, and when decisions are made, the better researchers have little say in the process.

A similar sentiment was latter expressed by a member of the transgenic fish research community:

> Many aquaculturists are trying to answer problems which cannot be answered with the current state of knowledge and not only don't they recognize that basic science can provide this knowledge but unfortunately they are actively hostile to it. . . they all want a vaccine that will work but they seem to think they can conjure one out of thin air without understanding how the immune system of the fish works.

Second, in conducting this survey I asked: Who or what research group has significantly advanced aquacultural science? In response, faculty identified water quality, fish nutrition and genetics as leading world-class research groups. All three groups made extensive use of analytical laboratories and ponds. The water quality and nutrition labs were based on campus with research ponds located off campus at a massive run-down research station. In contrast, genetics research consisting of a recently constructed laboratory, hatchery and ponds were centrally located at a two and one half million dollar facility completely separated from the other pond facilities. I further noted that the annual genetics research budget (excluding salaries) was approximately one half million dollars which represented one quarter of the overall department grants. In profile, the genetics program clearly stood out and cut an image as the world leader in this technoscientific field of aquaculture.

At the same time I was conducting the survey, an article in Science by Fischetti (1991) and another one in World Aquaculture by Dillon (1991) attracted my attention. Both articles featured the transgenic fish research being conducted at Auburn. In particular, Fischetti (1991) described the genetics facility along the lines of a "carp panoptic" which in my naiveness at the time I found to be startling and sociologically compelling. Fischetti (1991:513) obsesses on the prison-like conditions; twenty four hour surveillance cameras, police monitoring, locked gates, signs, barbed wire fences, dikes and a poisoning system that would "make a military weapons laboratory proud." In a later interview, the Auburn PI stated that Fischetti's (1991) article had greatly distorted their work and a letter objecting to this characterization was sent to him.

Entry into a laboratory is accomplished through negotiations. Given my tentative selection of the genetics facility, I then approached the Director who was alternatively bemused and cautious about having a sociologist participate and observe activities at the lab/field station. He requested that I outline my proposed intentions in written form. Subsequently, I wrote that:

> My intention would be to participate and observe (unobtrusively) the activities of the scientists at the facility. This approach facilitates the production of data required to build an internal example of science in the making as opposed to external accounts of it. In particular, genetic engineering has drawn substantial attention and provides me with the kind of sociological interfaces which would make an extremely interesting topic. Moreover, I note that the published literature on aquaculture biotechnology from a sociological angle is non-existent.

In response, the Director expressed no objections to my intentions. Thus, I began a nine month immersion into the daily social context of transgenic fish research and development at the genetics facility. The nine month period allowed me to observe a complete research cycle as put forth in Chapter 5.

Actor Networks and Key Definitions

As Winner (1986:x) has remarked, in "choosing our terms we express a vision of the world and name our deepest commitments." As put forth in the following pages with the problematization of aquaculture development in Chapter 3 and application of actor-network theory (ANT) and methodology in Chapter 4, a specific language emerges which engages the reader throughout the remainder of the text. From the onset of this work I will define the following key terms: *technoscience, actant, actor network, nature and society.*

> *Technoscience*: is a hybrid term derived from the problematization of maintaining a boundary between science and technology. As Bijker (1995: 240) puts it, "The old image of technology as being merely applied science was already dismissed . . . it is no adequate description of the entanglement of the two." Latour's (1987: 174-175) usage of the term describes "all the elements tied to the scientific contents no matter how dirty, unexpected or foreign they seem . . . the expression *science and*

technology designate what is kept of technoscience once all the trials of responsibility have been settled."

Actant: "refers to any entity endowed with the ability to act" (Callon 1995: 53); "whoever and whatever is represented . . . what the spokesperson represents" (Latour 1987: 84; 89). An actor "is a patterned network of heterogeneous relations, or an effect produced by such a network" (Law 1992: 384).

Actor-Network: "The structure and operation of an actor-world [the world of entities generated by an actor-network . . . for any given actor, there is nothing beyond the network which it has created, which constitutes it, and of which it forms a part]: an interrelated set of entities that have been successfully translated [the methods by which an actor enrols others] or enrolled [the definition and distribution of roles by an actor-world] by an actor that is thereby able to borrow their force and speak or act on their behalf or with their support. The entities may be seen as forming a network of simplified points . . . whose simplicity is maintained by virtue of the fact that they are juxtaposed with others. The actor who speaks or acts with the support of these others also forms part of the network . . . Hence the term actor-network, for the actor is both the network and a point therein" (Callon et al., 1986: xvi-xvii). Actor-networks are materially heterogeneous -- and extend to non-human entities. Things act (Law 1992; 1994).

Nature and Society. Actor network theorists take issue with a priori distinctions between nature and society which arise from modernist ontological variability. Thus, actor network theorists argue that nature and society are dynamic and not distilled as essences. Nature and society are generated as effects of sociotechnical ordering (Law 1994:85). As Latour (1993:85) puts it, "They [Nature and Society] become convenient and relative reference points that moderns use to differentiate that moderns use to differentiate intermediaries, some of which are called 'natural' and others 'social', while others are termed 'purely natural' and others 'purely social', and yet others are considered 'not only' natural 'but also' a little bit social."

Thus Law (1994:18) states that "the vision is of many semiotic systems, many orderings, jostling together to generate the social."

I find that the most direct address of the previously noted problematics of aquaculture consists of examining aquaculture research and development processes through the analytical frame of technoscience, actants and actor-networks. Overall, a better characterization of a dynamic technoscience in the making results. Law (1994: 18) notes that actor-network theory:

> tends to tell stories, stories that have to do with the processes of ordering that generate effects such as technologies, stories about how actor-networks elaborate themselves, and stories which erode the analytical status of the distinction between the macro and micro-social.

What follows then in this work is a set of elaborated stories about aquaculture research and development. Given the relatively recent turn towards genetic engineering in aquaculture, there is much that remains uncertain, contingent and unsettled. At the same time, the relatively early arrival of this work underlies the critical importance of studying aquacultural technoscience at the formative stages of actor-network construction and representation.

ORGANIZATION

This volume consists of seven chapters. In Chapter Two, I begin by sketching the aquaculture universe. Although there is no definitive social history of aquaculture, I begin by outlining aquaculture's origins, practices and techniques in diverse regions of the world. Beginning in the aftermath of the Second World War, international aid agencies identified aquaculture as a development strategy. Case studies of aquaculture development in Thailand and Rwanda illustrate the institutional establishment of aquaculture. I then examine aquaculture as a bureaucratic intervention through the growth of Auburn's International Center for Aquaculture (ICA), the Asian Institute of Technology (AIT) and the World Bank. The chapter concludes with an outline which traces the recent arrival of aquaculture biotechnology and genetic engineering of transgenic fish.

Early international aquaculture development efforts eventually witnessed the entry of social scientists for project evaluation purposes. These instances provided the spark for the emergence of the Sociology of Aquaculture. In Chapter 3, I summarize a representative range of sociological literature on aquaculture development in order to problematize it. Deconstructing texts on the "sociological side" demonstrates that regardless of the approach deployed, sociologists do not problematize technoscience. Deconstructing texts on the "technoscientific side" demonstrates that conversely aquaculture scientists do not problematize society.

In Chapter 4, the theoretical limitations evident in the sociology of aquaculture are critiqued through an analysis of diffusion theory -- the overwhelmingly dominant framework in the sociology of aquaculture. The critique of diffusion theory lays the groundwork for introducing the sociology of scientific knowledge and, in particular, actor-network theory. The Chapter concludes with a redirecting of aquaculture research and development in terms of actor-network theory.

Chapters 5 and 6 present the case study of transgenic fish research and development. In Chapter 5, how scientists, lab workers and technicians go about building transgenic fish is initially depicted from the situatedness of everyday laboratory life. Modes of organizing and ordering are the two major hybridized forms of building transgenic fish networks at the laboratory bench and in experimental ponds. Importantly, I found that scientists work with and from instruments. They produce inscriptions which provide a transition point between craft work and the realm of ideas, concepts and theories (Latour and Woolgar 1979). An inscription informs the participants' activity which carries into broader sociotechnical ordering. In Chapter 6, we move quite literally from "inside" the laboratory microworld to the "outside" arenas of society, technoscience and nature. A proposal to move transgenic fish to outdoor experimental ponds at Auburn sparked a controversy which led to the creation of Federally sanctioned voluntary performance standards for the safe conduct of this type of research. The sociotechnical effects of the performance standards are still contested as of this writing as they have encountered some resistance due to their restricted scope and enrollment of only some of the major actors.

In concluding this volume, Chapter 7 puts forth the view of aquaculture as technoscience in society. This summary characterization of a nascent technoscience is focused on the effects of aquaculture research and development. Modern aquaculture is situated at the crossroads of sustainability. But the "promise" of aquaculture development to supply the world's population with much needed protein has been cast into doubt by a variety of intertwined environmental and social problems.

The concluding sections of Chapter 7 also offer an opportunity to examine the broader sociological dimensions of this work by re-examining some fundamental and problematic sociological concepts and relations. In particular, I draw out and recast the relationships between knowledge-power and structure-agency. Within the context posed by this re-examination and the case study on aquaculture research and development, I outline directions and implications for a sociology of objectivity and the contributions that actor-networks can make to it.

Chapter 2

TOWARDS A SOCIOLOGY OF AQUACULTURE

INTRODUCTION

Industrial aquaculture is a very recent phenomenon. Lacking a definitive history, the universe of aquaculture contains innumerable stories which draw links between "traditional" forms of aquatic cultivation to commercial, industrial and biotechnological growth. The notion of "technological progress" has underscored this continuous transformation. Modern aquaculture has evolved out of dramatic natural resource crises and agricultural development which occurred after the Second World War. Early developers envisioned a "small-scale" aquaculture that would feed people, promote social well-being and supplement production from the world's oceans. This earlier vision has been effectively translated from subsistence to capital and technologically intensive forms of production and consumption. Along these same lines, biotechnology and genetic engineering stand poised at the cusp of far reaching social and environmental change.

Modern aquaculture can be traced to earlier historical associations with capture fisheries and agriculture. Countries such as those in Asia with extensive maritime coastlines and subsistence inland rice cultivation have always displayed a pronounced food dependency on aquatic resources (Edwards et al., 1983). Currently capture fisheries accounts for eighty percent of global production with aquaculture making up the other twenty percent (Goldberg and Triplett 1997). These figures however, obscure the observation that marine capture fisheries have remained stagnant while aquaculture exhibits dramatic growth in various regions of the world. Over the past decade, global aquaculture production has doubled from ten million to twenty million metric tons (Goldberg and Triplett 1997).

Within this global scenario, China accounts for sixty percent of total aquaculture production. Chinese aquafarming practices are ancient and predominantly consist of inland carp polycultures integrated with other agricultural activities (Goldberg and Triplett 1997). While China is somewhat of an exception to other regions of the world, recent advances in hormonal breeding, feeds, disease control and genetic improvement are also dramatically modernizing Chinese aquaculture production practices. Moreover, the Chinese have also recently embarked on aggressive export-oriented aquaculture of marine shrimp and crayfish. Thus modern aquaculture represents a turn in the global organizational form of aquatic cultivation from subsistence to commercial and industrial modes of production and mass consumption.

This chapter brings forth a social historical account of aquaculture. The aim is twofold: the first is to provide a background context for the emergence of the sociology of aquaculture which is presented in Chapter 3; the second is to illustrate that aquaculturists essentially tell stories about its development. Because these stories assume a separation between science and society, accounts of aquaculture development are problematized as being partial and asymmetrical. As told by aquaculturists, stories about aquaculture development often evoke a mixed mythological representation of the activity characterized by the linear progress of science *in* service to the alleviation of a world food crisis. These stories however, mask the capital and technological intensity of aquaculture industrialization as well as the distributional effects where cultured aquatic products such as shrimp and salmon enter into export and relatively affluent domestic markets.

In contrast, this chapter demonstrates that aquaculture development is best seen as a social activity. In the aquaculture literature however, technoscience is postulated as the engine of social change and transformation. I intend to demonstrate that aquaculture is inseparable from society. By considering both technoscientific and societal contexts in the formation of modern aquaculture, the role of farmers, international agencies and the desires of certain scientists are posited as part of the dynamic behind the creation of modern aquaculture research and development *in the making*. In other words, farmers, aid agencies and scientists forged aquaculture research and development networks.

Development stories about aquaculture are diverse, widely scattered and cover an enormous range of species, culture systems, places and project initiatives. However, these accounts all start with the implicit assumption that science and society are separate entities. By examining accounts written by aquaculturists, an effort was made to group selected aquaculture literature under some representative themes. Themes developed are (1) traditional aquaculture practices, (2) the emergence of aquaculture development and (3) aquaculture as a bureaucratic intervention. In conclusion, a sketch of the emerging field of aquaculture biotechnology and in particular genetic engineering concludes the chapter.

First, aquaculturists originally characterized fish culture as a subsistence-oriented farming practice (e.g., Edwards et al. 1983). While Edwards et a., (1983) provides a well researched archival account of aquaculture development in Thailand, in most cases aquaculturists tend toward highly anecdotal histories of the origins of aquaculture and early fish culture systems. They use these representations to then situate the rapid emergence of modern industrial aquaculture as a science and a diversified, often corporate, farming practice. Descriptions of early fish culture in Asia, Europe and North America, specific species and culture systems and the development of particular techniques characterize these accounts. Some authors feature the role played by individual scientists and entrepreneurs in the development of aquaculture as a science and industry.

Second, over the past fifty years tropical aquaculture attracted growing development agency interest. Interest in aquaculture was brought on by dramatic post-Second World War changes in world food production. In the 1960s development agencies directed attention to aquaculture because of the widespread perception that agricultural and fisheries resources were encountering a crisis in production and consumption. Development agencies saw aquaculture, especially in the tropics, as a strategic means to supplement world protein shortages. In the 1970s, aquaculture development was accelerated in Asia, introduced into Latin America and renewed in postcolonial Africa under technical assistance projects. However, this strategy of meeting basic human needs was short-lived. By the mid-1980s significant industrial forms of aquaculture production emerged in Asia, Latin America, North America and Europe. Nonetheless, in 1990 the contribution from aquaculture to total fish production has remained relatively insignificant at fifteen million metric tons. Eighty-five percent of aquaculture production came from Asia with China accounting for seventy-five percent of the regional total (AIT 1994; Pullin et al. 1993). In this section, case studies from Thailand and Rwanda illustrate aquaculture development efforts.

Third, I argue that the development of aquaculture has been stimulated by institutional interventions. Extending Bauin's (1986) portrayal of French aquaculture as a "field by bureaucratic fiat" shows that a range of international and national agencies and institutions have attempted to shape the direction of modern aquaculture as a science and development strategy. For example, Auburn University's International Center for Aquaculture (ICA) with sustained USAID support, played a prominent role in early efforts at tropical aquaculture development (Moss et al. 1979). More recently, the Asian Institute of Technology (AIT) in Thailand has taken a lead role in conceptualizing integrated agriculture-aquaculture research, education and outreach in the tropics (AIT 1994; Edwards et al. 1988). Similarly, the World Bank has reviewed tropical aquaculture research and development with the intention of strengthening capability (World Bank 1991a; 1991b; 1991c; 1991d).

In closing, I provide an overview of aquaculture biotechnology and more specifically the recent genetic engineering of aquatic organisms. This intensified research and development effort stands on the brink of far reaching and environmental impacts and social consequences. For these reasons, aquaculture biotechnology and genetic engineering warrants more attention by social scientists. However, the manner in which social science involvements began and continue within the realm of aquaculture development as well as disciplinary divides inhibits thoroughgoing attention, interest and examination. In large measure, this is due to the separation of science and society evident in the approaches undertaken by social scientists *and* aquaculturists.

TRADITIONAL AQUACULTURE: ORIGINS AND PRACTICES

There is no comprehensive history of aquaculture. Anecdotal and convoluted historical accounts, however, are frequently made by aquaculturists about ancient aquacultural farming practices. For instance, Bardach et al. (1972), Bell (1978), Brown (1977), Hickling (1962), Ling (1977), Shell (1993) and Tiddens (1990) all speculate about the origins of fish farming in Asia, North America and Europe, specific species and culture systems, the development of particular sets of techniques and in some instances the pioneering efforts of individual scientists and entrepreneurs. Typically, the aim of these accounts is to introduce reviews, "state of the art" descriptions which usher in contemporary portrayals of modern aquaculture practices, research and development. Another intention is to illustrate aquaculture as a modern science and food production strategy of growing global importance.

Bardach et al. (1972) note that oyster culture was well developed in ancient Rome. Bell (1978), Brown (1977), Hickling (1962) and Tiddens (1990) make similar reference to ancient Roman finfish and shellfish culture along the Italian coast. Brown (1977) adds that the Romans may have developed aquaculture through contact with the Etruscans who learned it from the Phoenicians. In Southeast Asia, Ling (1977:4) states that aquaculture originated in China about four thousand years ago "in harmony with a traditional rural-agrarian economy." In contrast, Bardach et al. (1972:1) suggest that claims about the Chinese origins of aquaculture are speculative, adding that "aquaculture may have even more remote roots in the highly organized ancient water-civilizations of the Near East, in which fish were an important dietary component."

Nonetheless, Ling (1977) credits Fan Lee in the year 500 B.C. with coining the term "aquahusbandry." Early aquahusbandry in China consisted of common carp (Cyprinus carpio), pond culture. Hickling (1962) noted that as early as 2968 B.C., carp culture in China was integrated with silk production. Ling (1977) suggests that Chinese immigrants introduced fish culture, typically carp polyculture, into other parts of Southeast Asia. Both Bardach et al. (1972) and Edwards et al. (1983) confirm this point in describing early carp polyculture efforts by Chinese immigrants in Taiwan 300 to 400 years ago and in Thailand around 1900. Shell (1993) also mentions Chinese influence in extending aquaculture into Japan and Korea.

Shell (1993) states that aquaculture is approximately 3,000 years old. He noted that common carp is not endemic to China and suggests that Central Asia or ancient Europe may predate China in originating aquaculture. Although the exact origin of aquaculture cannot be determined, Shell (1993) suggests that China, Europe and even Hawaii as regions of the world is where various forms of aquaculture may have begun. Early Hawaiian efforts involved coastal mariculture. In Europe, Shell (1993) suggests that carp culture began in the eleventh century and by the sixteenth century there were over 100,000 hectares of fish ponds in Bohemia. Hickling (1962) adds that in Europe fish culture may have been established by monastic houses during medieval times.

Specific Species and Countries

Worldwide there are over two hundred cultured aquatic species (AIT 1994). As previously mentioned, oyster, carp and shrimp culture are many centuries old. However, many aquaculturists highlight more recent efforts in terms of specific species and countries. For example, Su and Liao (1992) review the history of marine shrimp culture in Taiwan. They state that shrimp culture has existed in Taiwan for over three hundred years. Early aquaculturists collected wild milkfish, (Chanos chanos), and some incidental tiger shrimp, (Penaeus monodon), fry from the sea. Both species were then stocked into coastal enclosures which relied on tidal flows to exchange water and add nutrients. According to Su and Liao (1992), the key development in expanding shrimp culture was the successful development of mass propagation techniques for (Penaeus monodon) in 1968 and the development of formulated feed in 1977.

Responding to favorable prices in the Japanese export market, Taiwanese shrimp culture boomed in the 1980s. By 1988, over ninety percent of Taiwanese shrimp culture was intensive and included high stocking densities, formulated feed inputs, frequent water exchanges and aeration. Taiwanese shrimp culture was concentrated in a relatively small coastal land area. The industry, one of the world's largest at that time, collapsed in 1988 due to a severe viral disease outbreak. Since the collapse of the industry, Taiwanese shrimp culture technology and capital has been exported to other areas of Southeast Asia, North America and Latin America (Baird 1993; Skladany and Harris 1995).

Shell (1993: 115-130) discussed the historical growth of U.S. channel catfish, (Ictalurus punctatus), culture. In the Southeastern region of the United States, river channel catfish as a food source had long been realized by early fishers and inhabitants of the region. Pond catfish culture grew out of a confluence of efforts to culture catfish for food, recreation, changes in baitfish farming and a switch by Delta farmers to catfish as an alternative crop. Due to its value as a sportsfish, channel catfish were spawned in hatchery conditions as early as 1892. Shell (1993) notes that in 1934, H.S. Swingle at Auburn University, Alabama began investigations of channel catfish for use as food and in recreational fishing ponds. In Arkansas, the development of pond baitfish culture in the late 1940s included some efforts to produce channel catfish for stocking into farm ponds.

According to Shell (1993), the development of industrial catfish culture came about when large Delta farmers switched from growing cotton and rice to catfish. In the Delta, the clay soils, flat topography, and the presence of the Mississippi River alluvial aquifer provided good soils for pond construction and excellent water quality for aquaculture. Mississippi delta farmers saw catfish as an alternative crop. As a result, the uptake of large-scale catfish culture expanded rapidly in the 1960s in Arkansas, Mississippi and western Alabama. Processing plants were also started at this time. Systematic research on catfish culture was established in the mid-1950s at the University of Oklahoma, Auburn University, the U.S. Bureau of Sport Fishing and Wildlife fish farming station at Stuttgart, Arkansas and the Southeastern Fish Cultural Laboratory at Marion, Alabama. At present, catfish is the largest aquaculture industry in the United States and ranks eleventh among finfish cultured worldwide (Shell 1993).

Culture Methods

Some aquaculturists organize accounts of aquaculture development by highlighting particular culture systems. Ling (1977) described cage culture in Southeast Asia as beginning when fishers attempted to keep surplus catch alive for market. Hickling (1962) discussed wooden cage culture of Asian river catfishes (Pangasius spp.), in pre-war Cambodia. Bardach et al. (1972) devote chapters in their classic Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms to detailed descriptions of pond culture for species such as common carp, Chinese and Indian carps, marine shrimps, trouts, milkfish, tilapias, catfishes, black bass, sunfish, perch, pikes and frogs. Moreover, Bardach et al. (1972) described cage culture of channel catfish, Asian river catfishes, salmon and yellowtail. Bardach et al. (1972) extend their coverage to include descriptions of crayfish, prawns, marine crabs, oysters, clams, cockles, scallops, mussels, abalone and seaweed culture. For each species, Bardach et al. (1972) also review what was known at that time about hatchery breeding techniques. They also add a chapter on aquaculture economics and an appendix on pond construction. Hickling's (1962) classic, Fish Culture, covers all known aspects of pond culture at that time including water quality, soil types, pond construction techniques, pond management practices, fertilizer applications, feeding rates, stocking ratios and production yields. Hickling (1962) devotes chapters to fish culture in running water, rice-field fisheries, cage culture, genetics, fish diseases and public health. Examples for each chapter are derived from Asia, Africa, Europe and North America and from Hickling's tenure as Acting Director of the Tropical Fish Research Institute in Malacca, Malaya (Malaysia).

Due to the plethora of different culture systems and practices, aquaculturists have developed biological classification schemes based on relative levels of intentional nutrient inputs and more broadly, magnitudes of modification and control over the culture environment (AIT 1994; Aquatic Farms Limited 1989; Bardach et al. 1972; Edwards et al. 1988; Pullin 1993; Shell 1993). Although there are exceptions (e.g., Donaldson 1994; Schmittou et al. 1985), aquaculturists generally classify production systems into three biological categories: extensive, semi-intensive and intensive. In each classification scheme both yield and risk increase as production moves from extensive to intensive forms.

Extensive aquaculture refers to production systems which exhibit relatively little, if any, modification and control over the culture environment. An example is early milkfish-shrimp culture in Taiwan involving harvest of wild fry and stocking into coastal enclosures (Ling 1977; Su and Liao 1992). There is little management and no intentional nutrient inputs used in these systems. Semi-intensive aquaculture exhibits some directed modification and control over the culture environment. An example is Delta catfish culture in the United States (Shell 1993). Stocking of hatchery produced fingerlings, fertilization, supplemental feeding, aeration of pond water and skilled management are required. Intensive aquaculture strives for total modification and control over all aspects of the culture environment. An example is the mid-1980s shrimp culture practiced in Taiwan (Su and Liao 1992). High stocking rates, frequent water exchange, high levels of supplemental feeding, aeration and scientific management are required in intensive aquaculture systems.

The Development of Specific Techniques

A few authors provide historical summaries of the development of specific techniques. For example, Woynarovich and Horvath (1984:181) list "milestone" dates in the development of fish breeding. They begin with Jacobi's (Germany) stripping and artificial fertilization of trout eggs in 1767 noting that Remy and Gehin (France) "rediscovered" this technique in 1842. In 1934, R. Von Ihering (Brazil) was credited with developing techniques for inducing fish to spawn through the use of pituitary extracts from "donor" fish.

Induced spawning through hormonal injection was a turning point in the development of fish breeding and subsequently farming. The focus of fish breeding shifted almost exclusively to the application of biological materials in order to induce fish to spawn in controlled hatchery conditions. A variety of cultured fish were successfully propagated through induced spawning and included Indian carps in 1957, channel catfish in 1957 and Chinese carps in 1960-61 (Woynarovich and Horvath 1984). In a broad sense, fish breeding through application of different hormonal injection techniques represented some of the first applications of biotechnology in fisheries and aquaculture (Kapuscinski and Hallerman 1994).

Science, Scientists and Entrepreneurs

In Aquaculture in America, Tiddens (1990) portrays individual U.S. scientists and entrepreneurs as developing aquaculture in the United States. Tiddens (1990) traces the development of aquaculture science to late nineteenth century efforts made by U.S. marine biologists such as Spencer Fullerton Baird, the first U.S. Fish Commissioner. Baird created the Marine Biological Station at Woods Hole, Massachusetts a leading marine biology research center. According to Tiddens (1990: 40), "Baird's efforts provided the impetus and structure around which much of the fisheries knowledge of the 20th century would be built." From these efforts, Tiddens (1990) described the growth of U.S. marine biology in the post World War Two era. Eventually, marine biologists "viewed their research as aquaculture related and by the late 1970s several institutions offered aquaculture programs" such as the University of California at Davis, the University of Miami and the University of Hawaii (Tiddens 1990:41).

As graduates left aquaculture programs, Tiddens (1990) claims that unlike agriculture, many of these scientists turned entrepreneurs formed private aquaculture companies. According to Tiddens (1990:46), the "discovery" of oyster culture techniques is "an excellent example of science transforming an industry." Tiddens (1990: 46-50: 155-156) describes oyster culture in the United States in terms of the careers of individual scientists such as Herbert Prytherch at the U.S. Bureau of Fisheries laboratory in Milford, Connecticut. In particular, Tiddens (12990) claims that the U.S oyster industry can be traced to Victor L. Loosanoff who succeeded Prytherch at the Milford laboratory. As Tiddens (1990: 48) puts it "over some 40 years his [Loosanoff's] work on all aspects of oyster growth and culture essentially established the industry." Finally, Tiddens (1990) attempts to draw the connection that early research into oyster culture enabled one private oyster hatchery in California to develop techniques to produce single and unattached oyster larvae, clutchless "spat," which made oyster seed widely available for growers on both U.S. coasts in the mid-1970s.

In sum, regardless of region of origin or species cultured, aquaculture has been a highly localized and relatively minor global food production activity. The growth of modern aquaculture as a science and industrial food production system however, represents a significant shift towards globalization and standardization of the principles and practices associated with these earlier localized situations. The science of aquaculture and its contemporary farming practices are emerging out of a confluence of diverse social contexts, resource configurations and local practices. Aquaculturists organize development stories by separating science and society. They feature culture systems, species and techniques to account for the diffusion of aquaculture practices. In order to account for the diffusion of non-humans in society, they often attribute the growth of aquaculture to individual scientists, entrepreneurs, discoveries or ideas. This view mystifies science by stripping away social context, power relations and resource use in which science, including aquaculture, takes shape (Harding 1991). Thus it is important in Harding's (1991) words to "seek social context" when examining the development of science and society.

More inclusive in terms of social context is a pattern which accounts for the growth of aquaculture: in societies which are linked to substantial water resources, aquaculture has emerged from social organizational forms associated with capture and in some cases recreational fisheries; in societies with limited water resources, aquaculture has often been an externally imposed or an introduced agricultural activity by colonialists and more recently development agencies. The emergence of aquaculture development projects in the 1960s and 1970s was brought on by international aid agencies that accelerated efforts in Asia, introduced the activity into Latin America and renewed it in parts of postcolonial Africa. In temperate countries, aquaculture emerged from earlier developments in capture and recreational fisheries as a science based industry. The next three sections illustrate aquaculture development and examples drawn from Thailand and Rwanda.

THE EMERGENCE OF AQUACULTURE DEVELOPMENT

In the post Second World War era world food production underwent dramatic global change. The advent of the Cold War, national liberation movements, increased population growth, state consolidation, and widespread food shortages instigated the search for new markets, food sources and intensified production techniques. In this post-war political economic milieu, the modern science of aquaculture gradually began to take on global shape highlighted by the first world meeting on aquaculture organized by the FAO in 1976 (FAO 1976). Key to the formation of modern aquaculture were concurrent industrial resource exploitation efforts in capture fisheries and agriculture. As a consequence, aquaculture technoscience development were incorporated into more pronounced organizational roles in world food production. Initially, international development agencies were key catalysts in staging this strategic transformation.

In part, aquaculture development was brought on by perceptions of insufficient protein availability inland and that the world's fish supplies were rapidly approaching finite limits (FAO 1976). In the 1950s there was little awareness of the growing severity of these constraints. Shell (1993:117) captures U.S. thinking on these matters in the late 1950s

> no one really appreciated or could imagine the potential of aquaculture. There was little concern for world population growth, and certainly no one . . . . could foresee how increased exploitation would affect the harvest of fish from the oceans.

In the 1960s, the "Green Revolution" attempted to address world food problems by packaging and increasing agricultural production (Cleaver, 1972; Hayami and Ruttan 1985). The Green Revolution was a research derived package of agricultural inputs such as irrigation, inorganic fertilizers, pesticides, high-yielding rice, wheat and corn varieties and mechanization (Busch et al. 1991; Cleaver, 1972; Hayami and Ruttan 1985). The intention was to increase agricultural productivity so that food self-sufficiency could be attained in areas which were experiencing food deficits. Despite some rapid production increases, the Green Revolution failed to live up to expectations (Scott 1985; Shell 1993; Smith and Peterson 1982). Improved strains were often monocropped and eliminated local varieties which provided for other essential community needs. Traditional labor patterns were disrupted due to outside ownership, consolidation of fields and mechanization of harvest (Busch et al. 1991; Scott 1985; Smith and Peterson 1982).

Parallel to inland agricultural efforts was a corresponding "Blue Revolution" in marine fisheries. In the 1950s tropical maritime nations began industrializing their fishing fleets (Alexander 1975; Bailey et al. 1986; Bailey et al. 1987; Bailey 1988; Chua 1986; Menasveta and Matics 1980; Panayoutou and Jetanavanich 1987). At this time oceanic fisheries stocks were thought to be unlimited but beyond the reach of traditional non-mechanized fisheries. In particular, the development of mechanized fisheries and industrial-scale fisheries organizations led to initial production gains only to quickly reach finite biological limits for wild fish stocks (Bailey 1988; Finlayson 1994; Hongskul 1987).

As in the Green Revolution, the industrialization of marine fisheries has been attributed to increased conflict in numerous fisheries sectors around the world (Bailey 1988;

Pollnac 1981; Pollnac and Poggie 1991; Smith 1979). These polarized conditions were further exacerbated by the imposition of Exclusive Economic Zones in the mid-1970s (Christy 1980; Chua 1986; Panayoutou and Jetanavanich 1987). At present, the world's fish stocks are heavily exploited, overfished and at near capacity in terms of production limits (Finlayson 1994). The view at this time shifted to aquaculture as a means to increase global production of aquatic organisms to meet growing global demand.

Given the uneven developmental impacts associated with the Green and Blue Revolutions, development agencies expanded upon aquaculture as a means to partially alleviate protein 2shortages and income differentials in the tropics (ADCP 1976; FAO 1976; Nakamura 1985). For development agencies, aquaculture offered strategic food production venues. In the next two sections, aquaculture development examples from Thailand and Rwanda provide a comparative basis to characterize tropical aquaculture development. These two countries exhibit common as well as unique features with respect to aquaculture development. However, both examples illustrate the social contexts of how aquaculture development unfolded in diverse environmental settings.

Aquaculture Development in Thailand

Despite aquaculturists' claims about "the long tradition" of aquaculture in Asia, Thailand possessed very little fish culture before the mid-twentieth century (AIT 1994; Edwards et al. 1983; Shell and Lovell 1973). From 1923 to 1935, a U.S. scientist from the Smithsonian Institution, H.M.Smith studied the fisheries fauna of Thailand and served as the first adviser to the Thai Department of Fisheries (DOF)(Edwards et al. 1983; Smith 1945;

Wongratana 1991). After the Second World War, Food and Agricultural Organization (FAO) missions visited the country to investigate fisheries resources. In 1951, technical assistance to Thailand was provided by the FAO to develop inland fisheries due to the importance of fish in the Thai diet (Edwards et al. 1983). In 1957, H.S. Swingle from Auburn University, Alabama worked with the Thai DOF. Swingle's (1957) trip report provides a fascinating view of Thai fisheries during that period.

In identifying "important fisheries problems in Thailand" Swingle (1957) made a preliminary assessment of the fisheries resources in the central Chao Phyra River basin with particular attention to the environmental impacts of dam construction on river and flood plain fish populations. Swingle (1957) suggested that surveys be conducted on inland fish populations and on the number of fishers. Survey work would enable a clearer assessment of the environmental impacts of dams and fishing effort on river and flood plain fish stocks. Swingle (1957) also recommended that large drainable-swamps be studied as these were important subsistence fisheries. With a view to developing management guidelines, Swingle (1957) anticipated irrigation reservoir and village pond construction and encouraged stocking of hatchery produced fish as a means to enhance natural productivity.

With respect to aquaculture, Swingle (1957) recommended considerable attention be devoted to developing culture of freshwater prawns, (Macrobrachium spp.), and Asian river catfishes, (Pangasius spp.), in ponds. Swingle (1957) suggested intensive study of indigenous Thai species such as Leptobarbus, Catlocarpio siamensis, Pangasius laurnaudii, Clarius spp., and Mystus nemurus for aquaculture. In ensuing years, the walking catfish, (Clarius spp.), freshwater prawns, (Macrobrachium spp.), and Asian river catfishes, (Pangasius spp.), achieved industrial culture proportions in Thailand (Bardach et al. 1972; Brown 1977; Panayotou et al. 1982; Edwards et al. 1983). Swingle (1957) also identified inland rice-fish culture of carps and tilapia and pond culture of marine shrimps as potential aquaculture activities for food and income purposes.

By the early 1970s, Thailand trip reports by Swingle and Moss (1968), Swingle and Smitherman (1969), Swingle et al. (1969), Swingle et al. (1970), Swingle and Allison (1971), Swingle and Shell (1972) and Shell and Lovell (1973) reveal three significant changes in the overall composition of Thai fisheries development. First, the United States Overseas Mission-Agency for International Development (USOM-AID) began supporting technical assistance to the Thai DOF by Auburn University's recently established International Center for Aquaculture (ICA). Second, the focus of these early efforts clearly shifted to inland aquaculture development during this period. Third, USOM-AID would support creation of a Thai DOF research and extension base to identify suitable culture methods, breeding techniques, formulation of fish feeds, and the establishment of laboratories for fish diseases and parasites. During this period, Auburn scientists conducted short-term training in country and proposed that selected Thai DOF biologists receive advanced M.Sc. and PhD level training at Auburn University.

The presence of a substantial USOM-AID mission in Thailand reflected the escalating U.S. war in Vietnam (Chareonsin-o-larn 1988). A number of Thai provinces became major staging areas for the massive U.S. air war in Vietnam, Laos and Cambodia. Internally, Thailand experienced widespread political unrest during this period (Anderson 1991; Chareonsin-o-larn 1988). Within this contested political economic terrain, the Thai state attempted to consolidate control over an unstable countryside. In essence, USOM-AID accelerated Thai rural development, including fish culture, as part of broader counter-insurgency strategies and a means to strengthen central government presence in rural areas deemed "sensitive" (Anderson 1991; Chareonsin-o-larn 1988; USAID 1994).

As a consequence of these political economic concerns by the Thai state, fisheries projects shifted to inland aquaculture development. Inland areas were greatly constrained in terms of meeting basic food needs and bypassed by increased marine fisheries production which entered urban and export markets. Moreover, Swingle and Moss (1968) anticipated the growing impacts of dam construction and industrialization which would result in reductions of river and flood fisheries stocks. They suggested that more Thai DOF effort be applied to fish culture production. Swingle and Moss (1968) recommended major facilities expansion at all fifteen of Thailand's freshwater fish stations for pond production purposes. Clearly, the rise of Thai aquaculture was closely tied to the political and social conditions in the country.

Swingle and Smitherman (1969) reviewed DOF activities at six brackishwater and marine fisheries stations. Despite rapid production growth in marine capture fisheries and a DOF effort on marine fisheries technoscience at this time, their recommendations exclusively focused on identifying potential marine aquaculture species and culture systems. At this time, the overall effort devoted to coastal aquaculture in Thailand was minimal due to more pressing political concerns inland. Swingle et al. (1969; 1970) proposed accelerated efforts inland with respect to construction of village fish ponds, development of practical fish culture methods, intensified research on finding the best ways to increase fish production, a fellowships program, establishing formulated feed, building a disease laboratory and the upgrading of all inland department stations for pond based research.

At this point USOM-AID was supporting extensive Auburn University involvements in Thai fisheries. Trip reports by Swingle and Allison (1971), Swingle and Shell (1972) and Shell and Lovell (1973) all show an increasingly strong turn towards Thai aquaculture development. For instance, Swingle and Allison (1971) recommend expanded USOM-AID support for village fish ponds through the use of war-surplus construction equipment. Moreover, a set of species and culture systems were identified which became the basis for inland aquaculture production. Extension services were emphasized. In terms of research, Shell and Lovell (1973) reviewed many divergent research aspects of inland Thai fisheries development. They stressed better experimental design and coordination at the research stations as well as concerted research effort on fish culture, nutrition, processing, and enhanced fisheries management of large reservoirs and village ponds.

Thailand trip reports by members of Auburn's ICA reflect similar themes and efforts at Asian aquaculture development initiated by other agencies. In particular, the Aquaculture Development and Coordination Programme (ADCP) of the Food and Agriculture Organization of the United Nations undertook a broad review of Asian aquaculture development, including Thailand, in the mid 1970s (ADCP 1976). Although Asia accounted for eighty percent of the world's aquaculture output, overall mean production was relatively low and largely consisted of subsistence production by small-scale producers. Some countries however, were beginning to promote commercial scale aquaculture of marine shrimp and freshwater prawns. Along these lines, the ADCP (1976:5) identified cooperatives where the "small farmer will continue to be the backbone of the aquaculture industry" as important development catalysts for establishing large-scale aquaculture ventures.

In summarizing Asian aquaculture development, the ADCP (1976) noted that much like agriculture, increases in aquaculture production were being achieved through expansion of cultivation areas and intensification of production techniques. In summarizing constraints in Asia, the ADCP (1976:3) stated that, "well organized extension services and provision of inputs and credit" were lacking in the region. Moreover, the lack of adequate production and distribution of seed was considered another significant obstacle. In conclusion, the ADCP (1976) stressed the need for accelerated training, planning, research and the establishment of a regional center for investigation into all aspects of aquaculture.

In Thailand, other international agencies such as the Canadian International Development Agency (CIDA) also undertook fisheries and aquaculture development projects. The centerpiece of the Canadian effort was the creation of the National Inland Fisheries Institute (NIFI) in the mid-1970s. Allsopp (1985) has evaluated this project. According to Allsopp (1985:94) the purpose behind building NIFI was a need "for comprehensive staff training to improve biological investigations that addressed national priorities." Allsopp (1985) devotes the majority of his discussion to describing physical inputs, outputs and effects attained by this institute. Surprisingly, Allsopp (1985) assessed the impacts of NIFI exclusively around contributions to inland capture fisheries development and traditional pursuits in fisheries taxonomy, parasitology and aquatic ecology. In Allsopp's (1985) view, fish culture seems to have only played a secondary role. Allsopp (1985:98-99) evaluated NIFI as an institute which:

> enjoys regional and international prestige. It has attracted aid from donors and international investment agencies that have not previously supported fisheries projects in that country. The institute has provided the basis for national policy decisions on inland fisheries and their relationship with national fisheries. The trainees, fish, feed-formulae, and services are used throughout the country and its work . . . has spread through many stations in the country.

However, a profound shift in the bureaucratic orientation of Thailand's DOF in the late 1970s led to a Thai-directed informal reorganization of NIFI away from "biological investigations that addressed national priorities" towards accelerated inland aquaculture development in impoverished rural areas (ADB 1985). Quite literally, NIFI wet labs were changed into development planning and operations rooms almost overnight. The case in point which best captures this abrupt shift in Thai development dynamics was the massive Village Fish Pond Project (VFPP).

The rural development ideas behind village fish ponds in Thailand had been proposed over a number of years. Swingle (1957) referred to the concept and subsequent Auburn/USOM-AID trip reports (e.g., Swingle and Moss 1968; Swingle et al. 1969: 1970; Shell and Lovell 1973) identified "village fish ponds" as a potential project for rural and impoverished inland areas of Thailand. Essentially, the Thai DOF oversaw local contracting for the construction or upgrading of large fish ponds next to villages. A group of villagers were selected and made responsible for all aspects of pond management. Other agricultural and livestock activities were encouraged at the pond site. DOF staff provided fish for stocking and extension advice. After the fish had grown villagers would pay a fee to harvest the fish. Monies generated were utilized for village based development purposes including the refurbishing of the pond.

In 1977 a joint Thai-Canadian effort built two village ponds and stocked them with fish but shortly thereafter discontinued the project (USAID 1981). The VFPP was then picked up by USAID as a pilot project in 1979. USAID financed the construction of fourteen village fish ponds in twelve northeast provinces of the country in order to "improve the nutrition and quality of life in these rural communities" (USAID 1981:1). In 1981 a Thai-American evaluation team found that "in broad economic and social terms the VFP is having less impact than was anticipated, due, in part, to the fact that the project was over-designed and lacked strong management" (USAID 1981:1). Furthermore the USAID evaluation team (1981:1) surmised that "welfare of the villagers, as indicated by increased incomes from greater production and sale of fish, garden and orchard crops, livestock and surplus rice has not improved significantly as a result of the VFP."

In short, the early VFPP was roundly criticized in numerous evaluation studies (Calavan 1986; Schmittou and Cremer 1980; USAID 1981). Calavan (1986:103) noted "mixed results" and in particular pointed to "lessened capacity for natural resource management" on the part of villagers. In the VFPP scheme, villagers were recipients of a top-down project which undercut well-established village work patterns and collective organization. Villagers often expressed dissatisfaction with the VFPP complaining that local contractors designed the ponds poorly and then overcharged for construction (Calavan 1986). In terms of the VFPP, Schmittou and Cremer (1980) from Auburn's ICA severely criticized DOF's planning, management, coordination, limited field support, poor site selection and pond construction techniques. They felt that aquaculture development in Northeast Thailand was limited due to an unsuitable environment, low-technology and a low farmer economic base. As a result of these studies USAID terminated support for the VFPP (USAID 1981).

The Thai DOF was greatly stung by these criticisms. In short order, however, the Thai DOF reacted by enrolling numerous other donors and central Thai government sources to fund aquaculture development including an expanded VFPP. In the 1980s a succession of donors such as the Asian Development Bank (ADB), Canadian International Development Agency (CIDA), The Japanese International Cooperation Agency (JICA), the Japanese Overseas Economic Cooperation Fund (OECF), the British Overseas Development Agency (ODA), Thai banks and the central Thai government all directly funded Thai aquaculture development projects. A significant portion of these donor commitments went to an expanded VFPP making it one of the largest development projects in the country. From 1976 to 1984, at least $U.S. 106 million was committed by foreign donors to Thai fisheries and aquaculture development (ADB 1985). Largely centered at NIFI, where an informally constituted Inland Fisheries Development Operations Center (IFDOC) managed all foreign projects, this revolving door atmosphere of foreign aid effectively ended USAID and Auburn's ICA as the major force in Thai aquaculture development.

At present, development impacts of the Thai VFPP remain mixed in terms of improving village nutrition and the quality of life (Chantarawarathit 1989; Sai-ngarm 1988). Chantarawarathit (1989) reports that a lack of villager participation in the VFPP has led to little concern for long-term pond management and only short-term interest in immediate gains (e.g., fish harvest days). Sai-ngarm (1989) concludes that over centralization of decision-making, lack of villager participation and the lack of bottom-top communication remain major obstacles in the VFPP. Sai-ngarm (1989) adds that the VFPP is technically complex because of the level of inputs and pond management required and has numerous design and administrative deficiencies. However, both sources recognize that the VFPP stimulated private efforts at fish rearing and has become institutionalized in the Thai DOF.

As Thailand accelerated modernization efforts in the mid-1980s aquaculture was identified as a private investment strategy. Thai aquaculture grew substantially during this period through private sector and transnational corporate initiatives. In inland areas integrated aquaculture-agriculture, seedfish hatcheries, and rice-fish culture received increased attention from numerous foreign donors, central Thai line agencies and farmers. Moreover, non-government organizations and agro-industrial companies became increasingly active in aquaculture (AIT 1994; Edwards et al. 1988; Engle and Skladany 1992; Fedoruk 1985; Little et al. 1987; Tomich 1988).

A 1985 ADB Thailand fisheries sector study built on an earlier strategic report on international shrimp markets (ADB/FAO 1983). The 1985 ADB study identified a broad range of fisheries and aquaculture development investment strategies. In particular, attention was focused on investment in coastal aquaculture and especially shrimp culture (ADB 1985). The ADB study laid out the groundwork for industrial forms of aquaculture which was captured in the explosive growth of coastal shrimp culture in the late 1980s. Complementing the Bank's view was Thailand's relative political-economic stability, liberalized foreign investment incentives and the call for more private sector involvement in national development plans (Anderson 1991; Heim et al. 1986).

The expansive growth of Thai coastal shrimp culture occurred during the late 1980s and continues to overflow into neighboring countries. A decade earlier, multilateral and bilateral lending agencies such as the World Bank, ADB, and JICA undertook multi-million dollar shrimp culture projects (ADB 1985). In the early 1980s, pond shrimp from these projects came from extensive systems and total production was relatively insignificant when compared to the marine harvest (ADB 1985). However, these extensive operations were highly profitable and loans were quickly repaid by farmer-clients to Thai banks (ADB 1985). By the mid-1980s, entry into shrimp farming by large transnational corporations, consulting firms and individual entrepreneurs brought Thailand to the forefront of global shrimp culture production. Pond cultured shrimp grew from 10,000 metric tons in 1980 to 110,000 metric tons by 1990 (United States Department of Commerce 1992). At present, Thailand ranks as the largest producer of pond raised shrimp with 250,000 metric tons or 30% of global pond production (Goss et al. 1999).

Transnational firms such as the Thai agro-industrial Charoen Pokphand Group and the British Petroleum-Aquastar company brought new forms of industrial organization to coastal shrimp production (Goss et al. 1999; Skladany and Harris 1995). Both firms employed vertically integrated agro-industrial organization to produce pond shrimp for export. In essence, much like the previously described "Blue Revolution," multilateral and bilateral aid agencies acted as catalysts which stimulated private investment and hyper-intensive capitalist reorganization of coastal property, production and social relations. The rapid growth in Thai shrimp culture reflected high world demand and the 1988 collapse of the shrimp culture industry in Taiwan (Baird 1993; Lin 1989; Su and Liao 1992). As a consequence, Taiwanese investors brought intensive production technologies and capital to Thailand's shrimp culture industry (Baird 1993; Skladany and Harris 1995).

In part, the Thai DOF has benefitted from export-oriented shrimp culture in terms of new infrastructure, increased staffing and fiscal recognition from the central government. The Thai DOF however, contends with the aggressive efforts of the private sector in directing the industry. The Thai DOF has been forced to develop enforcement measures to regulate the industry which brings it into conflict with other Thai line agencies, private corporations and producers. In one highly controversial case, a private company undertook an unprecedented coastal land reorganization scheme in order to consolidate contract farming efforts to optimize shrimp pond production (Petrocci 1992; Srisuksai 1990).

In conclusion, Thailand has followed a dual aquaculture development policy (Suraswadi 1987; 1989). Generally, inland aquaculture is viewed as rural development in order to supplement nutrition and income. A general shift to more semi-intensive production characterizes diverse aquacultural farming practices in all inland regions of the country (AIT 1994). In coastal areas, some finfish (e.g., sea bass, grouper) but mainly shrimp are primarily viewed as export commodities (Suraswadi 1989). The Thai DOF is faced with long-term environmental and social problems associated with the rapid growth of largely uncontrolled shrimp culture (Aquatic Farms Limited 1989; Baird 1993; Goss et al. 1999; Skladany and Harris 1995; United States Department of Commerce 1992; World Bank 1991b)). Large areas of mangroves and adjacent agricultural lands have been destroyed by shrimp farming, multi-purpose coastal resource use has been eliminated, communities have been disrupted and the ecological integrity of coastal zones has been permanently altered (Baird 1993; Sirisup 1988; Skladany and Harris 1995).

On one hand, efforts to regulate shrimp culture have largely failed and as a result Thailand has encountered mounting environmental and social costs associated with this particular form of industrial aquaculture (Baird 1993; Skladany and Harris 1995; World Bank 1991b). On the other hand, shrimp culture has catapulted the Thai DOF into prominent new national policy and project configurations which involves establishing national laws prohibiting the cutting of mangroves, reforesting depleted coastal mangrove areas and improving water systems for shrimp ponds in established cultivation areas (Shrimp Farming International 1995).

Aquaculture Development in Rwanda

In contrast to Asia and Thailand, Sub-Saharan African aquaculture is best characterized as an externally driven activity (World Bank 1991d). Overall, aquaculture development in much of Sub-Saharan Africa and in particular, Rwanda, is greatly limited due to combinations of environmental constraints in terms of water resources, altitude and/or temperature (Balarin 1988). Moreover, continuing political strife, war, genocide and massive refugee movements in Rwanda and outside it have severely affected future prospects for national development, let alone aquaculture, which is best seen as marginal in the country and region. Nonetheless efforts to promote aquaculture in Sub-Saharan Africa have existed for at least one hundred years and continue at present despite very uneven results (Christensen 1995; Costa-Pierce et al. 1991; Harrison 1991; New 1991; World Bank 1991c). In Rwanda, aquaculture was introduced by Belgian colonialists in the 1920s who attempted to establish practices employed in the Congo (Hatch and Hanson 1991; Hishamunda and Moehl 1989). Although inaccurate, colonialists viewed fish culture as a means to increase rural labor efficiency by creating a rural food supply. By the 1950s over two thousand small ponds had been constructed through coercive measures (Hatch and Hanson 1991; Shell 1993). Moreover, the colonial administration built a series of fish stations to be used for stocking of natural bodies of water and fish ponds. As in other parts of Sub-Saharan Africa, by 1960, most of these facilities had been abandoned or were barely functional (Bardach et al. 1972; Grover et al. 1980; Harrison 1991; Hishamunda and Moehl 1989; Kalinga 1991).

In the postcolonial era, fisheries and aquaculture development efforts in Sub-Saharan Africa were renewed by international development agencies such as the FAO, Canada's International Development Research Center (IDRC), the Swedish International Development Agency (SIDA), the Norwegian Agency for International Development (NORAD), ICLARM and USAID (Harrison 1991; Hishamunda and Moehl 1989). From 1980 to 1990, over $U.S. 140 million was spent on five hundred aquaculture projects in Sub-Saharan Africa by various donors (Costa-Pierce et al. 1991; Harrison 1991). Nonetheless, total African aquaculture production remained negligible amounting to about one percent of global production (Harrison 1991).

By 1960, aquaculture was dormant in Rwanda. Reasons given were that aquaculture was forced upon Rwandans during colonial times, fish consumption was not widespread, there was a lack of trained personnel and a lack of technical understanding existed on the part of farmers (Hishamunda and Moehl 1989; Shell 1993). Of the few ponds operational at this time yields were very low (Hatch and Hanson 1991). In 1967 and 1975, the FAO conducted appraisals of Rwandan fishery resources in the Lakes region of the country. Although oriented towards capture fisheries these projects consisted of some aquaculture activities including experiments on cultured species and estimates on the potential for fish culture (Hishamunda and Moehl 1989).

Outside of the Kivu and Ihema lakes regions of Rwanda, fish were not part of rural food consumption (Shell 1993). In 1978, the Canadian IDRC initiated a fisheries development project which contained some aquaculture activities such as fingerling production and diet studies. In 1980, the FAO undertook a USAID funded study to explore the potential for small-scale aquaculture development. This study concluded that there was some interest in fish culture on the part of Rwandan farmers. A lack of extension personnel and appropriate aquaculture techniques suitable to Rwanda's high altitude environment were considered major constraining factors (Hatch and Hanson 1991). The Rwandan government's ability to provide these services as well as adequate seed supplies was also extremely limited (Hatch and Hanson 1991).

In 1983 the Government of Rwanda (GOR) and USAID launched a five year aquaculture development project entitled the Rwanda National Fish Culture Project (RNFCP). Pre-project conditions in 1982 showed 1,492 fish ponds amounting to 120 hectares and twenty-six government stations with 276 ponds totaling 70 hectares (Hatch and Hanson 1991; Hishamunda and Moehl 1989). Fish yields were very low and many government stations were in a state of disrepair. In the RNFCP, Auburn University's ICA was contracted to provide long-term in-country technical assistance to establish a trained aquaculture extension service, develop appropriate pond management practices, refurbish six regional fish stations and increase aquaculture production in rehabilitated ponds as well as accelerate the construction of new ponds (Hatch and Hanson 1991; Hishamunda and Moehl 1989; Shell 1993).

In general, attempts at fish culture in Rwanda take place at altitudes between 1,000 and 2,500 meters. The high altitudes, low temperatures and mountainous terrain found at these sites all act to greatly limit primary pond productivity. The major cultivated species, Nile tilapia, (Oreochromis niloticus), does not reproduce at higher altitudes. Moreover, tilapia growth is slow and off-farm inputs such as feed are extremely limited. Moreover, high fuel costs greatly constrains transportation. Subsistence farming practices take place on private hillside plots and involve mixed crops and livestock. The average farm size is a little over one hectare. In contrast, fish culture takes place on public lands located in valley bottomlands. While hillside farms are private property, public bottomland use is allocated by local administrators who attempt to maximize land use among a high density subsistence farming population.

The RNFCP staff attempted to overcome these obstacles by obtaining the highest possible production utilizing the lowest possible inputs. Over the project period (1983 to 1988) the expatriate Auburn staff modified existing pond management techniques by reducing continuous flow of water into and out of fish ponds to raise water temperatures, identifying on-farm inputs for composting and importing a pure strain of Oreochromis niloticus from Auburn University for seed production and farmer cultivation. In addition, the RNFCP trained extensionists, and farmers rehabilitated six government fish stations. Extensionists were subsequently supported in the field through the provision of bicycles, short-term training and equipment. A national center for fish culture at Kigembe was also established which involved large integrated livestock/aquaculture demonstration ponds as well as training facilities (Hishamunda and Moehl 1989). The project also established a data base on all farmer ponds.

The RNFCP staff attempted to quantify results of the project and it is through these measures that claims about the "success" of the project were created and vigorously promoted up to the present (e.g., Moehl and Molnar 1995; Molnar et al. 1995). In sum, the RNFCP provided extension support to groups and owners of 1,582 rehabilitated farm ponds and 661 new ones covering an area of about 60 hectares. By following project established guidelines, average fish production was reported to increase from 340 kilograms per hectare per year to 1,450 kilograms per hectare per year (Hishamunda and Moehl 1989). Improvements were made at six regional fish stations and managers, extensionists and extension supervisors were trained during the project period (Hishamunda and Moehl 1989). In conjunction with the RNFCP, another USAID supported research project, the Pond Dynamics Aquaculture Collaborative Research Support Program (PD/A CRSP) was initiated in 1982 until forced to terminate in April of 1994 (Hanson et al. 1988; Hishamunda and Moehl 1989; Moehl et al. 1988; Moehl 1993; Molnar et al. 1995; PD/A CRSP 1992).

Aquaculture development in both Thailand and Rwanda was stimulated by foreign development agencies who initially identified the strategic political importance of fish in terms of supplementing national diets. They then linked these applied strategies to national development policy formations. Although there are enormous differences in scale, in both countries early aquaculture development efforts have singularly focused on defining, organizing and engineering a social context for increased fish production through aquaculture.

In Thailand, aquaculture emerged out of finite natural resource limitations brought on by rapid modernization and economic development of capture fisheries and agriculture. With fish as a staple food source for rural populations aquaculture became strategically important but was further modified into broader rural development, private investment and export commodity organizational forms. Guiding these transformations was a modern capitalist Thai state which in conjunction with aid agencies and the private sector provided the necessary social and economic organizational infrastructure to complement the relative growth of aquaculture. The results from these efforts, as the examples of village fish ponds and costal shrimp culture have shown, have been mixed with shrimp culture in particular posing enormous environmental and social costs.

In contrast, Rwandan aquaculture emerged as an externally driven activity and efforts to sustain it were largely directed by foreign donors. Although Rwanda faced severe natural resource limitations, fish were never a staple food source and the total area devoted to, and production from fish culture is negligible in comparison with capture fisheries and more vital subsistence agricultural food systems. In short, aquaculture development in Rwanda has taken place in a donor generated vacuum best exemplified by fragmented and wavering pre-1994 support from the GOR and rural populations. As a consequence, aquaculture tends to oscillate between periods of project-driven activity and post-project dormancy. The dissolution of the social and economic infrastructure brought on by the genocide of 1994 will further accentuate this development legacy far into the foreseeable future.

There is no concise or definitive history of Thai and Rwandan aquaculture development. In both Thailand and Rwanda the dominant modes of aquaculture development discourse are embedded in project documents, working papers, and project evaluations. In these technical documents there are four common assumptions that guide development:

(1) that protein deficiencies in inland rural areas can be addressed through aquaculture production,

(2) that aquaculture fits into agricultural systems and farmers are willing to adopt the activity,

(3) that government and farmers require appropriate organizational forms, resources and policies to establish aquaculture, and

(4) beneficial potentials and impacts of aquaculture development can be measured through surveys and project evaluations.

Rhetorically, aquaculturists advocate that the activity can address inland protein deficiencies while the reality in both Rwanda and Thailand clearly shows that cultured aquatic products overwhelmingly enter into urban and/or international export markets.

For example, the RNFCP and the recent Rwandan PD/A /CRSP illustrate these assumptions which assert highly beneficial aquaculture development impacts in the country. In brief, expatriate project staff created a centralized data base. The number and characteristics of ponds, inputs and operators, and multiplier effects are used to claim that 978 families, 1,950 farmer groups with 12,933 members, 77 institutions with 10,009 members have benefitted from aquaculture development (e.g., Engle and Gamman 1993; Moehl and Molnar 1995; Molnar et al. 1995). In essence, extrapolated production yields, number of ponds and number of beneficiaries from the estimated *140 hectares* of fish ponds in Rwanda are used to promote aquaculture. These figures, however, distort biological constraints, variable farming practices and the *minuscule* area devoted to fish culture in the country.

In this light, personal observations and seining of group and farmer ponds in early 1994 showed that only a few ponds were managed in accordance with project directed management guidelines. Other ponds in the same bottomlands were in a state of neglect. Participants in PD/A CRSP on-farm experiments were further subsidized for exotic inputs (e.g., urea, triple super-phosphate, hormonally treated sex-reversed fingerlings) often imported from the United States. In early 1994, USAID-Kigali was exploring privatization of many poorly functioning fish stations including the massive National Fish Culture Center in Kigembe. Moreover, in early 1994 the extension service which featured in the RNFCP was inactive because the Hutu-dominated government had diverted resources away from rural development to military and political mobilization.

In sum, USAID-supported Rwandan aquaculture projects have set in motion a series of tenuous claims, extrapolated figures and a promotional discourse through reports which have attempted to establish an aquaculture development "success" story. Linked to a narrow focus on technoscience through production increases, meeting donor requirements and career advancements, advocates of Rwandan aquaculture development have produced a mythological portrait of the activity in the country. A project based image of small-scale aquaculture in Rwanda has come to dominate the development discourse over the *actual* activities which were conducted there from 1970 to 1994. Frankly, very little is known or has been convincingly documented *empirically* regarding the village-level organization, perceptions and attitudes toward fish culture in Rwanda. The Rwandan example, like many others in the field of aquaculture (e.g., Tiddens 1990; Moss et al. 1979) reduces development to a matter of scientist initiated technological progress and farmer adoption. The question remains unanswered: Has Rwandan aquaculture development benefitted rural communities?

In conjunction with the Thai and Rwandan development examples it becomes apparent that international development agencies and affiliated institutions have played catalytic roles in attempts to define, structure, promote and legitimate aquaculture development. The next section examines prominent institutional interventions in aquaculture and their influence on the articulation of modern aquaculture as a science and development strategy. An analysis by Bauin (1986) provides insight into the institutionalization of aquaculture. However, Bauin's (1986) analysis is restricted in scope. He does provide a basis to extend empirical examples of efforts by Auburn University's ICA, AIT, and the World Bank to articulate, organize and legitimate aquaculture.

AQUACULTURE AS BUREAUCRATIC INTERVENTION

It is commonly stated that aquaculture bears strong resemblances to agriculture (e.g., Bardach et al. 1972; McCraren 1993; Tiddens 1990). In a restricted comparative farm production sense or a policy setting this analogy may hold true. If, however, this analogy is pursued along broader historical development lines, it tends to obscure the hybrid character of aquaculture emerging in a much more organizationally complex era than agriculture (Chew 1993). Modern aquaculture is a very recent phenomenon and is poorly understood when compared with agriculture (AIT 1994; Chew 1993; Edwards et al. 1988; Pillay 1992). In many areas *including* much of Asia outside of China, aquaculture has in fact been a recently introduced activity (AIT 1994). Guiding early interventions, however, has been the consistent involvements of what Bauin (1986) labels "bureaucracies" such as international aid agencies, academic institutions or national fisheries departments.

Bauin (1986: 124) observed that "aquaculture is not a real field but rather a bureaucratic category." By "real field" Bauin (1986: 139) meant "a unified field of preoccupations and objects." If aquaculture were a "real field" then "results from autonomous localities [would be] brought together and made available to all those involved" (Bauin 1986:124). Bauin (1986) found that in France, this was not the case and that aquaculture research was a highly dispersed activity. Using 1979 and 1981 French aquaculture abstracts drawn from FAO files to map co-word associations between various fields loosely representative of "aquaculture." According to Bauin (1986:138), "the only meaningful structures detected are a rough separation into subspecies (e.g., crustaceans, molluscs, fish), very general problems (e.g., aquaculture development) and a few specific research problems (e.g., growth or rearing)."

Within these structures however, Bauin (1986) detected evolving clusters of research topics where one structural concentration was linked to a number of others. For example, in 1979 a feeding and nutrition cluster examined in some detail reveals associations between species, places, food conversion, feed composition, food organisms, diets, nutritional requirements, fish larvae, nutritive value and proteins under a central structure of "artificial feeding." By 1981, a more extensive feeding and nutrition cluster had evolved to include more associations between more species, places, food conversion, feed composition etc., but the central structure of "artificial feeding" had been replaced by "fish culture" as the focal research point. In addition, more associations between the nutrition and feeding cluster had been established with other central structures such as "breeding and cultivation," "stock assessment," and "pond and brackishwater aquaculture."

Bauin (1986) claimed that from 1979 to 1981 research on feed and nutrition became more focused and systematically explored which suggested a more thorough integration of this particular field of aquaculture. In contrast, other structures such as "breeding and culture" became fragmented or incorporated into other structures. How did this come about? Although Bauin's (1986: 139) analysis is limited to a two year period and one country, he explains these shifting configurations in France through bureaucratic interventions and the organizing efforts of certain key actors who were attempting to create a unified field through political means:

> aquaculture as a unified field of preoccupation and objectives, does not exist outside the political influence of certain decision-makers, researchers have maintained their respective approaches even though they have agreed to link their work.

Furthermore Bauin (1986:139-140) adds that,

> words like 'conference,' 'annual reports,' 'historical accounts' or 'sociological aspects' appear on the maps. These words are not found in other fields and reveal the desire of decision-makers, and sometimes certain scientists whose aims are similar, to bring about the simplifications necessary for the success of their political plan.

Bauin (1986:140) noted that the field of aquaculture was fragmented with researchers generally pursuing locality based interests. In contrast French "decision-makers and some scientists are trying to create a real field" (Bauin 1986:140). To achieve this objective, an Interministerial Committee for the Development of Aquaculture was established to centralize information and coordinate activities between a range of different ministries and departments.

Laboratories were moved from Paris to coastal environments and researchers were required to consider more applied questions that related to producer concerns.

While Bauin's (1986) analysis is restricted to an account of French aquaculture over a two year period, his claim that "bureaucratic interventions" play a significant role in shaping the field of aquaculture reveals the simultaneous confluence of political and scientific aims within a social context. Although Bauin characterized aquaculture as a fragmented field, a set of political actors (Bauin's decision-makers and scientists) have attempted to create a comprehensive field in terms consistent with their own institutional outlooks and agendas. The insight generated by Bauin (1986) obscures the separation between science and society that characterizes the aquaculture development literature. In this regard, three representative institutional actors, Auburn University's International Center for Aquaculture, The Asian Institute of Technology and the World Bank are examined in terms of their interventions to "create a real field" of aquaculture.

Auburn University's International Center for Aquaculture

Outside of the FAO, Auburn's International Center for Aquaculture (ICA) was one of the first organizations collectively engaged in tropical aquaculture development (e.g., Moss et al. 1979) in Sub-Saharan Africa (e.g., Grover et al. 1980; Hishamunda and Moehl 1989) Latin America (e.g., Lovshin et al. 1986) and in Asia (e.g., Schmittou and Cremer 1980; Schmittou et al. 1985; Swingle 1957). International fish culture research and development at Auburn grew out of domestic efforts in the 1930s to manage warmwater U.S. farm ponds for food and recreational purposes (Swingle 1970). Auburn's approach to optimize utilization of fish crops from these water sources led to construction of experimental station ponds and test plot methods for fish culture research (Swingle 1970). The growth of catfish culture and farm pond construction in the 1940s, encouraged by the USDA, provided an opportunity for Auburn to expand its activities (Carlander 1970; Swingle 1970).

Due to the growing worldwide recognition of warmwater pond culture, Auburn decided to internationalize its program in the 1960s (Moss et al. 1979). Grants in the mid-1960s from the Ford, Kresge and Rockefeller Foundations provided Auburn the means to develop one of the first U.S. based international fisheries and aquaculture education and training programs (Carlander 1970; Moss et al. 1979). Moreover, USAID provided a long-term strengthening grant throughout the 1980s and contracted for technical aquaculture assistance in numerous countries of Asia, Africa, Latin America and the Caribbean (Moss et al. 1979). As of 1979, Auburn's ICA was annually administrating millions of dollars of grants for international aquaculture development (Moss et al. 1979). Many host country nationals were trained at Auburn under these arrangements. In order to create a unified approach, the ICA developed a "philosophy" and method for international aquacultural development (Moss et al. 1979).

During the ICA's peak period in the late 1970s, Moss et al. (1979) outlined a strategy for international aquaculture development. Moss et al. (1979) characterize Auburn's strategy as an "oil spot phenomenon." In short, the goal of Auburn's international development efforts was:

> to create centers of excellence in aquaculture in which established fish cultural techniques are tested under local conditions, modified as needed, retested to prove the methodology and subsequently extended to production areas adjacent to the aquaculture center (Moss et al. 1979: 68).

Much like an oil spot on water, the ICA felt that the establishment of aquaculture centers, extension services and rapidly improved production capabilities would lead to the further spread of aquaculture in more distant areas of a given client country.

Based on extensive international experience, Moss et al. (1979) building on the work of Rogers (1971) provided a five stage methodology by which to accelerate aquaculture development. First, a technical survey is conducted to assess the physical, economic and social potential for aquaculture and fish consumption. Second, if the survey exhibits potential for aquaculture a research center is either upgraded or built in the host country. Third, once field facilities are developed, rapid deployment of "proven" tilapia culture packages provide immediate increases in fish production to host countries and donor agencies due to their ease in rearing (Bardach et al. 1972). Fourth, training and continuing education of host-country aquaculturists complements field activities. Educational needs are unique to each country but can range from in-country short-courses to doctoral training abroad. Fifth, the ICA stressed a strong Training and Visit (T&V) extension service by which to disseminate the technology from the aquaculture center to early adopters.

Auburn's ICA dominated early international aquaculture development efforts and attempted to articulate a strategy for promoting it. At present, Auburn maintains one of the largest academic aquaculture faculties, graduate programs and research facilities in the world. Currently there are eighteen tenured aquaculture faculty and about one hundred graduate students who conduct research, education and outreach activities both domestically and to a lesser extent abroad. A unique institutional feature has been Auburn's relative longevity in the field of aquaculture. In contrast to many emerging academic aquaculture programs (e.g., AIT, Stirling UK), Auburn is into its third generation of scientists.

Auburn, however, no longer dominates international aquaculture development. A variety of factors have precipitated this outcome. First, the 1980s global shift to private sector sources as the "vehicle" of development was instituted in numerous countries such as Thailand (Heim et al. 1986). Government downsizing stimulated new privatized organizational forms of aquaculture development. A plethora of new institutional arrangements took form such as international joint ventures, turn-key operations, private consulting and corporate investment in the United States and abroad.

These developments must be seen against the historical backdrop of low priority U.S. support for international fisheries and aquaculture development. For example, USAID budget allocations (1992 base year) in its 72 missions and field offices overseas shows a total of U.S. $450 million for agriculture development with aquaculture only receiving U.S. $20 million spread over about a dozen projects. Trott (1992) concluded that it is unlikely that USAID would prioritize aquaculture and fisheries because most efforts are currently undertaken through private sector arrangements.

In contrast, other donors such as Canada's IDRC and the FAO allocate thirteen and fourteen percent of their budgets respectively to aquaculture and fisheries development (Trott 1992). In particular, the British Overseas Development Administration (ODA), as of 1991, had allocated U.S.$ 70 million to 54 fisheries and aquaculture development projects in twenty nine tropical countries. ODA's fisheries and aquaculture program supports over 75 British scientists in long-term posts overseas (ODA 1991). The Asian Institute of Technology, discussed in the next section, has been favorably positioned to capture substantial ODA and other donor funding in the 1990s and has begun to articulate a global strategy for sustainable aquaculture development.

Second, the new institutional arrangements of the 1980s witnessed the explosive formation of export-oriented industrial aquaculture such as the shrimp aquaculture industry. Stimulated by the stagnation of marine shrimp harvests, technoscientific advancement, high profits and the catalytic efforts of the international development banks, shrimp pond production grew at extraordinary rates in the latter half of the 1980s in Asia and Latin America (Skladany and Harris 1995). In contrast, Auburn's ICA was bypassed in large measure because their international research and development had centered on inland aquaculture featuring relatively localized Tilapia culture "packages" which hinged on government supported extension efforts (e.g., Moss et al. 1979). Auburn's emphasis on Tilapia was closely tied to parallel domestic research and development on industrial catfish in the United States. As such, the U.S. catfish industry was seen as a development model on how to do aquaculture development which did not cohere with emerging global trajectories.

Third, as a consequence of government downsizing and restructuring in the 1980s and a global shift to export-oriented coastal shrimp aquaculture, USAID eventually ended a long-term strengthening grant to Auburn's ICA. As a result, the ICA was forced to release a number of staff, curtail travel and cut a number of international aquaculture development services. At the same time, Auburn's ICA faced widespread competition from a host of nascent international public (e.g., ICLARM, AIT-Stirling, University of Hawaii) programs and private firms in Asia (e.g., Charoen Pokphand,), and North America (e.g., Aquatic Farms

Inc.). These institutions and firms, such as AIT and Aquatic Farms, are also heavily tied to substantial funding support from bilateral, multilateral and private sources.

At Auburn this changing and evolving scenario became readily apparent. The termination of USAID support, competition from other institutions and key retirements led one prominent aquaculture scientist to summarize the current status of the department:

> The AU Fisheries Department has emphasized quantity rather than quality: many diverse programs, and, consequently let research facilities in established areas (where Auburn has gained recognition) not be kept up to date. Thus, our research capabilities in areas where we should be strong are not competitive with emerging programs at other institutions.

Although Auburn faculty have made major contributions to established fields of aquaculture such as water quality, fish nutrition, fish diseases and more recently genetics, in Bauin's (1986) terms their plans to unify the field of aquaculture development were not successful.

The Asian Institute of Technology

In contrast to long-term aquaculture development efforts by Auburn's ICA, the rise of the Thailand-based Asian Institute of Technology (AIT) has occurred over the last decade. In 1959, AIT was established as a regional engineering graduate school and the aquaculture program began in 1981 (AIT 1994). Overall, 23 externally funded aquaculture research projects have been conducted at AIT over the past 15 years (AIT 1994). Over the past decade, AIT has averaged approximately U.S.$ 1 million per annum for aquaculture research, development and outreach efforts in the region. The largest funding source has been the British Overseas Development Agency (ODA) which accounts for forty percent of the total. Other donors such as USAID, FAO, SIDA, DANIDA, IDRC, GTZ, ICLARM, the

Rockefeller Foundation, Commission of the European Communities, and the Charoen Pokaphand Company have also supported a range of research projects from recycling nightsoil to development of channel catfish culture in the tropics (AIT 1994).

At AIT, research and development activities are carried out by over one hundred faculty and staff, nine of whom hold doctoral degrees. About thirty sponsored graduate students, largely from Asia, currently pursue advanced degrees (M.Sc. and PhD) at a given time. AIT also offers aquaculture short-courses to professionals from government, non-government organizations and business. AIT has well equipped laboratories, a large hatchery complex and four hectares of experimental ponds. A large aquaculture outreach effort is currently conducted out of field offices in Northeast Thailand and Laos in order to "transfer the findings of strategic research conducted by AIT to the region" (AIT 1994: 58).

Since its inception, the AIT aquaculture program has steadily grown in stature to where it currently plays a global role in small-scale integrated aquaculture research, development and outreach. Other research interests pertain to a wide range of topics and has included fish nutrition, fish seed production, pond dynamics, sewage-fed aquaculture, semi-intensive aquaculture and intensive aquaculture. Social and economic research, typically large surveys, has been included in about half of these research projects. The majority of research has been conducted on-campus although some work was conducted on-farm in Central and Northeast Thailand (AIT 1986; Edwards et al. 1983). An increasingly strong emphasis has pertained to ODA, SIDA and DANIDA funded outreach efforts in Northeast Thailand, Laos and more recently Cambodia and Vietnam.

AIT's outreach effort complements on-campus research into small-scale integrated aquaculture and represents a growing global role played by this small program. The AIT aquaculture program however has established significant linkages with influential institutional actors in aquaculture development (AIT 1994; Edwards et al. 1988). In particular, strong international links are maintained with the Institute of Aquaculture, Stirling U.K. and the global aquaculture program at the Manilla based International Center for Living Aquatic Resources Management (ICLARM), a recent member of the Consultative Group on International Agricultural Research (CGIAR). Moreover, the AIT aquaculture program works closely with national institutions such as provincial Thai DOF fish stations, agricultural colleges and non-government organizations in the outreach project. Through the Pond Dynamics Aquaculture Collaborative Research Support (PD/A CRSP) program, AIT has collaborated with Michigan State University, Auburn University, the University of Michigan and the University of Hawaii on pond experiments. Most significant has been the funding committed to AIT by ODA from 1988 to the present. As a result, AIT's evolving program surpasses previous short-term donor projects in terms of a long-term commitment to research and a field level outreach presence in the region.

Overall, AIT publications and educational activities are influential and reach a wide range of individuals and institutions concerned with aquaculture development (e.g., Edwards et al. 1983; Edwards et al. 1988; Little and Muir 1987). AIT researchers bring a long-term systems approach to their efforts and the central location of the institute in a major aquaculture region of the world further allows staff to keep abreast on current developments in the field. Moreover, collaboration with ICLARM has resulted in the publication of a series of widely distributed reviews pertaining to various aspects of aquaculture including integrated farming, detritus and microbial ecology, aquaculture and the environment and a framework for research and education for the development of small-scale tropical aquaculture (Colman and Edwards 1987; Edwards et al. 1988; Pullin et al. 1993).

In many respects, AIT's aquaculture development strategy resembles that developed by Auburn's ICA. A center was established in an academic setting and applied research and outreach efforts are conducted in order to promote aquaculture. However, AIT has had success in articulating its outlook in accordance with the emerging global character of aquaculture. Auburn's ICA never articulated a global vision and concentrated on particular countries and limited themselves to production and adoption strategies. AIT was early to define aquaculture in terms of sustainability and takes a multi-disciplinary systems approach in order to develop technological appraisals and guidelines. AIT views sustainable aquaculture in terms of three interrelated components: production technology, socioeconomics and environment. The combination of these components has led AIT to profile integrated agriculture/aquaculture research in terms of small-scale and commercial farming systems.

In sum, AIT has progressively researched and defined small-scale tropical aquaculture systems. Due to a strong set of international and national linkages, AIT has emerged as a major research center for further research and development of small-scale inland tropical aquaculture. Amplifying this role has been significant donor contributions for on-campus research and outreach to farmers in the region. Although AIT research and outreach can be best considered incremental, the ability to develop a long-term program and maintain a multilateral set of strong linkages and support has set AIT apart from many other short-term international development projects. As a result, AIT is strategically positioned to play an influential role in setting agendas regarding the strategies used in tropical aquaculture development. In Bauin's (1986) terms, AIT's effort to articulate a field of aquaculture has achieved a level of recognized visibility and closely parallels a broader review of tropical aquaculture research undertaken by the World Bank which is profiled in the next section.

The World Bank

Although not directly engaged in aquaculture research, the World Bank undertook a highly critical review of tropical fisheries and aquaculture research capabilities and needs in Asia, Latin America and Africa (World Bank 1991a; 1991b; 1991c; 1991d). This study was conducted by several missions and working groups over the period 1989-90 (World Bank 1991a). A variety of major multilateral (e.g., UNDP, FAO, Commission of European Communities) and bilateral donors (e.g., USAID, DANIDA, SIDA, ODA, GTZ) supported these studies. Members of each mission were drawn from representative fisheries and aquaculture institutes and organizations. Interestingly, a significant proportion of the mission members came from the FAO, AIT, ICLARM, and the Institute of Aquaculture, Stirling, United Kingdom. The specific objectives were to:

> identify constraints to fisheries management and development (including aquaculture) posed by the lack of information or the inaccessibility of existing knowledge; to determine high priority research needs; to examine the capacity of developing countries to undertake research; and to propose a strategy and action plan for improving donor support (World Bank 1991a: vii).

Overall, emphasis was placed on fisheries in the majority of regions and countries reviewed. Aquaculture is featured in Asia and to a much lesser extent in Africa and Latin America.

In terms of tropical aquaculture, the missions noted that past research had made some contributions to hatchery techniques, biology and husbandry practices for important commercial species such as carps and shrimps. Moreover, private sector funding for the development of intensive shrimp and salmon systems was noted along with private research initiatives in areas such as developing red tilapia fingerlings, micro-encapsulated feeds for larvae and bacterins for disease prevention (World Bank 1991a: 33). However, in broader global terms:

> research is not contributing as it could to the development of tropical aquaculture. An overall experience was missing. More importantly, research agendas are characterized by the same shortcomings as development approaches: their scope is too narrow (World Bank 1991a: 33).

More specifically, the authors attributed the lack of past research contributions to tropical aquaculture to a singular focus on zoological disciplinary leanings and subsequent technological solutions which were concentrated on improving the performance of the fish. As a result, social and economic dimensions, the environment, appropriate aspects of local farming and production systems were ignored as researchers paid the majority of attention to biological and technical aspects of intensive aquaculture systems. Often these research and development initiatives were ad hoc in nature and subject to severe resource and time limitations. The multi-disciplinary aspects of aquaculture were also neglected (World Bank 1991a).

At present, aquaculture research in developing countries was characterized as complex and requiring a much more coordinated and concerted focus. Overall, the World Bank (1991a:34) mission noted that:

> A majority of research institutions lack long-term financial support from governments to implement comprehensive research strategies and innovative investigations. Opportunistic changes in research focus are common. Distribution of expenses is imbalanced. Salary and professional and support staffing are often grossly inadequate. Operating funds are insufficient, while capital outlay and equipment are more attainable from government and donor agencies allocations.

Compounding this assessment were related insufficiencies in education and training, short-term duration of foreign sponsored projects, disparities in the distribution of knowledge, inadequate research communication venues and little attention paid to effective extension mechanisms.

The authors assume that if aid agencies prioritize small-scale systems of aquaculture production, three thematic programs of investigation could enhance global research capabilities: "intensification of freshwater pond aquaculture systems; the initiation of small-scale aquaculture in new areas; and the prospects and conditions of open aquaculture development" (World Bank 1991a:41). The first pond intensification theme applies to Asia while the next two, initiation of small-scale aquaculture in new areas and open aquaculture development (e.g., fish stock enhancement, seaweed, shellfish, sea ranching), apply to Africa and Latin America. In order to reduce redundancy and coordinate this global thematic research program, collaborative arrangements between developing countries and developed countries are recommended through extensive networks of research institutions. As the World Bank mission put it:

> If a few inter-connected programs could be initiated on major research areas determined by needs of presently and potentially dominant aquaculture systems in tropical regions, the somewhat antagonistic requirements of geographic distribution, discipline coverage and program comprehensiveness would be easier to satisfy.

Finally, greater attention to regional and national institutional strengthening and human resources development was needed rather than the past overemphasis on facilities and equipment. In particular, strengthening national capacities was especially noted in Africa for all phases of aquaculture. In terms of a working model by which to better realize the benefits of tropical aquaculture research, the review (World Bank 1991a: 37) mentioned the example of the CGIAR system:

> which has ensured continuity in funding, autonomy in programming and emphasis in innovative research, all conditions which, today, are dramatically missing in aquaculture research in developing countries.

Clearly, from the perspective of this World Bank review of tropical aquaculture research, substantial upgrading and reorganization in nearly all phases of tropical aquaculture research and development is required if aquaculture is to become a "real field."

AQUACULTURE BIOTECHNOLOGY AND GENETIC ENGINEERING

Aquaculture biotechnology and the genetic engineering of transgenic fish can be directly traced to the long standing field of fisheries genetics. Transgenic fish research, however, makes use of and intersects with more broader scientific and public policy dimensions due to the specific application or recombinant DNA to fish. As a consequence, transgenic fish research displays a highly unique profile which is sustained by a transscientific discourse. In point, fish used for aquaculture are only a few generations removed from wild stocks (Kapuscinski and Hallerman 1994; USDA 1988). Hence, the emergence of molecular approaches in aquacultural genetics is controversial, disputed and debated because little is known about the long-term effects which comprise recent efforts to domesticate aquatic organisms (Dunham n.d.; Kapuscinski and Hallerman 1990:1994; Rosendal 1992; Sagoff 1989; Tave; USDA 1988).

While popular conjectures focus on laboratory created "superfish" for aquaculture or recreational purposes (e.g., Fishchetti 1991; Rosendal 1992), fisheries genetics has had a relatively long history of mixed results in altering aquatic organisms and their habitat (Bradach et al. 1972; Crosby 1986; Dunham n.d.; Dunham and Smitherman 1987; Kapuscinski and Hallerman 1994; Sagoff 1989; Tave 1983; USDA 1988; Utter 1991). In particular, the growing field of aquacultural genetics seeks to improve the *commercial production performance* of a cultured species (USDA 1988). Traditional strategies encompassed the developmental of experimental techniques, strain evaluation, intraspecific crossbreeding, interspecific hybridization and mass selection (Smitherman et al. 1983; Tave 1993). These techniques have been undertaken intentionally as well as unintentionally as "modified" aquatic organisms from these processes are created in hatcheries, research institutions, situated on farms and released in less controlled aquatic environments throughout the world.

Tave (1993: 267-304) outlined four broad areas of aquacultural genetics biotechnology: (1) sex reversal and the production of monosex populations, (2) chromosomal manipulation, (3) electrophoresis and (4) genetic engineering. Sex reversal occurs when fish fry are fed or immersed in hormones containing androgens or estrogens. This technique is widely known in the production of all male Tilapia. The United States prohibits commercial application of this technique. However, it is widely used in other countries including those that export Tilapia to the United States. Altered chromosome number in fertilized fish eggs (e.g., to create sterile triploids) is created by means of temperature, pressure and chemical shock. These techniques are widespread in the United States and influenced by federal and state regulations concerning the introduction of exotic species (e.g., grass carp) into various aquatic habitats. Electrophoresis allows for the study of DNA and RNA to determine protein phenotypes and their genotypes. For example, this technique is used to quantitative analysis of wild stocks of fish. Historically, electrophoresis provided a significant advance over immunogenetic studies, lessening the time required to accurately detect Mendelian variation in fishes (Utter 1991).

More specific and central to this work is genetic engineering. Genetic engineering is where one or a few genes are transferred from desired cloned genes obtained from different sources (Tave 1993). Transfer takes place on the molecular level, with the desired genes inserted during the early stage of embryo development. Fish which have undergone this process are referred to as "genetically modified aquatic organisms" (GMOs). Dunham (n.d.: 64-65) defined transgenic organisms as follows:

> Individual genes from one species are isolated, linked to promotors (regulatory DNA sequences or on/off switches), cloned, and grown in hosts such as bacteria, bacteriophages, cosmids and plasmids. These genes are then transferred into genomes of other species by vectors, microinjection, electroporation, sperm mediated transport or gene gun. Organisms containing these foreign genes are termed transgenic.

These techniques set genetic engineering apart from traditional genetics research and have drawn more public attention and debate (Kapuscinski and Hallerman 1994). In Chapter 6, the politics of defining what constitutes a transgenic organism is central to public policy decision making. As a result, the research in North America is confined to laboratories and in Auburn's case, to containment ponds which minimizes their escape. At present, only Auburn conducts outdoor pond research in North America.

Modern aquaculture biotechnology and genetic engineering are recent developments (Chen and Powers 1990; Dunham n.d.). Some of the products from this work, such as transgenic fish, are matters of continuing speculation and controversy regarding their eventual usefulness and potential impacts (Hallerman and Kapuscinski 1990: 1994; Rosendal 1992; Tave 1993). As Teidje et al. (1989: 298) stated:

> because many novel combinations of properties can be achieved only by molecular and cellular techniques, products of these techniques may often be subjected to greater scrutiny than the products of traditional techniques.

Relative intensive scrutiny by external agencies sets North American transgenic fish research apart from other fields of aquaculture. Transgenic fish researchers have tended to question "conservative" regulators and policymakers in what they view as overly cautious oversight of their research. These researchers characterize themselves as "liberals" advocating the technoscientific development of transgenic fish. They aggressively promote transgenic fish as capable of "feeding the world" as well as increasing fundamental understanding of gene expression in fish. In contrast, regulators, policymakers and fisheries geneticists have raised broader questions and concerns about anticipated social impacts of the research and development in terms of ethics, food safety, the environment and fish population genetics. This transscientific discourse has marked the field since its inception in the mid-1980s and remains ongoing.

Transgenic fish research was sparked by earlier gene transfer efforts in other animal species, most notably mice (Chen And Powers 1992; Palmiter et al. 1982; Pante 1989). Early genetic transfer efforts from 1985-1990 resulted in variable rates of integration, expression and transmission of growth hormone genes in about ten fish species (Chen and Powers 1990). Human (hGH), rat (rGH) and rainbow trout (rtGH) hormones were microinjected into fertilized fish eggs after spawning. After hatching fry are reared to fingerling to adult sizes, depending on the availability of facilities. At various stages, DNA is extracted from biopsy tissue (e.g., fin clips) and blood samples, amplified by polymerase chain reaction (PCR) and then analyzed by Southern blot hybridization techniques to determine the presence and location of the transgene. At present these techniques are considered standard in the routine study of transgenic individuals (Chen et al. 1995). Positively identified transgenic individuals, which express the transgenic gene in their reproductive organs, are raised for further selective breeding and study purposes.

Before conclusive results can be obtained, scientists caution that a long-term effort over many generations is required to stabilize selected transgenic lines. Initial results indicate however, that transgenic fish *on average* grow faster than controls of the same species. Zhang et al., (1985) first reported that F_1 offspring of transgenic goldfish grew twice as fast as non-transgenic controls. Dunham et al. (1993) and Chen et al. (1993) have demonstrated significant although variable growth increases in transgenic catfish and common carp. Devlin (1994) reported an average eleven-fold weight increase in transgenic coho salmon when compared with controls. Among other factors, growth variability in transgenic fish has been traced to mosaicism, a pattern where the transgenes are randomly located in the host genome but not in every cell or tissue of the host (Chen et al. 1995; Dunham n.d.). As Donaldson (n.d.: 66) explained:

> Successful transmission of the construct to the F_1 generation depends on the construct being present in the gametes and the degree of mosaicism in the gametes. Thus transmission to the F_1 is normally less than the theoretical 50% when non transgenic gametes are fertilized with the gametes from a transgenic fish.

At present there are about fifty laboratories worldwide that produce transgenic fish (Hileman 1995). About one half of these laboratories work with non-cultured species (e.g., zebrafish) while the other half work with cultured species such as carps, catfish and salmon (Dunham n.d.). Researchers select aquatic organisms which can be theoretically modeled and where substantial endocrinological, reproductive and physiological work has already been accomplished (Chen et al. 1995). Hence, catfish, carp and salmonids have featured in transgenic research while in contrast work on crustaceans lags due to limited background biological knowledge.

By the mid-nineties, estimates show that about twenty two aquatic organisms have been subjected to forty different foreign gene transfer constructs (Donaldson n.d.). Mass transfer techniques such as electroporation have replaced the tedious microinjection procedures. Notably, gene transfer work has shifted away from the earlier use of cloned mammalian constructs to cloned fish gene constructs due to no or modest growth effects and public concerns over the use of non-homologous DNA sources (Devlin et al. 1994). Moreover, the field has expanded to include areas such as engineering disease resistance, reproduction and the transfer of the anti-freeze gene from winter flounder to salmon (Chen et al. 1995). Clearly, the field has passed its inception stage. As one scientist assessed the current state of the field:

> I've been in the field long enough... when a new and important technique is developed, if you are using it, you can get almost anything... the technique will carry you through. Then, after the technique becomes more widely utilized, the "Gee Whiz" aspects of it begin to fade. Then people on the funding panels, the reviewers start to ask questions about the importance of the research, not the technique that is being used. Is the research important? If the research is important are the techniques appropriate? Are the experiments going to lead to an important new development in knowledge or potential new commercial applications... and transgenic fish research work has certainly gone through the first of those phases and is now in the second, so it is evaluated strictly on its merits rather than as a "Gee Whiz."

Parallel to the laboratory and scientific research inception of the genetic engineering of transgenic fish has been much external scrutiny. As covered in Chapters 5-6, Auburn's initial proposal to move transgenic fish to outdoor ponds served as a critical exemplar for the field because they originally failed to satisfy environmental containment requirements. As a result, this case became the focal point in ongoing negotiations and debates which transcended particular localities and informed a whole ordering of the field.

Scientists anticipate that it will take at least a decade for transgenic fish to be approved for commercial aquaculture production in North America given unresolved regulatory, food safety, environmental and population genetic issues. While scientists point to early advances made in research, they caution that much more work and time is required to control and stabilize the specific host genome along successive generational lines. At the same time, North American scientists and policymakers anticipate the possibility of much quicker releases of transgenic fish in less regulated countries such as China (Young et al. 1995).

Transgenic fish scientists seek to address questions in molecular biology and fish genetics through the development of whole animal model systems. Using fish, an understanding of these model systems is predicted to contribute a better understanding of growth factors, immunology, gene expression and the evolution of lower invertebrates while also stressing the potential aquaculture benefits. The advantage of transgenics was put by one scientist in the following manner:

> all the kinds of things you want to do as an agricultural scientist, select, improve the genetic background of the seeds, improving production . . . all that instead of achieving it by natural selection, hybridization and so on you can do it in transgenics in very much, much less time and also with much, much better control because each time you are only introducing one or two genes into it rather than hybridization which is throwing in everything you have.

Chen et al. (1995: 914) concluded that several scientific breakthroughs are still required before the full potential of transgenic fish can be realized; development of more efficient mass gene transfer technologies; identification of genes of desirable traits for aquaculture and other applications; development of targeted gene transfer technology; identification of suitable promotors to direct the expression of transgenes at optimal levels during the desired developmental stages; determination of physiological, nutritional, immunological and environmental factors that will maximize the performance of transgenic individuals, and assessment of the safety and environmental impacts of transgenic fish.

CONCLUSION

This chapter has examined some representative depictions of aquaculture: traditional aquaculture, aquaculture development, aquaculture as a bureaucratic intervention and aquaculture biotechnology and the recent making of transgenic fish. The Thai and Rwandan examples illustrated that aquaculture development is a poorly understood phenomena and that aquaculture has given rise to mixed developmental impacts. Throughout the modernization of aquaculture, international aid agencies have played a prominent role in articulating, defining, organizing and legitimating aquaculture science and development. As a result, a complex and fragmented image of aquaculture emerges which escapes neatly divided classification schemes or agricultural analogies based on development in a particular country or region. Aquaculture remains a highly hybridized field of human endeavor.

Bauin's (1986) analysis of French aquaculture obscured the separation between science and society which characterizes much of the aquaculture development literature. This insight was then used to account for three institutional actors, Auburn's ICA, AIT and the World Bank and their intervention efforts at articulating, defining, organizing and legitimating an emerging global framework for aquaculture research and development. At the same time, the shift to private sectors as the catalysts of development in many regions of the world have brought forth industrialized forms of aquaculture for mass production and consumption.

Within this industrial milieu, aquaculture biotechnology and in particular the genetic engineering of transgenic fish have gained growing research and development momentum. While a nascent technoscientific activity, the field carries the added dimension of public scrutiny. Similar to other areas of biotechnology and genetic engineering, this dynamic has shaped the way research is conducted and how decisions are formulated around GMOs. In particular, poised at the cusp of far reaching social and environmental change, genetic engineering of transgenic fish projects a series of unresolved problematics. Notwithstanding these dilemmas, the notion of technological progress anchors continuing efforts to bring these GMOs to the commercial production sphere.

Within these development interventions, the applied involvement of social scientists in aquaculture has been recognized but has not been effectively operationalized in any meaningful sense. In general, social science input into aquaculture has been historically undertaken in terms of short-term field research and project evaluations. The orientation of early social scientists pertained to quantified assessments of "socioeconomic" impacts of projects and were skewed towards economic factors related to fish production. Nonetheless, there is a growing recognition that greater sociological and anthropological input into aquaculture research and development is required given the relevance of development, institutional interventions, global aquaculture ordering and especially biotechnology and genetic engineering. Aquaculture is a legitimate field of study for sociologists and anthropologists. The next chapter examines this emerging field designated as the sociology of aquaculture.

Chapter 3

THE SOCIOLOGY OF AQUACULTURE

INTRODUCTION

In Chapter 2, the emerging field of aquaculture was examined in a variety of world development contexts. The chapter was organized around a series of sociohistorical themes which featured traditional aquaculture practices, the emergence of international aquaculture development and aquaculture as a bureaucratic intervention. Moreover, three different development institutions were profiled in their organizing efforts to unify and extend the field of aquaculture. In closing, remarks were made about early social science involvements in aid agency driven technical assistance projects.

In this chapter, I contend that first, the emergence of industrial aquaculture along with uneven social, environmental and developmental impacts has stimulated greater interest into aquaculture *development* by sociologists and anthropologists. This emerging field is designated as the "sociology of aquaculture." In establishing the field, a recently edited volume by Bailey et al. (1996) builds upon the work of Smith and Peterson 1982, Hannig 1988 and the 1988 and 1992 World Congress of Rural Sociology sessions on aquaculture.

The Bailey et al. (1996) volume represents the first systematic effort to address the sociology of aquaculture development in industrialized and non-industrialized nations. More recently, the Rural Sociological Society held sessions on aquaculture in 1996 at its annual meetings.

Second, in conjunction and closely tied to these academic interests, international aid and government agencies have proposed more involvements by social scientists in fisheries and aquaculture research and development (Bailey et al. 1985; Office of Technology Assessment 1994; PD/A CRSP 1994; World Bank 1991a). These proposals envision a role for social scientists *within* the parameters of technical assistance projects and collaborative research designs set forth by production-oriented aquaculture and fisheries scientists, managers and policymakers. However, it remains to be seen how these agencies will actually utilize social scientists in project and program terms.

More specifically, social scientist accounts of aquaculture development can be characterized by an atheoretical empiricism (Runes 1974). In brief, social scientists marshal forth a myriad of social factors and essentially advocate that aquaculture can be a rural development "success story" if more attention be paid to the social factors of production, organization and policy making. Questions concerning technoscience are not asked by social scientists and herein lies the problem: aquaculture technoscience, as part of the social world, remains silent in sociological accounts. Social scientists avoid problematizing technoscience which leads to the analytical construction of a social world where non-human actors are discounted, ignored and remain unexamined.

Third, a critical examination of the sociological writing about aquaculture development, however reveals some implicit theoretical assumptions, partial frameworks and conceptual schemes imported from conventional disciplinary divides. In particular, the adoption and diffusion of innovations (e.g., Rogers 1983) dominates the field. The adoption and diffusion of innovations is more or less used as a prop for interpreting extensive empirical data. While the adoption and diffusion of innovations dominates developmental explanations of aquaculture a small number of sociologists and anthropologists have introduced theoretical and applied approaches derived from agriculture such as participatory research, and political economy. These approaches round out the nascent sociology of aquaculture field.

Conversely, aquaculturists avoid problematizing society. However, much like Callon's (1987) engineers, they develop an implicit "sociology" in their writings about aquaculture research and development (e.g., Edwards et al. 1988; 1994; Boyd 1994). Aquaculturists make explicit reference to technoscience while implicitly developing an "impure" sociology in order to legitimate choices for both science and society. The notion of "technological progress" is posited as driving social change. As a result, peculiar asymmetries characterize the literature, policy and development activities.

The aim of this chapter is to critically review the sociology of aquaculture whether undertaken by social scientists or aquaculturists. In so doing, I seek to illuminate both the relative strengths and weaknesses of an emerging sociological field. I first examine some representative writings from sociology and then examine some writings by aquaculture scientists who essentially act as sociologists. In conclusion, I argue that to advance the field, an approach from the sociology of scientific knowledge opens up and directly addresses the problematic asymmetries of social scientists and aquaculturists. More specifically actor network theory offers a more theoretically informed empirical basis from which to problematize science *and* society, and to address my central research questions concerning aquaculture research, development and its effects.

The Origins of the Sociology of Aquaculture

Social science analyses of aquaculture began within internationally sponsored tropical development projects. By conducting short-term socioeconomic surveys and evaluations, social scientists were called on in an ad hoc manner to assess and legitimate prior decisions made by biologists and aid agency decision-makers. Rarely were these decisions critically examined because they were not considered within the realm of social scientists' capability. Moreover, socioeconomic studies and measures of aquaculture development were often skewed toward quantitative economic measures. These background contributions also fostered development collaborations between host country fisheries ministries and international aid agencies.

This generalized scenario of aid-induced tropical fisheries and aquaculture development provides the substantive base for the historical emergence of the sociology of aquaculture. An early volume, <u>Aquaculture Development in Less Developed Countries: Social, Economic, and Political Problems</u>, edited by Smith and Peterson (1982) provided one of the first social scientific oriented accounts of social, economic and technical constraints to tropical aquaculture development projects in Latin America and Africa. Surprisingly, Smith and Peterson (1982:8) do not include Asia because the:

> traditional strengths of aquaculture in that region of the world has mitigated against the existence of the social and economic problems found when aquaculture is introduced as a new activity.

In contrast, Chapter 2 (p.40) emphasized that Asian aquaculture has been for the most part a recently introduced development activity and that in the case of Asian shrimp pond development a host of social and economic problems have produced serious societal and environmental effects (AIT 1994; Edwards et al. 1983; Shell and Lovell 1973).

Smith and Peterson (1982) assess aquaculture development project issues and data requirements. They conclude that "background research on social, economic, and technical aspects of development may help avoid some of the pitfalls of aquaculture ventures" (Smith and Peterson 1982:10). The contributors range over issues such as resource allocation, labor availability, product acceptability, marketing, technology and site selection. Social aspects include sociocultural factors, power relations and social stratification that may arise due to an aquaculture intervention.

In the last chapter, Pollnac et al. (1982) discuss successful and unsuccessful aquaculture projects. Within the aid-administered project mode of thinking, they define aquaculture development as a "structure of decisions, each of which requires some information" (Pollnac et al. 1982:131). In terms of evaluations, successful projects carefully considered economic, sociocultural, scientific and technological factors. Overall, the volume has a decidedly economistic bent and appeals to development policymakers, planners, aid officials and project personnel.

The volume Aquaculture Development represents one of the first social science efforts specifically devoted to aquaculture. By the mid-1980s, aquaculture development shifted towards an industrial economic development strategy (e.g., Ben Yami 1986; Kent 1986; Scura 1985) while still retaining a tenuous commitment to small-scale farming (e.g., Edwards et al. 1988). Moreover, the sociological writing about aquaculture development projects continued but in higher profile disciplinary publications (e.g. Molnar et al. 1985; Molnar et al. 1986; Schwartz et al. 1988). At the same time, a few social scientists began publishing critical accounts about industrial shrimp aquaculture and the environmental consequences of unbridled aquacultural growth (Meltzoff and Li Puma 1986; Bailey 1988a; 1988b; Hannig 1988). In sum, the stage was set for a growing interest in the sociological aspects of aquaculture development.

PROBLEMATIZING TECHNOSCIENCE? SOCIAL SCIENTIST VIEWS

More recently, Weeks (1992) and Fiske and Ple (1992) provided sociological and anthropological accounts of aquaculture development. Weeks (1992) succinctly summarizes a broad literature on aquaculture development. She traces social scientific involvement with aquaculture to agricultural development and fisheries management. Weeks notes (1992:345) that historically:

> the inclusion of the social scientific perspective into aquacultural projects mirrors that of the social sciences in technology transfer and resource management . . . A history of failures in technology transfer and resistance to the regulation of natural resources led to the realization of the importance of other types of social scientific analyses.

Weeks (1992) organizes sociological approaches to aquaculture from two viewpoints: rural development and commonality with capture fisheries. Weeks (1992: 348) identifies differences in property regimes as the basis for the two perspectives:

> Aquaculture sited on private property is approached as rural development. Aquaculture sited on open-access or communal property is approached in a manner similar to other shared resources.

The thematic of "aquaculture and rural development" also includes the organization of labor, health and nutrition. The thematic "aquaculture and fisheries" entails ecological degradation, social dislocation and the privatization of communal resources.

Weeks (1992) distinguishes differences in property regimes as the basis for aquaculture as rural development (private or public property) or commonality with capture fisheries (open-access or communal property). In this manner, Weeks (1992) argues that property regimes serve as a fundamental bases for explaining how exploitation and extraction of surplus value from labor and nature take place in fisheries and aquaculture. Although not developed by Weeks (1992), aquacultural technoscience must also be taken into account because property regimes, whether public, private, common or open access, *consist of social relations of which non-human actors must be taken into account*. Scott (1985:308) adds that property regimes "are always the focus of symbolic manipulation, struggle and conflict" and this includes access to and application of technoscience in conjunction with property and associated property rights.

In contrast to Weeks (1992), Fiske and Ple (1992) outline the potential development of U.S marine aquaculture. They (1992: 253) state that marine aquaculture "will reorganize the social organization for producing fish for consumption, and it involves changing or capitalizing on long-standing cultural attitudes and practices." They characterize marine aquaculture as planned social change for economic development. In their conceptual framework on the social aspects of U.S. marine aquaculture, technology is beyond the scope of analysis as they anticipate bureaucratically directed U.S. marine aquaculture development.

In marine aquaculture, Fiske and Ple (1992) add that appropriate technology, a benefit-flow strategy and an identified institutional strategy comprise successfully planned change. Appropriate technology refers to adoption of technology by the target group and some understanding of the social and economic effects of a particular adoption. Benefit-flow strategy refers to the target group seeing themselves as part of the development process therefore increasing rates of technology adoption. An institutional strategy refers to the organizations likely to identify the best method of implementing marine aquaculture. Social scientists can contribute to this process by understanding adoption of marine aquaculture through the Farming Systems Research (FSR) approach, by identifying consumer attitudes and refining market strategies, and by assessing unintentional and long-range social impacts associated with marine aquaculture.

Fiske and Ple's (1992) article appears as an Appendix in a book by the Committee on Assessment of Technology and Opportunities for Marine Aquaculture in the United States that was a committee of the National Research Council and other standing U.S. scientific public boards and commissions. As such, the Appendix approximates technocratically driven sociological and anthropological thinking on U.S. aquaculture. The planning, economic and FSR outlook which prevails in the Appendix is consistent with earlier roles played by social scientists in legitimating prior technoscientific and policymaker decisions about tropical aquaculture development. Moreover, development is driven by simple diffusion and adoption of aquacultural innovations. Fiske and Ple (1992) take technoscience as a given and then proceed to identify social aspects which would enhance marine aquaculture development. There are no options or participation avenues made available to fish farmers as well as consumers in these technocratically driven schemes.

In sum, the sociology of aquaculture emerged from applied social scientists' involvements in tropical and more recently domestic development projects and programs. By the mid-1980s, three distinct trajectories in the literature are apparent;

(1) higher profile publications in the sociological literature on aquaculture development projects but not contributing or elaborating a theorizing of aquaculture,

(2) a dualistic view of aquaculture emerging as industrial economic development or commercial small scale farming, and

(3) criticism focused on the social and environmental consequences of industrial aquaculture, most notably tropical shrimp culture.

In particular, the recent development of tropical shrimp culture was the most visible and dramatic social transformation ever in the history of aquaculture. Sociologists and anthropologists who had worked and kept abreast on tropical marine capture fisheries and coastal communities recognized this early on and began to critically write about this new industrialization process.

As a result of this scholarship and to a lesser extent, activism, the field has attracted greater attention from social scientists and aid-agencies (e.g. World Bank 1991a). Moreover, the examples by Weeks (1992) and Fiske and Ple (1992) illustrate the growing interest in aquaculture development in academic and applied settings. The publication of a volume edited by Bailey et. al. (1996) provides a good example of this growing interest in aquaculture and is reviewed in the next section.

Social Dimensions of Aquaculture Development

The recently published Aquacultural Development is directed towards "policymakers responsible for managing this growing industry as they begin to research and design appropriate institutional structures" (Bailey et al. 1996:287). The aim of this volume (Bailey et al. 1996: vii-viii) is to draw out:

> lessons to be learned from comparing aquaculture systems in various countries regardless of the social and environmental contrasts that exist among them. At the present stage of social research on aquaculture, our primary objective is to develop hypotheses and to identify concerns that need to be addressed in practical social planning as well as in further social research.

The editors divide the book into two sections. The first part examines aquaculture development in North America and Europe. The second part examines aquaculture development in Africa, Southeast Asia and Latin America.

The editors propose that there is a need to promote sustainable aquaculture development in a socially and environmentally sound manner. They add that most effort to-date has revolved around biological studies with little attention paid to social aspects of aquaculture. In their view (Bailey et al 1997:7) the primary concerns of social researchers:

> are not questions of how to improve the productive capacity of aquaculture through improved hatchery technology or pond management, better fish nutrition, or better control over water quality and disease. Instead our focus is on the extent to which technology has developed as a result of particular social conditions and the extent to which it refashions power relations among classes, genders and ethnic groups.

Bailey et al. (1996) organize the fifteen contributions around seven conceptual threads: innovation and change, environmental impacts, organization of production, property rights, user-group conflicts, community linkages, and the role of the state.

Aquacultural Development advances the fledgling sociology of aquaculture field by building upon the work of Smith and Peterson (1982). The volume acts to consolidate leading sociological and anthropological views on aquaculture development. The majority of contributors spell out various social, cultural and especially institutional factors which may inhibit sustainable development. The volume has an applied focus and case studies are derived from diverse nation-state locations. Aquacultural Development anticipates entry into research, policy, and institutional development arenas.

The volume however, suffers from a lack of a strong and comprehensive theoretical orientation on aquaculture development. With the exception of a chapter on a scientific controversy, contributors do not problematize technoscience and restrict outcomes to exclusive "social" categorical realms. As a result, an infinite array of human actors populate these chapters. Non-human actors are absent from these accounts. Hence, a partial view on aquacultural development emerges which is loosely held together by some conceptual threads. These schemes tend to avoid the primary questions of the why and how of development.

Although brief mention is made of the "social construction" of aquaculture, the dominant framework is the adoption and diffusion of innovations. This implicit framework shores up the claim that aquaculture is desirable for rural development. Where aquaculture is problematic, the authors suggest sound policy and appeals to political will as the means to rectify problems and promote sustainable development. Finally and most critically, there is a lack of attention devoted to aquacultural science *and* society in the making.

Conceptual Threads

A closer reading of Aquacultural Development shows that the majority of contributions could easily fit under multiple conceptual schemes. For example, Holm and Jentoft (1996) describe the rise and fall of the Norwegian salmon aquaculture industry. While classified by the editors under "innovation and change" and the "role of the state," Holm and Jentoft (1996) also significantly substantiate other conceptual domains such as "community linkages," "property rights" and the "organization of production." According to Holm and Jentoft (1996) the closely knit social structure of Norwegian coastal communities greatly facilitated the growth of salmon aquaculture. Property rights were legitimated by the state through licensing and designed to preserve small-scale salmon aquaculture.

Holm and Jentoft (1996) also discuss the economic organization of Norwegian salmon aquaculture production in terms of marketing, economies of scale and the entry of private corporations in a politically conservative era. As a result, overproduction of salmon and increased international competition will continue to create a volatile set of conditions around this emerging global commodity.

Likewise, other contributions fall under these conceptual threads. A chapter by Torres on shrimp culture in Mexico can be extended to include class conflict, underemployment, corporatization, farmer cooperatives, organization of production and user-group conflicts, besides the editor-identified property rights and community linkage themes. In short, Torres (1996) undertakes an ethnographic account of two shrimp aquaculture cooperative projects sponsored by the Mexican government. In both cases, the consequences negatively impacted the community. In one community, land use conflicts developed as well as increased competition for resources when a corporation took control of the pond complex. In the other community, the shrimp culture cooperative disintegrated due to what Torres (1996: 188) surmises as "the division of this community into two politically charged segments." Despite a wealth of ethnographic data which implicates the negative social consequences of shrimp aquaculture, Torres (1996:189) conservatively concludes with "the need to take social structure and cultural context into consideration when introducing technical innovations such as mariculture."

These two examples from Holm and Jentoft (1996) and Torres (1996) illustrate that social scientists do in fact problematize society. On one hand, the translation of aquaculture into a sociological discourse advances a tentative conceptual understanding of the phenomena, proposes hypotheses, and suggests concerns. On the other hand, the reliance on exclusive social factors puts aquaculture development on a social deterministic basis. As a result aquaculture development remains partial and poorly understood when compared to agriculture.

The Adoption and Diffusion of Innovations

In Aquacultural Development the dominant theoretical framework is the adoption and diffusion of innovations. In outlining future research directions, the editors (1996:8) state that:

> considerable scope exists for research on adoption and diffusion of innovations in aquaculture. Standard research along these lines focuses on characteristics of early adopters and mechanisms for the diffusion of technology (Rogers 1983).

The use of adoption and diffusion of innovations is traceable to the first involvements by social scientists in tropical development projects. In Aquacultural Development, every contribution, with the exception of a chapter on a scientific controversy refers to the adoption and diffusion of innovations. In the majority of cases, the process by which adoption and diffusion of aquacultural innovations occurs is not specified in any substantive manner. For example, Aarset and Foss (1996) describe the relationship between institutions and the organization of cod aquaculture in Norway. The scant "theoretical framework" in this chapter by Aarset and Foss (1996:43-44) utilizes:

> the concepts adaptation, imitation and innovation to describe general strategies. First, cod farmers may **adapt** to the existing structure of coastal fishing; second, they may **imitate** the structure of traditional salmon farming; and third, they may develop an entirely new approach for organizing -- the strategy of **innovation.**

Aarset and Foss (1996) do no more than this in terms of theoretical development.

In other chapters such as Ruddle (1996) and Moehl and Molnar (1996) the adoption and diffusion of innovations is applied on "micro" and "macro" levels of analyses. For example, Ruddle's (1996) micro analysis focuses on the sociocultural-cultural level of the "rural African household." Ruddle (1996: 227) concludes that:

> In large part, failures in promoting fish farming development have stemmed from social, cultural and economic causes. . . . Household and community factors play a major role in the successful adoption of an innovation like fish farming, and its continuing development.

Critically, Ruddle (1996) does not resolve the micro/macro distinction to account for aquacultural development in Africa.

In contrast, Moehl and Molnar (1996) address the macro dimensions of aquaculture development in Rwanda. In reviewing Auburn University's National Fish Culture Project in Rwanda, Moehl and Molnar (1996:242) claim that:

> The extension effort successfully diffused a viable technology that was popular among farmers and widely emulated by their neighbors. Aquaculture succeeded in Rwanda because it was properly supported during the initial diffusion stage.

While the accuracy of these claims was discussed in Chapter 2 of this dissertation (pp. 58-60), Moehl and Molnar (1996:239) use adoption and diffusion of aquaculture in Rwanda to account for how aquaculture development came about from a top-down national aid-sponsored planning and project initiative:

> A period of 10 years is generally accepted as a realistic period for the diffusion of aquaculture innovations (FAO 1987:78). The initial diffusion period is then followed by a longer period of industry development and accelerating technological advancement. Extension plays a central role in the initial diffusion and subsequent intensification of aquaculture.

In short, the adoption and diffusion of aquacultural innovations in the Rwandan case is used to legitimate aid agency decision making apparatus which strictly emphasizes technoscientific choices made by a few scientists.

In Aquacultural Development, Skladany (1996) is the only contributor who takes a social constructivist view in analyzing a scientific controversy concerning aquaculture practices and influenza pandemics. In this light, the editors (1996:16) briefly address "social constructivism" when they state:

> Sociologists would argue that aquaculture is fundamentally a social construction that has to be studied as such. Aquaculture is not simply a technical process, but one that involves social relationships. The structures of these relationships are influenced by social forces. That is, the power of social groups interested in aquaculture production comes to be reflected in its

> organization. Thus, aquacultural development is a political process which governments, as the ultimate level of force, clearly have a part to play.

This quote reveals a misunderstanding of "social constructivism" because the editors separate technology and social relationships. A social constructivist understands that "as such" *both* technology and social relationships cannot be separated. Moreover, misunderstanding social constructivism also leads to the editors to portray Skladany's (1996) contribution as one pertaining to "environmental impacts" rather than about the social construction of science and society.

Aquaculture as Rural Development

Overall, contributors to Aquacultural Development situate fish farming within the context of rural development. The authors implicitly endorse aquaculture as a highly desirable rural development activity. They don't question the activity in terms of other alternatives. For example, Moehl and Molnar (1996) take a top-down developmentalist approach in describing past efforts in Rwanda. Despite some serious questions about the overall feasibility of aquaculture and the minuscule scale of its development in the country, they ignore other food alternatives which have historically served rural Rwandan populations. Other contributors to Aquacultural Development such as Dwire (1996), Torres (1996) and Weeks and Sturmer (1996) address aquaculture conflicts and projects concluding that more attention to the social, economic and cultural context would mitigate conflicts and push projects on to success. In short, all of this is an implicit endorsement of aquaculture as rural development with a call for attendant state institution building and policy processes for promoting growth and mitigating conflicts.

Along these lines, another problematic area in Aquacultural Development pertains to future directions of various case study scenarios. In general, social scientist contributors call for sound policy and institutional frameworks to promote sustainable aquacultural development, a concept which is never defined. They appeal to "political will" to rectify problems associated with aquaculture development. For example, Muluk and Bailey (1996) call on the Indonesian government to reassert political will through effective policy measures in regards to regulating coastal shrimp aquaculture. Perez et al., (1996) in discussing catfish production in western Alabama recommend that in the design of catfish research and extension programs, the diversity of farm production needs to taken into clearer account by policymakers. Dwire (1996) suggests that social science research can mitigate conflicts over aquaculture siting for the state. Torres (1996) and Ruddle (1996) both note that development policymakers and planners are at fault for ignoring social factors in aquaculture development.

Problematizing Aquaculture Technoscience

In Aquacultural Development the editors and the majority of contributors distance themselves from "technoscience" while arguing for more research effort on the purely "social aspects" of aquacultural development. Yet as Skladany and Harris (1996) have argued: by ignoring technoscience, social scientists attend to only the visible effects related to aquaculture development "out there." Skladany and Harris (1996) examined the growth of global aquaculture and find that for a given cultured species, technoscience development such as hatcheries are key developments which illustrate how capture fisheries are translated into particular aquaculture/social systems. In other words, the study of technoscience is a necessary part of sociological analysis (Callon 1986; 1987; Latour 1987; 1993).

The editors of Aquacultural Development refer to a chapter by Skladany (1996) as one that is primarily associated with potential environmental impacts. Under "environmental impacts" Bailey et al. (1996:9) state, the chapter:

> recounts the controversy among scientists concerning the possibility of viral epidemics in human populations caused by the practice of integrated fish farming with other types of food production, such as pigs and poultry.

The editors miss the theoretical intent of this chapter. In short, the potential environmental impacts associated with integrated aquaculture are highly uncertain and contingent. The controversy has not clearly not reached any sense of closure. Skladany (1996) deconstructs an ongoing *controversy*, that is a public dispute, between two groups of scientists. Virologists (based at virology institutes in Europe) claim that certain integrated farming practices involving a fish pond can lead to global influenza pandemics. Integrated aquaculture proponents (based at AIT and ICLARM) dispute this claim by bringing in field survey data which implicates animal husbandry, especially in China.

As the controversy continues, both groups of scientists marshal evidence, which becomes technically "harder," and both groups construct "societies" in order to situate their claims. The chapter makes the point that during the course of a controversy, scientists intertwine elements of society a well as technoscience in a heterogeneous manner. "Environmental impacts" may be an outcome of human and non-human activity which is not settled during the course of the influenza-integrated aquaculture controversy. It is ongoing and it remains to be seen "on whose behalf Nature will talk" (Latour 1987:95).

An Alternative Reading from Actor Network Theory

Lastly, by not taking into account aquaculture technoscience, contributors miss important opportunities to elaborate a theorizing of aquaculture. For example, Pollnac and Sihombing (1996) describe a successful cage culture project established in a multi-user body of freshwater, Lake Toba, Indonesia. Previous efforts with cage culture of common carp (Cyprinus carpio) failed due to inadequate feed, seed supply and technical knowledge. Pollnac and Sihombing (1996) ask why the cage culture project was a success when it had failed before. They identify six success factors: a technical suggestion made to reduce cage size to one cubic meter; the relatively low cost of operating such a cage; the suitability of raising common carp in cages; the close coordination between the technical expert and an NGO resulting in establishing effective technical guidelines; the effectiveness of the NGO in organizing and facilitating the fish farmer groups in training, credit and production activities. Finally, Lake Toba is deep and relatively nutrient poor and the surrounding area has low population density. As a result, potential conflicts and pollution were minimized because the Lake provides an ideal environment for this activity.

Alternatively, the chapter by Pollnac and Sihombing (1996) can be examined from the perspective of Actor Network Theory (Callon 1986; 1987; Latour 1987; 1993; Law 1992; 1994). While fully discussed in the next chapter, in brief, actor networks are both theory and methods. The radical departure made by actor network theorists is that the "social" is "nothing other than patterned networks of heterogeneous materials" composed of human *and non-human* entities (Law 1992:381). Rather than reduce the human to a social "heap" as the sociologists and anthropologists of aquaculture do, or reduce the technical to a scientific "heap" as aquacultural scientists do, actor network theorists state that "there is no reason to assume a priori, that *either* objects *or* people in general determine the character of social change or stability" (Law 1992:383).

The chapter by Pollnac and Sihombing (1986) can be read in this manner. They identify six success factors which are nothing more than patterned networks of heterogeneous materials. These materials such as NGOs, cages, common carp and farmers were "juxtaposed into a patterned network which overcomes their resistance" (Law 1992:381). In contrast to the adoption and diffusion of innovations which locates resistance in the subgroup "laggards", the developmental "success" of cage culture in Lake Toba, Indonesia can be more symmetrically attributed to this set of network dynamics involving both humans and non-humans.

In sum, Aquacultural Development lacks theoretical development and relies on social determinism as the means of development. In the majority of the chapters, the adoption and diffusion of innovations remains implicit without any substantive articulation outside of problematic micro/macro distinctions. The volume illustrates social scientists' avoidance of problematizing technoscience. Social scientists ground their analyses in social categories which results in social deterministic accounts of aquaculture and by inference rural development. This lack of theoretical cohesion reveals weaknesses which are characteristic of this particular volume and the field as a whole. The next two sections examine some political economic and participatory research accounts of aquaculture development.

Political Economic Approaches

In the sociology of aquaculture, a growing number of scholars have examined aquaculture from a political economic framework. In particular, Meltzoff and Li Puma (1986), Stonich (1992) and Skladany and Harris (1995) have advanced critical analyses of coastal shrimp aquaculture in terms of coastal zone management, poverty and global capitalist development. Much of the current writing and research on shrimp culture by sociologists and anthropologists was influenced by Meltzoff and Li Puma's (1986) analysis of shrimp mariculture in Ecuador. What is important about this article is that many of the current policy strategies being advocated by international donors seem unaware or unconcerned with the inherent contradictions apparent in coastal zone management schemes. In other words, Meltzoff and Li Puma's (1986) article holds as much critical relevance today as it did at the time the fieldwork was carried out in 1985.

Meltzoff and Li Puma (1986) were able to anticipate the growth of global shrimp culture by drawing on the case of Ecuador, an early entrant into industrial scale shrimp aquaculture. More importantly, they frame shrimp culture's development in terms of "First World" donor supported transfer of coastal zone management policy to the Ecuadorean coastal zone. Meltzoff and Li Puma (1986: 349) point out contradictions in this strategy by analyzing:

> local concepts of investment and conservation, the role of government and the law and the influence of the social economy on mariculture development. It illuminates how local use and management of coastal resources is inseparable from specifically Ecuadorean cultural concepts, institutions and practices.

They (1986:376) make the remarkably accurate prediction that:

> given the great need, it is clear that development agencies will continue to foster CZM in Ecuador and other Third World nations. It is equally clear, however, that, developed countries cannot simply transplant their own idealized programs and institutional arrangements. Coastal zone issues and policies are organically linked to determinate social, economic and political structures such that coastal zone programs inconsistent with these structures will wither.

These points are further elaborated by Skladany and Harris (1995) in their analysis of the global shrimp industry. Skladany and Harris (1995: 186) argue that transnational corporations utilize a "slash and burn" strategy where:

> the role of the state can be viewed as a mere backdrop against which rapid capital flows, international finance, technoscientific sophistry, environmental degradation, and social injustice are perpetuated by highly mobile TNCs.

They conclude that these contradictions will only become more exacerbated in the foreseeable future and are not amenable to coastal zone management schemes.

Stonich (1992) is able to effectively link the export of traditional agricultural commodities to the development of new non-traditional agriculture export commodities such as industrial-scale shrimp culture situated in the Gulf of Fonseca, Honduras. Stonich's (1992: 385) work, demonstrates "the systemic interconnections among the dynamics of agricultural development, patterns of capitalist accumulation, rural inequality and impoverishment, and problems of environmental destruction." Stonich (1992: 385) concludes her article by calling on the need for development policies to directly address increased social inequality and stratification "in order to reverse environmental decline."

These analyses critically highlight the contradictions in industrial aquaculture development. Moreover, they closely parallel efforts in the sociology of agriculture (e.g., Busch and Lacey 1983; Busch et al. 1991; Friedland 1984; Kloppenberg 1991). At the same time, these political economic accounts of aquaculture development assume an a priori distinction between the macro and micro. In short, political economic accounts favor macro categories in explaining the micro conditions which leaves the connections between the two problematic. It makes more sense to dissolve this arbitrary distinction and view them as *outcomes* of a set of relations (Juska and Busch 1994; Law 1992; Murdoch 1994). Likewise, participatory research strategies suffer from the same shortcoming in terms of a micro emphasis.

Participatory Research

In aquaculture development, participatory research strategies are viewed as methods rather than theories. In this manner, Ruddle's (1996) work reflects an interpretation of these techniques which are derived from "holistic" and farming systems ways to gather data. Largely the result of ICLARM/GTZ field work in Malawi and elsewhere, participatory research methods are directed at practicing aquacultural scientists and extensionists (Lightfoot 1990; Lightfoot and Tuan 1990; Lightfoot et al. 1991a: 1991b; Lightfoot et al., 1992; Lightfoot et al. 1993; Morales 1990; Noble and Kadongola 1990; Pullin 1992; Worby 1992).

These methods which are articulated in a series of training videos, handbooks and short articles develop one common theme: a closer collaborative interaction between scientists, including sociologists and anthropologists, and farmers is required. For example, Lightfoot (1990: 9) recognizes the need for a "new sustainable farming systems" approach but charges that "tunnel vision" currently constrains researchers who are "locked into their narrow disciplines and sectoral issues." Lightfoot (1990) further points to divisions between social and biological scientists at the university research level, a point also made by AIT's (1994) Partners in Development. Again, the adoption and diffusion of aquacultural innovations provides an implicit theoretical basis for participatory research. Participatory research techniques are framed at the micro level in conjunction with an agroecosystems modeling dynamic (e.g., Lightfoot 1990). The primary focus is on methodology, such as videos depicting farmers drawing pictures which describe their on-farm resource flows. In the final analysis, the researchers alone are responsible for validating these systems with an objective of improving them.

The general conclusion regarding contributions from social scientists shows them following the developmental lead and advocacy positions of production oriented aquacultural scientists and non-social scientist decision makers. Social science accounts of aquaculture development consistently advocate for a greater awareness of social factors. Social scientists appeal for policy decisions, informed by social factors, which can address conflicts brought on by industrial-scale aquaculture or small-scale farmer development. The overwhelming majority of studies of aquaculture development carry implicit assumptions that farmers simply will or will not *adopt* new production technologies through various *diffusion* mechanisms. In essence these studies which are often linked to development project settings, domestic programs and/or funding requests, are best seen as advocacy or service documents designed to specifically promote or appeal to funding agencies (Hoben 1980; Morgan 1985). As a whole, the literature suffers from a well developed theoretical approach and orientation.

In general, the sociology of aquaculture literature shows that constraints to adoption and diffusion of new technologies stem from key variables inherent in farmer practices, institutional arrangements and policy formulations. Throughout the literature, technoscience is not problematized within the scope of sociological analysis but is seen as "interacting with" or "separate" from social variables (e.g., Harrison 1991). As a result, many studies find weak linkages between social aspects such as policies, extensionists and farmers. This "social" diffusion model is then used to account for low adoption rates (see Callon 1986; especially Latour 1987: 132-144). As a consequence, the sociology of aquaculture has not addressed or elaborated on fundamental questions concerning technoscience and development.

As noted earlier, aquacultural scientists act as "sociologists." In their writings, aquaculturists essentially reverse the position of the sociologists of aquaculture. They avoid problematizing society. However, scientists' develop an implicit "sociology" in their writings on technoscience. As the representative examples illustrate in the next section, scientists construct "societies" around a given culture system and then argue that obstacles can be overcome if the proper technoscientific pathways. The notion of technological progress underscores society's development.

PROBLEMATIZING SOCIETY? AQUACULTURISTS' VIEWS

Following Callon (1986:1987), the claim is advanced that influential *quasi-sociological* accounts of aquaculture development have been authored by aquacultural and agricultural scientists (e.g., Bardach et al. 1972; Ben-Yami 1986; Boyd 1994; Edwards et al.

1988; Moss et al. 1979; Pillay 1990; Schmittou n.d.). Two representative accounts, one by Boyd (1994) and AIT (1988; 1994) provide examples aquaculture scientists indirectly acting as sociologists.

A Position Paper

In the context of the Pond Dynamics Aquaculture Collaborative Research Support Program's (PD/A CRSP) 1994 annual meeting, Boyd (1994) through a "discussion paper" argued for refocusing the efforts of selected scientists in the CRSP renewal proposal for the five year period 1995-2000. Boyd (1994) argues that:

> the potential of the PD/A CRSP to advance the frontiers of pond management will be lost if the idea of increasing the number of participants and decreasing the role of expatriate researchers is adopted.

Boyd (1994) is taking exception to fund proposals from researchers with no prior PD/A CRSP experience. The inclusion of these researchers "would reduce necessary efforts at each site and increase the work load of site researchers." Boyd (1994) argues that these inexperienced researchers "would result in another learning phase for new researchers," and the effort would be "destined to mediocrity and failure."

Over the past ten years, Boyd (1994) notes that the P D/A CRSP research agenda was concerned with fertilization, water quality and fish pond production. In conjunction with these research priorities, he argues that an additional and complementary effort be made on pond soils and the environmental effects of aquaculture. Boyd (1994) proposes specific research activities and individual scientists who possess the expertise associated with this agenda.

Boyd's (1994) argument is strategic. There are two stages to it: (1) inexperienced researchers will create problems by diluting past research gains, and; (2) a refocusing on pond soils and the environmental effects of intensive pond aquaculture systems can lead to a series of tangible benefits applicable to a wide variety of cultured species. Boyd (1994) backs up the second set of claims through a review of what has been accomplished, where gaps remain and where data is required. He shows that a focus on pond soils is the next logical step. He then adds that "there is a strong need to extend the research findings to farmers at all sites" and suggests that an aquacultural scientist be made responsible for this task. Thus Boyd (1994) is attempting to speak on behalf of a select group of experienced PD/A CRSP researchers by promoting his program within the social setting of an annual meeting.

An interpretation of Boyd's (1994) position suggests that it carries an implicit sociology because he proposes scientific [social] reorganization, restructuring, redefining and redistribution of social roles and resources that scientists and other actors will take in the renewed PD/A CRSP (Law and Callon 1988). Concretely, this paper was strategically positioned around decisions over funding at the 1994 annual PD/A CRSP Conference. In the position paper, Boyd is simply trying to insert a logical "next step" into the PD/A CRSP research agenda. This effort attempts to exclude an "opening up" of the CRSP to inexperienced aquaculture researchers from smaller institutions. These researchers were proposing activities not in line with past CRSP efforts.

In short, Boyd advocates an intensive focus on pond soils and the environmental effects of pond aquaculture. If adopted Boyd's proposal reorganizes research [social] effort and resources on those systems where heavy loading of organic matter creates sediment buildup and anaerobic conditions which adversely affect shrimp and fish production. He suggests that the whole array of social actors focus on those systems where intensive (e.g., high feeding, fertilization, high stocking densities, water quality, aquatic organisms and metabolism etc.) aquaculture is practiced.

Concretely, this takes place in intensive shrimp and finfish ponds. Low input systems and actors are marginalized. The paper's argument attempts to simultaneously alter the organization of the research project, exclude inexperienced actors, and by extension, address the needs of new clients and the non-human entities which comprise intensive pond aquaculture systems. If successful, actors will acquire new social definitions and roles which have been created by a scientist spokesperson (Callon 1986: 1987; Latour 1987; Law and Callon 1988).

AIT's Partners in Development

In a larger institutional sense, Edwards et al. (1988) advocate greater development of tropical aquacultural research and education. They compare the poorly developed tropical aquacultural research base with that of agriculture. They focus on institutional development of a "new farming systems research approach" directed towards improved and scientifically validated crop-livestock-fish farming systems. Social groups identified are students (future scientists, administrators, developers) and especially small-scale farmers in Asia. Parallels are also drawn for other regions of the world, especially Africa, with Asian institutions and organizations taking the lead in the formation of a proposed international regime for cooperative research in tropical agriculture-aquaculture.

This document was written at a time when the Asian Institute of Technology was rising in stature in terms of developing a comprehensive tropical crop-livestock-fish research, development and education program (see Chapter 2 pp. 68-72). A large outreach program had recently been funded by the British Overseas Development Administration. In connection with the more advanced 1994 Partners in Development: The Promotion of Sustainable Aquaculture we find strong evidence that a representative spokesperson (Peter Edwards from AIT) is articulating a relatively comprehensive perspective on tropical aquaculture research, development and outreach. There are no other comparable outlooks.

In the absence of any other such comprehensive vision on aquaculture, Partners in Development requires attention. The document is divided into two sections. The first section provides basic definitions and an overview Asian aquaculture development, research and education. The second section provides an overview of AIT's aquaculture program and proposes a revised strategy for development "in which a closer partnership with national institutions is the cornerstone" (AIT 1994: iv).

In section one, AIT (1994 :1) defines aquaculture "simply as farming in water" and draw analogies to the cultivation of crops and animal husbandry. After comparing aquaculture with capture fisheries, the notion of sustainable aquaculture systems is put forth in the figure reproduced below:

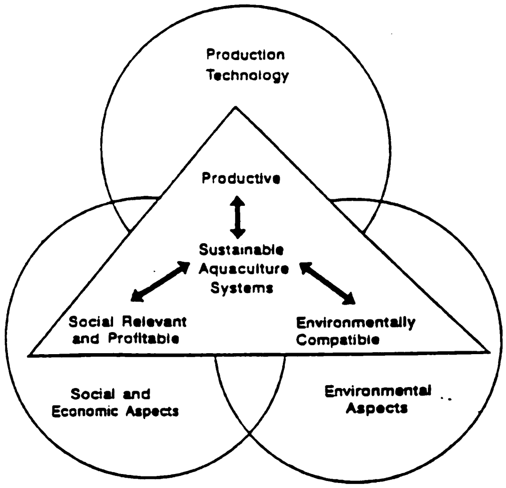

Figure 4.1: Components of Sustainable Aquaculture Systems (from AIT 1994:2).

It is important to note the implied symmetry that the figure conveys. The figure and subsequent text builds on the earlier definition of aquaculture by adding to it the qualifying concept of sustainability. Sustainable aquaculture is rationalized through considerations such as offering an attractive option to competing resource uses, resource availability to small-scale farmers, and environmental soundness. By tying aquaculture into the Bruntland Report's emphasis on the environment and the development priority of the world's poor, AIT's definition of sustainable aquaculture acquires a broader social meaning. AIT views sustainable aquaculture in terms of three interrelated components: production technology, social and economic aspects and environmental aspects.

Production technology is divided into cultured species, culture facility and husbandry. The main characteristics of these production components were reviewed in the last chapter but AIT (1994) adds a twist by building upon definition after (sub)definition. This sequence leads the reader through a further division of the three initial components. For example, husbandry is divided into seed, nursery and grow-out. From there, the three major types of aquaculture are divided into extensive, semi-intensive and intensive systems. AIT (1994:3) notes that "there are fundamental technical as well as social and economic differences between extensive/semi-intensive and intensive aquaculture systems." These differences are defined in terms of input costs which are comprised mainly of the addition of feeds/ fertilizers.

The types of aquaculture and the correspondent considerations of feeds and fertilizers lead AIT (1994) to establish low-cost input systems as suitable for "resource-poor small-scale farmers." The impetus however, is clearly directed toward intensification of aquaculture. This is the case for the following reasons (1), a semi-intensive system can be developed from an extensive system, (2), inputs can be farm by-products, (3), the cost of off-farm fertilizers and supplementary feeds (farm by-products) is cheaper than commercially and nutritionally balanced feeds, (4) the produce can be sold at lower cost making it more available to lower income groups thereby improving aggregate nutrition and household welfare, and (5) low-input systems provide resource-poor farmers a low-risk basis by which to gradually increase overall farm productivity and efficiency (AIT 1994).

This exposition on sustainable aquaculture is refreshing in many ways. First, a definition of aquaculture is sequentially linked to sustainability. Through consideration of production technology, AIT (1994) effortlessly moves into the social sphere using technoscience (feed and fertilizers) as a key translation (Callon 1986:1987). This illustrates the intertwined social and technoscientific characteristics of aquaculture. Moreover, the rationale for resource-poor small-scale farmers also implies an intensification which captures the changing dynamics of aquaculture production technology in Southeast Asia today.

AIT (1994:4) addresses the social and economic aspects of aquaculture by noting that they are greatly constrained by a lack of appreciation "at all levels from the central government down to the farm household." Similar to Weeks (1992), aquaculture should be viewed as rural development. AIT then divides social and economic aspects into two levels, the macro and the micro. Macro social and economic aspects pertain to international, national and regional levels and encompass aggregate trade, inequity, development, and the "social characteristics and social attitudes towards fish and fish culture" (AIT 1994:4). The micro level pertains to community and farm household levels. The main "questions concern the alternative uses of resources: land, water and farm by-products, and labor and capital" (AIT 1994:4). In short, the advantages of aquaculture need to be viewed against other resource use patterns with the possibility of integrating fish culture into the total farming system.

This section on the social and economic aspects of sustainable aquaculture is the weakest part of the document. It clearly reflects "development project" thinking in terms of questions formed around the problematic of "how to measure the social" which is divorced from the technoscientific. As noted earlier, the distinction between the "macro" and the "micro" levels of social and economic aspects entails an a priori separation of the two which is better seen as an outcome of a set of relations (see especially Juska and Busch 1994: 581-82; Law 1992; Murdoch 1994: 6). Moreover, AIT (1994) displays an economistic orientation which reduces social questions to a systems diffusion model.

Lastly, the environment is addressed in terms of sustainable aquaculture. Surprisingly, AIT (1994: 5-6) defines the environment as "external to the aquaculture system and includes the natural resources used for aquaculture development such as land, water, nutrition and biological diversity." The claim is also made that there is a "two-way" interaction between the environment and aquaculture and that some of the effects "induced by human activities are becoming increasingly important in developing Asia" (AIT: 6). Urban pollution, intensive agriculture and industrialization are listed as examples of adverse environmental impacts on aquaculture systems.

According to AIT (1994: 6) aquaculture related environmental problems take form because they:

> arise from the rapid development and capitalization of the natural resource base in many developing countries and are often combined with poor planning and management practices. In addition the true `value' of the aquatic resource is invariably underestimated.

Furthermore, AIT (1994:6) adds:

> As the environment deteriorates and competition for resources such as water, land, and feed between aquaculture, capture fisheries and other sectors the environmental impact will worsen. Such problems are most likely to impact most heavily on small-scale farmers, rural poor and coastal zone dwellers, many of whom rely heavily on a productive aquatic environment as a source of food and employment. Although problems are recognized in most instances, their extent and severity have not been well defined.

Conversely, AIT (1994) adds that in some cases of integrated aquaculture, the environmental impacts can be beneficial. For example, livestock manure can be productively recycled into a fish pond thereby decreasing pollution with an overall result of fish for consumption and increasingly sales (see for example Costa-Pierce et al. 1991; Edwards et al. 1983: 1988; Engle and Skladany 1992; Little and Muir 1987; Pullin and Shehadeh 1982).

In closing, AIT (1994:7) suggests that "there is a need to gather quantitative information on both the impact of the environment on aquaculture and the impact of aquaculture on the environment." An optimal use strategy for aquaculture and natural resources needs to be considered from a cost-benefit analysis framework. Moreover, effective management and planning methods need to be developed in order to avoid past ecological, social and economic disasters such as coastal shrimp culture and some cage culture developments. In sum. rigorous information systems are required by farmers and planners alike.

AIT's Partners in Development attempts to articulate the whole field of aquaculture. Given the lack of a comprehensive interdisciplinary perspective, Partners in Development is the best example of a total aquaculture treatise. In short, AIT (1994) advances the case of aquaculture in terms of production technology by effectively linking it in definitional sequence to the concept of sustainability. They link sustainable aquaculture with social and technoscientific arenas by identifying social groups likely to make use of feeds and fertilizers within extensive, semi-intensive and intensive aquaculture systems. However, they fail to follow through with this mode of analysis in the social and economic and environmental sections.

Specifically, a problematic categorical split is introduced in the exposition of poorly understood social and economic aspects of sustainable aquaculture. Even more problematic is the "macro/micro" split between different levels of social and economic phenomena. In the environmental section, the environmental and aquacultural dimensions are viewed as being "induced" by human intervention therefore introducing another skewing of the tripartite and implied symmetry presented in Figure 1. Moreover, AIT (1994) lapses into narrower development project categories while addressing very broad environmental considerations which surpasses short-term projects.

A "revised strategy for development" linking AIT in partnerships with national institutions concludes the document. Specifically, the criticism is made that uncoordinated activities in education/training, research and outreach have constrained AIT's program and many other projects in the past. For example, an AIT graduate may find little support upon return to the home work environment. Basing applications on academic merit and individual criteria from a large number of countries in the region has not been related to a specific development program whereby the graduate may be effective upon return. Building from the gains from AIT's progress in its outreach program in the region, a more focused approach is envisioned through intensive collaboration with national institutions.

AIT's revised development strategy, hailed as a "novel, more focused approach involving partnership with national institutions" entails four interconnected categories: institutional planning, educational curricula, research and development projects, and information dissemination and exchange (AIT 1994: 67). In each category, AIT faculty and staff will work with national institution counterparts in a collaborative and participatory manner. In a very brief paragraph, planning is defined as needs assistance in terms of upgrading institutional capacities and taking into account the resources available for aquaculture development. More importantly, educational curriculum development is broadly defined as a key human resources component and is central to the revised development strategy. Because of its recognized expertise in Asian aquaculture systems, AIT proposes to take the regional lead at various levels of education (e.g., vocational, undergraduate and graduate) with national institution collaborators through a variety of programs (e.g., workshops, short-courses, degree programs). The results of this effort are "a home-grown curriculum, a syllabus for classroom learning and practical field experience, and local faculty capability to continue the curriculum development process" (AIT 1994:67).

Research and development projects serve to upgrade indigenous research capacity and extend the findings of AIT's strategic research throughout the region. Research conducted with national institutions is initially proposed to be adaptive but as research capacity is strengthened it will eventually take on strategic parameters. Research and development projects are also tied into the curriculum development process at local institutions. The suggestion is made that AIT graduate students conduct thesis research on local problems within their country of origin. Moreover, given the recent political transformations in Vietnam, Cambodia and Laos, AIT proposes to act as a "sieve" by which to disseminate "external" sources of information. In other words, AIT is proposing to act as a "gatekeeper" in Southeast Asia. Coupled with the recent setting up of numerous activities and offices in other countries through AIT's extensive outreach program, the aquaculture program is strategically positioning itself to exert significant influence over aquaculture development in the region.

In conclusion, this section illustrates the pronounced role that key aquacultural scientists play in articulating a field of aquaculture research and development. They act implicitly as sociologists in terms of simultaneously attempting to engineer social contexts and organizations by which to insert and control the effects of technoscience. These scientists attempt to "act at a distance" (Latour 1987). In contrast to the reverse positions embodied by sociologists and anthropologists, aquaculturists-sociologists such as Boyd (1994) and AIT (1994) attempt to articulate and influence the shape of the relatively "new" field of modern aquaculture research and development. These writers, "constantly construct hypotheses and forms of argument that pull . . . participants into the field of sociological analyses" (Callon 1987: 83). These appeals, hypotheses and arguments are constructed in a manner which reveals the critically important and hitherto overlooked position of technoscience in terms of sociological analysis. The proposed frameworks put forth by Boyd (1994) and AIT (1994), are best seen as appeals being made to donors as well as other scientists. These appeals underscore the view of aquacultural technoscience as a bureaucratic field (Bauin 1986). They are as social as they are technical. It remains to be seen whether these scientists will be successful in their efforts to enroll relevant actors into their long-term plans. Nonetheless, these scientists act as sociologists by developing proposals which indirectly elicit a social context for their technoscience.

CONCLUSION

Whether articulated by either social or aquacultural scientists, the literature examined in this chapter displays peculiar asymmetries which distort and provide partial accounts of aquaculture research and development. While useful in narrower disciplinary terms and rationalizing project interventions and funding proposals, these studies overlook technoscience in the making.

In sum, I argue that sociological and aquacultural schemes based on farming systems research, agricultural modernization, adoption/diffusion, appropriate technology, benefit-flow strategy, institutional strategy, sociocultural variables, property regimes, community development, rural development and capture fisheries have become less persuasive and even arbitrary due to accelerated *change and extension of aquaculture research and development networks*.

Thus, given these problematics which essentially avoid either problematizing science or society, the next chapter recasts the sociology of aquaculture through the sociology of scientific knowledge. In particular, actor network theory and methods will be highlighted as a means to overcome the problematic divides that summarize our current efforts to articulate a broader approach to the sociology of aquaculture.

Chapter 4

RETHINKING AQUACULTURE THROUGH THE SOCIOLOGY OF SCIENTIFIC KNOWLEDGE

INTRODUCTION

The previous two chapters examined aquacultural development and recent sociological efforts to understand it. My intent was to historically situate the emergence of modern aquaculture as a science and its sociological development. In part, aquaculture's social history illustrates that within its developmental discourse social scientists' contributions are subordinated to the lead of production-oriented biological scientists and aid officials. Social scientists undertake activities which promote and support the claims made by scientists and aid agency officials. In other words, scientific and institutional forms of modern aquaculture have emerged through the concerted efforts of bureaucrats and certain scientists who have created and attempt to maintain a field (Bauin 1986). As a result, social science contributions to aquaculture can be viewed as legitimating institution building for the continued growth of the field.

Overall, the emergence of industrial scale aquaculture has stimulated greater academic and critical interest in the field. In brief, this growing literature consists of peculiar asymmetries resulting in partial accounts of aquaculture development. On the one hand sociologists and anthropologists ignore aquacultural technoscience. They separate science and society by taking technoscience as given and then proceed to analyze aquaculture from an exclusive "social" realm. Thus, sociological analyses are reducible to social factors. As a result, the sociology of aquaculture exhibits social determinism.

Conversely, aquacultural scientists start from the technoscience of a particular culture system and then create innovators, ideas and societies to account for the effects of the entities and associations they attempt to insert into it (Latour 1987). Innovators, ideas and societies are constructed from juxtaposed bits and pieces of biographical, social, technical, political and economic entities (Law 1987). In many development cases aquacultural scientists *act* as sociologists. Similar to social scientists, aquacultural scientists present asymmetrical accounts of aquacultural development. In the final analysis societies are reducible to technoscientific determinism.

In this chapter, the argument is made that fresh theoretical resources from the sociology of scientific knowledge (SSK) are available to rethink aquacultural technoscience. Specifically, actor network theory (ANT) offers a means by which to recast a series of problematics and questions unaddressed by conventional disciplinary thinking on aquacultural research and development. Actor network theory breaks with these conventions because analysis is extended to *things* as well as people -- in the same manner.

Actor network theorists attempt to overcome problematic categorical divides between people and things (Latour 1993; Law 1994). How and why actor network theorists take this position requires careful examination of the principles and relational materialism which underlie its dynamic form of theory and method. Moreover, actor network sociology departs from discipline-bound conventions in that its language is couched in the same terms for all *actants*. While there are important ontological reasons for this position, ANT's language radically diverges from that of conventional social science discourse. However, it is also critical, in light of the previous chapter, to consider that the study of aquaculture requires new approaches and a new language. In this volume, actor network theory is utilized as a substantive means to address and advance understanding of aquaculture research and development.

This chapter is first organized around a restatement of the major problems associated with the sociology of aquaculture. I trace these problems to limitations in the diffusion of innovations model. Through a priori assumptions, diffusion theory leaves unattended a series of problematics and questions in the sociology of aquaculture. Second, through a brief sketch of the development of the sociology of scientific knowledge I introduce actor network theory. In conclusion, actor network theory is proposed as a pragmatic means by which to address unanswered questions associated with the aquacultural technoscience. These questions pertain to: How do scientists go about doing research and development? How does one account for the effects of aquacultural research and development?

THE PROBLEM

In the previous chapter, the fledgling sociology of aquaculture was characterized as having several limitations. To summarize, weaknesses in the sociology of aquaculture are traceable to diffusion theory which dominates the writing on aquacultural development.

Simply put, we don't know how aquacultural scientists go about "doing aquaculture," nor do we adequately account for the effects of research and development. In analyzing aquacultural development, both sociologists and aquaculturists treat technoscience as a special status category. Causation, intentions and meaning are sought in a social realm by social scientists and in a technoscientific realm by aquacultural scientists. Ignored in these analyses are the relational material effects which give aquacultural technoscience its definition as a particular mode of ordering. In other words, the "stuff" of aquacultural technoscience (e.g., fish, gene constructs, laboratories, ponds, hatcheries, scientists, farmers etc.) remain assumed or arbitrarily inserted into accounts of its sociology. As a result, only partial analyses prevail in the field.

Applied and Theoretical Limitations in the Sociology of Aquaculture

In tracing limitations in the sociology of aquaculture, the observation is put forth that the manner in which the field has developed has significantly shaped its overall outlook. In an applied sense the sociology of aquaculture generally reflects *ad hoc* involvements by social scientists in tropical development projects. In more recent domestic programs "the lessons learned" are simply transferred from the previous tropical development experiences (e.g., Fiske and Ple 1992). These interactional dynamics have restricted a full fledged critical examination of aquaculture and especially its technoscience. Following the advocacy lead of development professionals, including aquacultural scientists, social scientists merely supplement justifications in order to legitimize the continued growth of the field.

For example, much of the previously reviewed literature on Rwanda (pp.52-60) clearly falls within this pattern. These settings favor pro-aquaculture innovations and production growth because the research and development agendas are set by scientists and aid administrators. These actors maintain a long-term presence during the project's life and "success" of the project is tied to career advancement, consultancies, travel and other opportunities. Moreover, given the hierarchical organization of aquacultural development, secondary social science research typically takes shape as an adjunct which depends on the short-term availability of extra funding to primary biologically driven programs. Worldwide there are very few long-term aquacultural social science research programs and where they exist the emphasis is on economics (e.g., ICLARM's Social Science Research Network).

In support of the above contentions a striking example of this generalized scenario took place in 1990 when I was asked by the USAID Pond Dynamics Aquaculture CRSP (PD/A CRSP) to conduct an impact assessment study of "new CRSP generated technologies." Upon arriving in Thailand, a CRSP research site, I quickly found out that pond dynamics research was largely confined to a few on-station activities. As a result, I was forced to scramble around Thailand's northeast in order to find actual farms which were using anything resembling experimental PD/A researcher inputs (e.g., tilapia and chicken manure). I accidentally stumbled onto a farming district using those inputs and proceeded to conduct four intensive farm case studies over a period of one month (Engle and Skladany 1992).

Upon returning to the United States, I was asked to write a report and produce a "one pager" summarizing results. At this time, I was informed by an AID official that the CRSP was shortly due for a U.S. Congressional review. As put to me by the AID official the "one pager" was crucial because "we are in a period of [Gulf] war!" This official felt that "external constituents," in this case Congress, would need a bit more persuading given the hyper-activity surrounding the Gulf War. Hence while writing up the report and one-page summary I was closely mentored and given suggestions by AID officials on how to present it in written form. Under this tutelage, I produced both a report and a glossy one page summary consisting of a series of hypothetical scenarios which were to be subject to further economic modeling exercises. We used a few elementary concepts from diffusion theory to drive the development side of the report and summary.

This example illustrates that diffusion theory research finds resonance with social and aquacultural scientists as well as aid agency officials. In short-term applied settings, the theory of diffusion of innovations provides a consensual basis for all parties to quickly justify the activity for external constituents. Put in other words, development professionals (and members of the U.S. Congress) all speak the rudiments of diffusion theory. Thus these implicit agreements become the standard criteria which shape and drive ad hoc social science research whether conducted by social or aquacultural scientists. Long-term actors such as aid officials and aquacultural scientists make the critical decisions, conduct the research and development and institutionalize various practices, procedures, and policies. In terms of social science involvements, diffusion theory fits the need for coherent momentum, results, structure and organization in support of the overall growth of aquaculture. Since diffusion theory is so predominant in the sociology of aquaculture it makes sense to examine its assumptions which are rarely articulated in the aquaculture literature.

The Adoption and Diffusion of Innovations

Building from applied settings, diffusion theory entails certain assumptions about the world. In essence, diffusion theory is a positivist theory of social change. Busch (1978) and Busch et al. (1991:40-44) argue that diffusion theory consists of the following central assumptions; ontological monism, objectivity of technical language, communication as monologue, tradition versus modernity and separateness. Ontological monism refers to a singular nature of being (Busch 1978; Runes 1974). Although Rogers (1983) notes different traditions of diffusion research, fundamental concepts, categories and mechanisms cohere into a single outlook which assumes a measurable and objective world consisting of physical and social objects "out there." In social systems, innovations arise and diffuse through specific communication mechanisms and steps. Moreover, ideal type adopter categories are comparable across a range of settings. Thus an early adopter of aquaculture in Thailand or Rwanda will exhibit the same types of attitudes and socioeconomic characteristics as one in Michigan. In sum, one world is posited with "objective rationality" separable from "subjective rationality" on the part of individuals (Busch 1978).

Closely related to diffusion theory's ontological monism is the assumption of the centrality of convergent (or divergent) communication embodied in the objectivity of technical language (Busch et al. 1991). As Rogers (1983:17) puts it, "Given that an innovation exists, communication must take place if the innovation is to spread beyond its inventor." In brief, various "communication channels" influence rates of adoption. In the diffusion of an innovation these are generally subjective, not objective evaluations made by adopters who are influenced to model and imitate near partners and peers (Rogers 1983).

Hence language is a key medium which holds communication (and subsequent adoption) of innovations together in the diffusion process. Here a key assumption is exposed by Busch (1978: 453) who aptly summarizes:

> They [Rogers et al.] appear inclined to assume that all normal, competent adults will attach univocal meaning and significance to particular words, phrases and sentences, when found in certain contexts. While there is room for misunderstanding, it occurs as a consequence of unnecessary ambiguities or erroneous usages introduced through communication.

As Busch et al. (1991) further note, differences in the purposes of language use are not readily recognized by diffusion theorists. For example, translating technical language into ordinary language is difficult and entails much more than a series of "communication steps" and direct language "translation" between scientists and farmers (cf. Molnar et al. 1996). Moreover, differences among the authors of technical language such as scientists are simply glossed over as innovations are assumed to share unequivocal meaning for all participants.

Therefore, in aquacultural development, one witnesses a steady stream of communications devices: cartoon books, videos and technical manuals "made simple." Aquacultural scientists author these materials in a language which assumes a single unequivocal set of meanings, intentions and practices as put forth by them. For example, a 1983 illustrated farmer manual by AIT (Edwards et al. 1983) depicts the rationale and simplified steps behind small-scale integrated Tilapia aquaculture. The AIT manual and its elaborated technical language is also representative of the widespread creation of more recent materials devoted to extending or modeling small-scale aquaculture from the monological view of scientists (e.g., ICLARM 1992; Lightfoot et al., 1991a: 1991b; Molnar et al. 1996; Morales 1991). Largely modeled on highly controlled AIT experimental pond research conducted at that time, the AIT manual states that many rural Thais are subject to low protein intake resulting in anatomical, physiological and social deficiencies (Edwards et al. 1983). From the authors' view, Tilapia are clearly desirable because of biological (e.g., fast growth) and what amounts to urban middle class consumptive (e.g., fried taste) qualities.

When examined closely these materials conflate an objectivity of technical language with intentionality (Busch 1978; Busch et al. 1991). For example, AIT's highly recommended choice of Tilapia, pond design, management and integration with ducks is put forth in a language consistent with AIT researcher assumptions, controls, meanings and ends. Moreover, the authors posit subsistence production as an end in itself. The manual elaborates on pond design and management which bears striking resemblance to AIT's experimental ponds and methods.

In contrast, as a participant observer of Thai aquaculture during this period I observed many instances of interpretive flexibility on the part of fish farmers. For example, ponds were explicitly designed to trap retreating wild fish stocks from large off-farm paddy areas. These open ponds sharply diverged from the closed AIT model. Farmers, for example, exhibited practices which were multi-purpose in order to secure fish, store water for livestock, garden and ensure an adequate rice crop. Farmers were responding to environmental extremes, immediate farming or household requirements, seasonal subsistence and some opportunities for off-farm sales (Heim et al. 1986).

In diffusion theory, technical manuals, videos and other extension materials represent key links in diffusion steps and communication channels. These materials are good examples of how scientists direct communication as monologue. There is little meaningful dialogue as communication is one-way from scientist to farmer (Busch et al. 1991). For instance, Tilapia is the culture fish of choice due to scientists' biologically based reasoning which bypasses the diverse social circumstances, preferences and practices of rural fish growers. When elicited by researchers, feedback is further subject to researcher based verification. In short, scientists hold views about farmers which are elaborated in their communications. Idealized sets of assumptions are derived from family subsistence or vaguely defined sustainable aquaculture informs scientists' monological communications. In these contexts, the communicative role of extension becomes the lynchpin towards inducing mass adoption and participation in science based and controlled research and development programs. In the diffusion model, scientists communicate through extension by endorsing a few options while saying little about a wide array of other possibilities available to and undertaken by farmers (Busch et al. 1991).

Above all, diffusion theory pits tradition against modernity (Busch et al. 1991). There is a pro-innovation bias throughout diffusion research, a point Rogers (1983: 99) recognizes:

> I believe that if diffusion scholars could more adequately see an innovation through the eyes of their respondents, including why the innovation was adopted, the diffusion researchers would be in a better position to shed their pro-innovation bias of the past.

On the surface Rogers (1983) seemingly calls for inclusive ethnographic approaches. Despite diffusion theory's anthropological tradition, however, its ontological monism inhibits more thoroughgoing and symmetrical cross-cultural applications. Rogers (1983: 92-112) recycles this shortcoming back into the diffusion framework and attempts to resolve it unconvincingly there. In contrast, Busch et al. (1991) state:

> From within the diffusion perspective, it is always "we" moderns against "those" traditionals . . . The disregard for tradition has often led scientists to jettison the experience that Third World people have of their particular agroclimatic zones.

In diffusion theory it follows then that the implicit problem is tradition. Adoption of modern innovations can lead to overcoming of tradition bound practices. For example, the aquacultural development literature is replete with scenarios advocating that modern aquacultural innovations are the next logical development step because of depleted traditional fishery stocks (e.g., Bailey et al. 1996; McGoodwin 1990). These scenarios mask the implicit divide which favors modern innovations such as aquaculture by excluding traditional fisheries and other protein sources. This is not to say that traditional fisheries are unlimited or unproblematic but that tradition and modernity are intertwined. For example, this point was recently recognized by AIT (1994:7) noting that wild fish, not necessarily aquaculture, will continue to play "an important role in the local fish supply" in many Asian locales. Likewise, after fifteen years of self-proclaimed development "success" in Rwanda only one hundred and forty hectares of fish ponds were in actual operation. In contrast, over three hundred thousand hectares of beans, a food protein staple, were in cultivation. Perhaps this says something more pointed about modern aquacultural development versus traditional crops, practices and choices in that country.

Finally, diffusion theorists separate science and society. Innovations simply emerge and "they are then either adopted by a willing audience or rejected by an unwilling audience" (Busch et al. 1991:44). This is precisely the central point in diffusion research: how an innovation gets adopted or rejected. But this view depends on a special status accorded to science separate from society. Innovations in the making are simply ignored or presented as an outcome of research and development (Rogers 1983). Latour (1987: 133) comments that the diffusion model is like a fairy tale; innovations seem to move about on their own accord:

> Spewed out by a few centres and laboratories, new things and beliefs are emerging, free floating through minds and hands, populating the world with replicas of themselves . . . it seems that the behaviour of people is *caused* by the diffusion of facts and machines. It is forgotten that the obedient behaviour of people is what turns the claims into facts and machines; the careful strategies that give the object the contours that will provide assent are also forgotten.

In diffusion theory innovations are a novel force with a life of their own. As Latour (1987) notes, the absurd consequences of inert objects embodying a novel force of their own must find a reconciliation point. So discovery, great innovators and ideas must be invented to account for the movement of facts and objects "out there." Moreover, where innovations meet resistance, become commonplace or slow down, societies must be invented. As Latour (1987:136) aptly puts it "In this model, society is simply a medium of different resistances *through which* ideas and machines travel." In sum, separation of science and society gives rise to technical or social determinism.

Diffusion theory's dominance in the sociology of aquaculture reflects the manner in which social scientists were initially and still are drawn into development projects. Moreover, many sociologists came of age in the 1960s when diffusion theory, the staple of the U.S. land grant mission, expanded into international aid efforts (Rogers 1983). In these settings, diffusion theory still holds advantages simply by appealing across a wide range of organizational and disciplinary contexts. Recently, both the Pond Dynamics Aquaculture CRSP and ICLARM made more refined use of diffusion theory to report on the results of long-term tropical aquaculture research and development programs (ICLARM 1996; Molnar et al. 1996). Yet as this section has demonstrated, diffusion theory exhibits a series of problematic assumptions regarding its ontological monism, objective language, monological communication mechanisms, endorsement of modernity over tradition and the special status it accords to science. Moreover, social or technical determinist accounts of aquaculture fall far short in accounting for the effects of research and development. In contrast, the sociology of scientific knowledge and in particular actor network theory offer substantial resources for a renewed theoretical and empirical investigation of aquacultural technoscience.

THE SOCIOLOGY OF SCIENTIFIC KNOWLEDGE

This section highlights the theoretical orientation for an empirical case study of transgenic fish research and development which is taken up over the remainder of this volume. In particular, actor network theory is featured as a means by which to adequately address the effects of aquacultural technoscience. First, the development of the sociology of scientific knowledge, laboratory studies and the anthropological turn in science studies is used to frame actor network theory. Second, I address how actor network theory and methods can contribute to a rethinking of the sociology of aquaculture. Specifically, how do actor networks reveal what scientists do and how can we account for the effects of technoscience?

Recent advances *and* limitations in the relatively recent sociology of scientific knowledge (SSK) are crucial initiation points for developing a renewed theoretical and empirical orientation into aquacultural research and development. This interdisciplinary literature poses new, interesting and in the final analysis, *critical* questions concerning modern science from interdisciplinary vantage points such as philosophy, (e.g., Foucault 1979:1980; Hesse 1974:1980; Harding 1991; Rouse 1987), sociology (e.g., Callon 1986: 1987; Clarke 1990; Knorr Cetina and Mulkay 1983; Latour 1983: 1987: 1993; Law 1994; Law and Callon 1988; Restivo 1988) and the anthropology of science (e.g., Latour 1979: 1993; Rabinow 1996; Restivo 1994; Traweek 1988).

In general, the SSK literature displays an empirical orientation concentrated in areas such as high-energy physics, artificial intelligence, biology and the medical sciences which some feel reflects an increasingly esoteric grip on science studies (Martin 1993). At the same time, with a few notable exceptions (e.g., Busch et al. 1991; Busch and Tanaka 1996; Clark and Murdoch 1994; Kloppenberg 1991; Murdoch 1994) little sociological work has been initiated in agriculture. It is likely that SSK approaches will multiply in agriculture as well as aquaculture. At present, nothing has ever been undertaken in aquaculture with the exception of Bauin (1986) and Callon (1986). These articles inform an initial approach for addressing the effects of aquacultural research and development.

The sociology of scientific knowledge is a diverse field which eludes simple synthesis and reduction (Knorr Cetina and Mulkay 1983). However, this literature does share "family resemblances" as well as some significant "dissemblances" (Callon 1995; Knorr Cetina and Mulkay 1983; Restivo 1994). These diverse studies direct us towards a fuller account of technoscience as a social phenomenon. Given the vast scope of this literature, a few qualifications are in order. First, it is important to emphasize the sociological orientation of SSK and actor network theory. This is not to disparage other contributions or promote sociology as the only science. But for brevity's sake, limits will have to be drawn. Second, SSK and actor network theories pose interesting challenges for sociologists working in agriculture and aquaculture. By contrast, SSK largely ignores these areas. Third, the sociology of aquaculture is dominated by diffusion theory which was found insufficient in accounting for technoscientific activity. It makes imaginative sociological sense then to approach these problematics from a different theoretical and empirical orientation.

Finally, an important analytical distinction that permeates this literature is that the once special status accorded to scientific knowledge is no longer maintained. As a result, some sociologists have gone directly to the scientific work site and its artifacts (e.g., laboratories, scientific texts, instruments) in a manner much like earlier anthropologists (Latour 1987; Latour and Woolgar 1979; Myers 1990). The results, methods and implications of this focus are perhaps SSK's greatest contributions to contemporary social theory and have remained a consistent theme since the field's inception in the early 1970s. Despite detractors, SSK has established that science, "the most authoritative and esoteric system of knowledge in modern societies," is social through and through (Knorr Cetina and Mulkay 1983: 2).

Origins of Science Studies

There are various histories and summations pertaining to the origins of SSK or the "new sociologies of science." Some authors locate the origins of SSK in social movements outside the university (e.g., Edge 1995; Martin 1993). Others retrace SSK's development in largely intellectual terms (e.g., Knorr Cetina and Mulkay 1983; Restivo 1994: 1995). In general, accounts of SSK's origins reveal multi-stranded influences across a range of academic interests, debates, experiential backgrounds and societal influences. Overall, it is important to emphasize that a special status which privileged science characterized the "old sociology of science." This distinction no longer holds after the "1970s watershed" (Bloor 1976; Restivo 1994). In order to situate actor network theory within the SSK tradition, two accounts of SSK's origins and some critiques of it are briefly summarized in the following paragraphs.

Edge (1995) identifies three mid-1960s themes which shaped the SSK field; research on science as a social system, reforms in science education and a democratic impulse. In this era, runaway growth in science expenditures elicited a need to conduct research on science "to understand its extension and development, its relationship to technology and economic growth... before its relentless exponential growth rendered us all penniless" (Edge 1995:6). The point was to articulate a basis for science policy. At the same time efforts were initiated to reform science education. The urge here was to provide future scientists with some humanistic understanding of the society in which they would eventually work. In the wake of new social movements the "science machine" was implicated by social activists as playing a major role in creating an unlimited capacity for destruction. As a result, the impetus of these groups was to explore "the possibilities of democratization of science and technology" (Edge 1995:10). Organizations such as "Science for the People" called for better public understanding of science, greater governmental accountability, and social responsibility on the part of scientific experts.

By means of contrast, Restivo (1994:1995) undertakes an intellectual history of the "new sociology of science." In particular, he locates the origins of science studies in the classical sociology of Weber, Marx and Durkheim. Summarizing, Weber drew a connection between science, capitalism and Protestantism; Marx identified science as social relations; Durkheim "speculated on the status of logical concepts as collective representations and elaborations" (Restivo 1994: 3). Weber influenced Merton (1973) who dominated the sociology of science up to the 1970s and who still remains influential at present. Marx's depiction of science in terms of bourgeois social relations was further developed in conflict science studies. Like Merton's focus on science as a social system, modern bourgeois science was embedded within the organization of capitalist industrial society (Restivo 1995). In part, Durkheim's sociology of knowledge influenced anthropological studies on traditional social structures which were eventually applied to industrial cultures (Restivo 1994).

While largely presenting an intellectual history leading up to the new sociologies of science, Restivo (1994:4-5) briefly goes outside the academy to further account for the eruption of the new sociology of science:

> It required the political and social upheavals of the 1960s to sufficiently tarnish the image of science and scientists and create an intellectual atmosphere in which the sanctity of scientific knowledge itself could be challenged.

In sum, contemporary theories of science and society were built from classical sociology, philosophy of science, the sociology of knowledge, intellectual developments within the university and social movements outside of it.

In leading up to contemporary theory, Restivo (1994: 1995) notes the end of Mertonian hegemony but still finds substantial traces of neo-Mertonianism in the area of science policy formulation. Merton (1973) developed a comprehensive approach to the study of science. According to Restivo (1994), Merton theorized that science as a social institution was capable of being influenced by social forces but the purity of scientific knowledge was immune from such contamination. In the Mertonian view, scientific knowledge is demarcated by a special status and autonomy regulated by an internal set of norms and rewards dictated by the scientific community. Merton's functionalist account is one of the last bastions for maintaining a special status for science or more specifically scientific knowledge. In this context, Restivo (1994) briefly characterizes Kuhn's (1962) "outside" influence as essentially drawing attention to social factors in science. Diverging from an internalist history of science, Kuhn (1962) is portrayed as following Merton's functionalist approach (Restivo 1995).

Restivo's (1994) discussion of contemporary theory largely reflects his intellectual pursuits and substantive interests in the sociology of science, mathematics, mind and objectivity. In reviewing contemporary theory in science studies Restivo (1994:1995) groups them into three main arenas; the strong program, laboratory studies and scientometrics (see also Chubin and Restivo 1983). The strong program and laboratory studies are classified as constructivist. In contrast, scientometrics attempts to quantitatively measure the world of science "out there" through citation analyses, productivity studies, and science indicators among other devices. Pinch and Bijker (1987) follow a somewhat similar grouping in their review of the sociology of scientific knowledge. Like Restivo (1994) they mention the contributions of the strong program. Thus attention will turn to a brief discussion of Pinch and Bijker (1987) and Restivo's (1994: 1995) treatment of constructivist accounts of science centered in the strong program.

Social constructivism leads us to examine the moment-to-moment content, situatedness and context of the social world. As Knorr Cetina and Mulkay (1983: 8) put it:

> what can loosely be described as a constructivist perspective is characterized by a concern for the processes by which outcomes are brought about through the mundane transactions of participants. It entails the assumption that outcomes are the result of participants' interactive and interpretative work.

Once we remove the special status accorded to science, including scientific knowledge, it too can be viewed as socially constructed. In other words, science and scientific knowledge embody the values, ideologies and ethics of society. Science is not special in this regard. In moving into the previously Mertonian fortified edifice of scientific knowledge, the strong program began to empirically apply a constructivist approach to "hard" science (Pinch and Bijker 1987). Restivo (1994: 19) summarizes the strong program in the sociology of knowledge in four propositions:

(1) beliefs and states of knowledge are products of social causes;

(2) truth and falsity, rationality and irrationality, success and failure are all studied impartially;

(3) true and false beliefs are symmetrically explained in terms of the same causes; and

(4) the explanatory patterns in the strong program apply reflexively to the program itself.

Proposition number one establishes a social contextualization of knowledge in that all knowledge and knowledge claims are socially constructed (Pinch and Bijker 1987; Restivo 1994). Propositions two, three and four outline an approach (Chubin and Restivo 1983). Although there are substantive internal dissimilarities between the strong program and the array of laboratory studies, some undertaken by actor network theorists, there are enough similarities to characterize them as central contributions (see for example Chubin and Restivo 1983; Collins and Yearly 1992, Callon and Latour 1992 and Woolgar 1992). In short, the strong program was able to empirically apply its propositions to a series of studies with a result that links "the standards of what constitutes `correct' sociological work with the standards of natural sciences" (Chubin and Restivo 1983: 55). The important point here is that we find science and especially scientific knowledge being directly and empirically examined much like any other social phenomenon by the new sociologists of science. In addition, new methodological approaches emerged for studying science at the sources of its production such as the laboratory, texts, historical case studies, discourse analysis and so on (Knorr Cetina and Mulkay 1983).

This brief exposition on the origins of the new sociology of science illustrates the recontextualization of science and scientific knowledge as a social phenomenon which is socially constructed. Yet, while the new social studies of science can be characterized as somewhat eclectic, diverse and interdisciplinary, this literature like others, is not exempt from criticism. SSK has been subjected to critiques from within its ranks as well as from outside. For example, in the so called "science wars" some of the writers in the SSK tradition are withstanding attacks by those who would like to maintain a privileged position for science and its institutions (see for example Gross and Levitt 1994; Ross 1995). From within the SSK ranks, critiques range from purely intellectual to social activist. A brief review of some of the more trenchant criticisms is presented below.

For many critics of SSK the lack of an activist component in science studies hinders its applied relevance. For example, Martin (1993) has charged that "social studies of science" have become mere "academic props" in disjunction from an earlier and radical social activist tradition focused on changing science and society. As Martin (1993: 248) recalls the development of science studies since its 1960s origins:

> As the years rolled on, sociological treatments of scientific knowledge seemed to me to become more insular, more disconnected from those early concerns about the human impact of science. As theory about the practice of science has become more sophisticated, it has become less accessible to scientists and activists. Still, it seems radical enough in principle.

Moreover, Martin's (1993: 249) critique of the professionalization of science studies in academia is captured in the following:

> my view is that much of this professional critique of science can be interpreted as a process of taking over the insights of the radical critics, recasting them in an academic and sanitized mold, and pursuing the dilemmas internal to the resulting intellectual terrain.

There is a creative tension which underlies Martin's (1993) charges; the new social studies of science while highly stimulating and academically compelling fails to answer a fundamental question: Knowledge for What?

Other writers offer similar critiques. In the words of Rouse (1987:viii) philosophers and sociologists of science have "been largely unconcerned with the extension of scientific practices and achievements outside the laboratory." Chubin and Restivo (1983: 55) charge that the strong program's case studies "share the deficiencies of internalist history; rank-and-file scientists, non-scientists and the `external culture' seldom command attention." In broader terms, Restivo (1988: 1994) sees science as a social problem because modern society is a social problem. Specifically, Restivo (1994:26-28) concludes that the new science studies:

> affirm the Grand Paradigm of modern science. They do not challenge or criticize modern science as a value system, a worldview, and a way of living and working . . . much of what goes by the name of science studies . . . remains fundamentally conservative on the question of the value of science . . . many of the most influential authorities on the `sociological' nature of science are science advocates. The idea that science "works" and a "science fix" orientation have been amplified by runaway technological "progress." In the heady atmosphere of material plenty, people have been seduced by the icons, myths, and ideologies of modern science. And sociologists of science cannot afford to alienate the scientists they study by criticizing their ideas and actions, including how their social roles, organizations, and products fit into society.

On a slightly different track, Winner (1993) takes science and technology constructivists (e.g., Pinch and Bijker 1987) to task for failing to adequately follow up on the question of the social consequences of technological choice. Although there is much that Winner (1993) finds of value in this approach (e.g., conceptual rigor, empirical orientation to technological change), the exclusion of "irrelevant" social groups (e.g., where are blue collar workers in manufacturing studies?) and deeper political, cultural and economic processes at work in the social choice of technology go unexamined. Winner (1993) finds social constructivist accounts of technological change currently fashionable but exceedingly narrow on extending into relevant political processes and arenas.

From the previous pages, it is clear from the origins of SSK and its critiques that SSK has developed theories and approaches to investigating science which are novel, potentially far reaching and far removed from treatments which privileged science as a special way of knowing about the world. The upshot of this all is that if the SSK project intellectually succeeds it entails no less than the total transformation of present-day academic disciplines and more critically, modes of knowing. In contrast, the most sustained critiques of SSK repeatedly question its application and relevance in places outside of its special domains (e.g., universities, texts, laboratories). If the new sociology of science is to become more than an accouterment to science and academic fashion perhaps Edge (1995: 4) most accurately anticipates the next phase of STS's development by calling for a "more urgent concern for *communication and translation*: for `making real' its [STS's] true potential." The next three sections sketch out the principles and relational materialism behind the development of actor network theory with attention to laboratory studies and the anthropological turn in science studies.

Laboratory Studies

Prior to the emergence of laboratory studies in the late 1970s, crucial experiments, the scientific method, the context of justification and the biographies of individual scientists carried much of the epistemological burden for theorizing about science (Latour and Woolgar 1979; Knorr Cetina 1995). The epistemology of scientific knowledge was tightly drawn around its methodology. Through a rigorous application of the scientific method, scientists uncovered the workings of an objective reality comprised of universal laws. At the same time, the Mertonian dichotomy which separated science as an institution and an independent scientific knowledge proper remained unchallenged in terms of sociological contextualization. As a result, science maintained a special epistemological status. As Knorr Cetina (1995:155) notes, the significance of the laboratory as "a space within which certain epistemic possibilities are bound up" went unexamined in the earlier sociology of science.

A major advance in the sociology of scientific knowledge has been the emergence of laboratory studies (e.g., Knorr Cetina 1981; Latour and Woolgar 1979; Traweek 1988).

Building from the strong program's sociological recontextualization of science, the "anthropological turn" in laboratory studies situated these localized sites in a revitalized epistemological and political examination of science. Through direct empirical investigation of laboratory practices, these studies revealed the social construction of scientific knowledge as cultural practices which could not be reduced to method or organization. As a result, *a priorism* was banished and replaced with an a posteriori approach for studying science.

Knorr Cetina (1995) labels the diverse field of lab studies as constructivist. Subsequently, lab studies have been extended into diverse theoretical terrain which includes actor networks (e.g., Latour and Woolgar 1979; Latour 1987; Law 1986: 1994), comparative symbolic constructivism (e.g., Traweek 1988), ethnomethodology (e.g., Lynch 1985) and the anthropology of science (e.g., Rabinow 1986). While far from complete, laboratory studies feature the contextualization of "lab as" sociocultural practice. In the modern laboratory, negotiations, "tinkering" and heterogeneous engineering obliterate "natural" and "social" ordering resulting in reconstituted epistemological and productive power effects.

Paradoxically, ethnographic accounts of laboratories consistently reveal that epistemologically, "nothing special," occurs in the daily activities of laboratory life (Knorr Cetina 1995; Latour 1987). These studies demonstrate that laboratories function in a manner which draws close parallels to other organizational settings. At the same time our world is inextricably populated by the "quasi-subjects," "quasi-objects" and the social bonds constructed in these laboratory microworlds. But if nothing special happens in laboratories then how can we account for far reaching sociotechnical effects? In short, laboratories deconstruct nature and society and then reconstitute it as heterogeneous social ordering, time and place. Laboratories are culturally bound. As Knorr Cetina (1995: 145-146) states, laboratories reorder the "natural world" but by not accommodating it:

> First, it does not need to put up with the object *as it is*; it can substitute all of its less literal or partial versions . . . Second, it does not need to accommodate the natural object *where it is*, anchored in a natural environment. Laboratory sciences bring objects *'home'* and manipulate them `on their own terms' in the laboratory. Third a laboratory science does not need to accommodate an event *when it happens*; it does not need to put up with natural cycles of occurrences but can try to make them happen enough for continuous study.

As Latour and Woolgar (1979) put it, laboratories socially construct "facts" by stripping away both the natural and social context of production.

In the laboratory, the reconfiguring of the "natural world" is reorganized to fit a social world. This apparent dualism collapses because laboratories simultaneously enculturate natural objects to social ordering through scaling up epistemic and productive power effects (Knorr Cetina 1995; Rouse 1987). If not, laboratory products and processes would simply remain there. Moreover, without the *malleability* of materials "human actions and words do not spread very far at all" (Law 1994: 24). Hence, laboratories "align the natural order with the social order by creating reconfigured, `workable objects in relation to agents of a given time and place" (Knorr Cetina 1995: 146).

Sociologists of scientific knowledge inform us that laboratories are not only cultural sites; they are also theoretical constructs (Knorr Cetina (1995). As a theoretical construct, the laboratory carries epistemological and political consequences. Knorr Cetina (1995: 142) has identified the shifting theoretical importance of the laboratory as being "linked to the reconfiguration of the natural and social order." Laboratory studies demonstrate how scientific knowledge is socially constructed, culturally grounded and situated in social order, time and place. These constructivist claims extend to the core of scientific knowledge production. For example, Knorr Cetina (1995: 143) argues that:

> If the practices observed in the laboratories were 'cultural' in the sense [that] they could not be reduced to the application of methodological rules, the 'facts' that were the consequences of these practices also had to be shaped by culture.

Actor network sociologists such as Latour (1983), Callon et al. (1986), and Law (1994) advance the argument that the laboratory is a strategic locus of social change and transformation. Callon et al. (1986) argue that the modern laboratory occupies a central political and epistemological position analogous to the position once held by the medieval cathedral and the nineteenth century factory. To do science is to do politics *as science*. For example, Pasteur not only changed the ordering within his laboratory, he also changed society to make it more lab-like in constructing a vaccine for anthrax (Latour1983).

To account for social bonds and network effects associated with laboratories. sociologists of scientific knowledge assert that these sites are situated within broader discursive "transscientific fields" - social relationships sustained by "the arguments among scientists and *non-scientists* inside and outside the laboratory proper" (Restivo 1994: 129). Latour and Woolgar (1979: 281) have suggested that the "full story will establish that there is a continuum between the controversies in daily life and those occurring in the laboratory." However, lab studies have consistently failed to tell the "full story" from laboratory microworlds to political and social transformation (Knorr Cetina 1981: 1995; Latour and Woolgar 1979; Rouse 1987).

Laboratory studies have stimulated new epistemological and theoretical projects in the sociology of scientific knowledge. Through reorganizing and reordering of natural phenomena into social time and place, laboratory products and processes simultaneously emerge into fields where locality is obscured and where knowledge and power are strategically translated into "action at a distance" (Latour 1987). Through ethnographic accounts of social interaction and scientific cultural practices, lab studies have erased the previous divides between method and social organization. While incomplete, the sociological recontextualization of laboratories has advanced a socially constructed scientific knowledge. As transscientific entities, laboratory studies suggest that "scientists are *strategists and politicians*; and the better they are at being strategists and politicians, 'the better the science they produce'" (Restivo 1994: 137). This characterization is inextricably intertwined with scientific knowledge production and productive power effects which alert us to the laboratory's central position in sociotechnical ordering (Law 1994; Rouse 1987).

The Anthropological Turn in Laboratory Studies

In their particular habitat scientists and their work environments present a series of elusive and esoteric obstacles to an intruding social scientist (Knorr Cetina 1981). In order to address obstacles of social access, scientists' received views of "doing science," and often distorted media accounts of spectacular discoveries, muckraking and the like, lab students have modified ethnographic approaches in order to cut to the core of scientific knowledge production by studying the everyday work-like composition of the laboratory (Knorr Cetina 1981). Laboratory studies reflect this "anthropological turn." For instance, Knorr Cetina (1981: 19) argued that in order to study the laboratory a *sensitive* methodology is required which seeks out "engagement rather than detachment; contact rather than distance; interest rather than disinterest; *methodological intersubjectivity* rather than neutrality." The methodological point is not merely understanding "but to *let speak*" by giving voice "of that about which is speaks" (Knorr Cetina 1981: 18).

Latour and Woolgar (1979) also employed the anthropological metaphor in the first ethnographic study of a laboratory and the attendant social construction of a scientific fact. In doing an "anthropology of science" Latour and Woolgar (1979: 278) state that "the problems of describing science proceeds best from an empirical basis." As they observed, "social factors" are stripped away in the construction of a scientific fact. As Latour and Woolgar (1979: 179) put it:

> A modification of the local context of the laboratory may result in the use of a modality whereby an accepted statement may be qualified or doubted. This yields perhaps the most fascinating observation to be made in the laboratory - the **deconstruction** of reality. The reality "out there" once again melts back into a statement, the conditions of production which are again made explicit.

As a result, scientific knowledge claims can become impossible to unravel once a "fact' has been established. Hence, the "received view" of "letting the facts speak for themselves" misrepresents by obliterating the social sources of fact construction.

In cutting to the social core of what occurs in the process of fact construction, Latour and Woolgar (1979) studied the everyday minutiae at the laboratory bench. In this manner they included not only participant observation techniques but also a semiotically inspired analysis of inscription devices such as instruments, figures and the career backgrounds of scientists. Latour and Woolgar's (1979) methodological point is twofold. First they overcame the assumption that scientific phenomena are distinct from social phenomena.

Second, they engaged uncertainty rather than exoticism in order to ground the context of scientific knowledge production in everyday practices.

In contrast, Traweek (1988) exemplified a classic ethnographic approach. Traweek's (1988: 8) comparative study of high-energy physics communities in Japan and the United States described:

> *patterns* of explanation and action, the meanings people bring from one situation to another, the connections and distinctions people make between certain actions, feelings, ideas, things and their environment: these patterns make up the culture.

For Traweek (1988) the study of culture is grounded in a discrete community. She links culture and community through the manifestation and interaction of four domains; ecology - to the physical and social environment which supports the scientist's activities; social organization - to the group's dynamic structure and how it carries out its daily work; the development cycle - to the training of future scientists and how skills, values, and knowledge are transmitted through scientific practices, and; the group's system of knowledge construction - to the actions and structures involved in the daily research process. In this manner, the physicists that Traweek (1988) studied draw comparisons with other community forms of symbolic cultural practices.

An interesting lab study is Law's (1994) ethnographic actor-network account of Daresbury, a high energy research laboratory. In contrast to classic ethnographic approaches, Law (1994: 39) is "chasing after issues in social theory, not matters to do with Daresbury." His interest is with a pragmatic approach to sociotechnical ordering. In particular, Law (1994:39) wants to "describe the organization in a way that doesn't involve commitment to any form of pure order." In doing so, Law (1994) operationalized actor-network principles of symmetry, non-reduction, recursivity and reflexivity. These assumptions are grounded in a relational materialism which includes people *and extends to things.*

Law's (1994) vehicle for describing network ordering is ethnography. Ethnography entails writing, in itself an act of ordering. His project is broader than earlier lab studies because of the twin concerns for social theory and the positioning of the ethnographer into one's own and other ordering processes. For Law (1994: 32) doing ethnography becomes an effect through:

> an interest in the work of *ordering* . . . a concern with the work of *distributing* . . . a concern with the *materials and representations* of those processes of ordering. So if you read this text you will learn something about the interaction between the Laboratory, social theory and the process of research. And you will also, to be sure, learn something about the contingencies that have generated an ethnographer and an author.

The analytical link between ethnography and actor-network sociology involves the search for, and articulation of contingent patterns of the sociotechnical through the heuristic device of storytelling. Stories are not naive accounts. They are the ethnographer's attempts to describe the contingent recursive processes of the social. Law's (1994) justification is to avoid the problems of pure order and remain consistent with actor network assumptions. The point is to elucidate *patterns.* As he (1994: 19) states, *"stories are often more than stories;* they are the clue to patterns that may be imputed to the recursive sociotechnical networks . . . the search for pattern is an attempt to tell stories about ordering that connect together local outcomes."

By following the actors, actor network sociologists describe the heterogeneous associations, translations and juxtapositions between people and things. In broader terms, lab studies, among other fields (e.g., media and feminist studies) also anticipated new methodological approaches to ethnography consisting of "multi-ethnographic sites" (Marcus 1995). As Marcus (1995: 96) puts it, multi-site ethnography:

> moves out from single sites and local situations of conventional ethnographic research designs to examine the circulation of cultural meanings, objects and identities in diffuse time-space. This mode defines for itself an object of study that cannot be accounted for ethnographically by remaining focused on a single site of intensive investigation. . . . This mobile ethnography takes unexpected trajectories in tracing a cultural formation across and within multiple sites of activity.

By grounding technoscience as cultural practice, the movement towards multi-site ethnographies "arises in response to empirical changes in the world and therefore to transformed locations of cultural production" (Marcus 1995: 97). In this sense, the anthropological study of technoscience entails multiple sites and actors. Technoscience is immutably mobile (Latour 1987). In other words, technoscientific effects are juxtaposed, situated and become manifested in multiple contexts through the organizing effects that people and things exert once resistance is overcome, defined, and enrolled into an ordering.

The field of lab studies in the sociology of scientific knowledge represents significant methodological *and* theoretical advances. It has focused the empirical study of science at its source of cultural production in, and to a much lesser extent, outside the laboratory. As a result, lab studies repositioned these social relations and practices within new epistemologies and political trajectories. Significantly, lab studies have challenged the problematic divides between science and society by methodologically extending to multi-site locations. The a priori divides between science and society, so evident in diffusion theory and other "social orders," have been problematized, obliterated and reconstituted into sociotechnical ordering as effects. Actor network sociologists have been at the forefront of these methodological and theoretical advances. The next two sections examines the theory of the actor network.

Actor Network Theory

In earlier mid-1980s accounts, actor networks appear under the guise of an approach for studying the dynamics of science at the most direct site of its production, the laboratory (Callon et al. 1986). Actor network sociologists (Callon et al. 1986: 4) begin by proposing a method:

> that does not distinguish on a priori grounds between 'science' (which is purportedly about the `truth') and 'politics' (which supposedly concerns 'power'). It is our argument that a proper understanding of social and scientific change requires the abandonment of this dichotomy.

In identifying the laboratory as an increasingly strategic locus of social change and transformation actor network sociologists allow for no distinction between science and politics. The two are inseparable or in Latour's (1983: 168) words "science is politics by other means and, accordingly that the study of science takes us straight into politics." Thus the methodological task is to "follow the actors closely when they enter strategic loci, for it is often in the interests of the forces at work to conceal the way in which they act" (Callon et al. 1986: 4).

Actor network sociologists are acutely aware of various reductionist traps. In approaching science and in particular, the laboratory, reductionism is to be avoided. As Callon et al. (1986) state:

> The notion of a society that can shape science without itself being influenced is as false as the converse image of a science and technology that find themselves able from their own resources to impose a structure unilaterally on their social environment.

Hence, anti-reductionism is established in the actor network approach but this leads to a dilemma regarding language use. If science and society are not separable then how should we describe them? Put in other words, should we employ a great scientist to speak to us in the language and concepts of science or a great sociologists who speaks to us in sociological terms? "Neither," say actor network sociologists:

> Rather a single, undifferentiated, vocabulary is necessary if we are to follow the daily actions of scientists as they act strategically to redefine both science and society while routinely ignoring a priori distinctions.

Thus in developing key analytical concepts around method, practitioners create a vocabulary which a conventional sociologist would find odd. Swept away are staples such as "class," "gender" and so forth (Latour 1987). Instead, actor network proponents operationalize analytical terms which erase categorical divides between the social and natural world therefore avoiding the reductionist end-game. Thus Callon et al. (1986: xvi-xvii) propose the term "actor-network" which means:

> an interrelated set of entities that have been successfully *translated* [the methods by which an actor enrols others. These methods involve: (a) the definition of roles, their distribution, and the delineation of a scenario; (b) the strategies in which an actor-world renders itself indispensable to others by creating a geography of obligatory passage points; and the displacement imposed on others as they are forced to follow the itinerary that has been imposed] . . . by an actor that is thereby able to borrow their force and speak on their behalf or with their support. The entities may be seen as forming a network of simplified points.

Callon et al. (1986) also operationalize other analytical terms such as forms of translation (e.g., interessement, centres of translation, problematisation and enrolment) and simplified points in an actor-network (e.g., black box).

A good concrete example of the sociology of translation (or actor networks) is displayed in Callon's (1986) study of researchers, scallops and fishermen in St. Brieuc Bay, France. Callon (1986: 196) uses a sociology of translation to describe how researchers attempted to "impose themselves and their definition of the situation on others." Because of declines in wild scallop stocks, a group of French researchers attempt to develop a scallop aquaculture program. This imposition fails when various spokespersons are effectively betrayed by the groups they claim to represent.

In St. Brieuc Bay, attempts to culture and conserve scallops rupture when the researchers, as spokespersons for several populations (scallops, fishermen and the community of specialists), fail in experiments to have scallop larvae anchor onto substratum. In Callon's (1986:220) words "the larvae detach themselves from the researchers' project and a crowd of other actors (sea currents, starfish) carry them away. The scallops become dissidents." Sensing this, fishermen began overharvesting what remained of the scallops in the Bay. Callon (1986:223-224) adds that the process of translation consists of "the continuity" of displacements and transformations in which the "social and natural worlds progressively take form."

In this case, translation failed. Callon (1986) demonstrates that an actor world broke down because quasi-network entities rejected the enrolment devices of a spokesperson (the researchers) into their network. First the scallops and then the fishermen dissented by not passing through the obligatory passage points as posed by the researchers. Note that we could also tell the story from that of other actors such as the scallops or the fishermen.

Another example comes from Latour's (1983) study of Pasteur and microbes. Latour (1983) shows how Pasteur was able to translate others' interests into his own by juxtaposing entities from his laboratory and the farm in order to combine them into a staged proof and cure for anthrax. In short, Pasteur modifies the interests of actors in microbiology (e.g., microbes, scientists) in his laboratory and French agriculture (e.g., animals, farmers, agricultural societies, field trials) by juxtaposing all the relevant actors together in a novel way whereby they must pass through his lab. In other words he simultaneously approximated farm conditions in his laboratory and laboratory conditions on the farm.

Specifically, he develops a vaccine. This makes his lab indispensable. At the Pouilly le Fort field trial Pasteur meticulously recreates the conditions of his laboratory on the farm in front of a public composed of prominent actors. Here Pasteur predicts what has been rehearsed countless times in his laboratory: that unvaccinated animals will die and other vaccinated animals will not. In short, the prediction holds and show "if you want to solve your anthrax problem go through my microbiology" (Latour 1983:152). In sum, Latour (1983: 166) illustrates that in the case of Pasteur:

> Since scientific facts are made inside laboratories, in order to make them circulate you need to build costly networks inside which they can maintain their fragile efficacy. *If this means transforming society into a vast laboratory, then do it.*

Latour (1983) dispels the myth of "great men" in science and argues that there is no "outside" of science. There is no doubt that Pasteur was brilliant *but* he was also an exceptional organizer and skilled politician. In other words he built a network where he tied together a series of heterogeneous elements and interests which made his lab and his interests indispensable for French agriculture. Moreover, the case shows that science and society are intertwined between the laboratory and the simultaneous translation of it into politics. Hence, actor networks sociologists reveal "science in the making" that are simultaneously political processes. If scientists are successful, they lead to a simultaneous transformation of society as in the case of Pasteur.

Underlying both examples are principles which outline the actor network approaches of Callon (1986) and Latour (1983). Callon (1986: 1995) defines three such principles underlying his study of the scallops of St. Bieuric Bay as:

> agnosticism (impartiality between actors engaged in controversy), generalized symmetry (the commitment to explain opposing viewpoints in the same terms) and free association (the abandonment of all a priori distinctions between the natural and the social).

Of these three principles the most problematic is agnosticism because it implies a pseudo-objectivity which masks partiality toward select actors. Yet, agnosticism keeps us aware that in the case of St. Bieuric Bay scallops and fishermen can tell and did tell their story as well. More importantly as sociologists, Latour (1983: 144) reminds us that "sociology of science is crippled from the start if it believes in the results of one science, namely sociology, to explain the others." In short agnosticism is less manifest in contemporary actor network outlines (e.g., Callon 1995; Latour 1993; Law 1994). The principle of free association pertains to an outlook which attempts to avoid social or technical reductionism. In more recent actor network expositions, the concept of "heterogenous engineering" or "juxtaposing" refines the principle of free association (Law 1992: 1994).

The principle of symmetry has a long history in the sociology of science. Its origins are traceable to proposition number three in the strong program and especially the work of Bloor (1976). In short, Bloor (1976) wanted to account for true *and* false knowledge claims in the same manner. As part of the empirical work in the strong program this was done in numerous historical cases and controversy studies (Restivo 1994). In more recent actor network theory the principle of "generalized" symmetry has been recast into a radical version whereby explanation, roles, interests and other machinations are extended to *things* as well as people (Law 1987: 1994). This extension distances actor networks from the more purely social constructivist approaches to science and technology (Pinch and Bijker 1987).

In sum, actor network sociologists identified and approached science at strategic sites of social transformation such as laboratories. In doing so, a priori distinctions between the social and the scientific are not drawn into the scope of analyses. Moreover, they propose analytical concepts and principles in order to do so (e.g. Law 1987). One apparent criticism of this approach remains embedded in critiques of actor network "jargon" (Bowden 1995: 76):

> The flaw in this approach -- that is, the presumption that the interpenetration of the natural and the social can only be understood through a language that denies traditional categories -- can be seen by contrasting actor-network theory with the multidisciplinary orientation of Hughes (1983).

Hughes (1983: 1987) characterizes large technological systems by drawing on their development and effects through use of a metaphoric "seamless web." A seamless web represents the blending of all components of a technological system. It ties together multi-stranded components of technical systems through the smooth functioning of contributing sources such as physical artifacts, organizations, legislative artifacts and natural resources

(Hughes 1987). However, Hughes (1987) like Callon (1986) and Latour (1987) does not want to draw a priori distinctions around categorical divisions such as innovators, the social, the technical, the political and so on (Pinch and Bijker 1987). A major difference is that actor network sociologists developed their own language from ontological assumptions and empirical initiation points while Hughes (1983: 1987), a historian, accounts for effects in terms of an all encompassing metaphor appropriate for the study of large technological systems. Moreover, the systems approach tends to focus on the concept of "technological momentum that seems to drive [the system] in a specific direction with a certain autonomy" (Bijker 1995:250). While ruling out a priori categories from the onset, systems approaches in SSK illustrate how technological momentum is "built up" for example through economies of scale thereby accounting for the seemingly autonomous nature of large electrical, transport, and communication systems.

In contrast, actor network sociologists begin with ontological assumptions and a focus on method to develop theory. By "following the actors," problematic a priori categories are eclipsed and associations between human and non-human actors are intertwined to illustrate sociotechnical ordering. Law's (1994) Organizing Modernity is an illustrative example of actor network method-theory building and is presented in the section below.

Organizing Modernity

Law's (1994) Organizing Modernity is perhaps the most comprehensive theory of the actor network currently available. For Law (1994) the problem is the timeless question of social *ordering*. In Law's (1994: 2) view there is no single "order" and "we have to replace this aspiration by a concern with plural and incomplete processes of social ordering." Social ordering is not purely social as much as we would like to tragically cling to some form of it. Instead Law (1994: 2) reshapes the question of social ordering through defining the social as:

> *materially heterogeneous:* talk, bodies, texts, machines, architectures, all of these and many more are implicated in and perform the 'social'. . . . The problem of the social order is replaced by a concern with the plural processes of sociotechnical ordering.

In other words, Law (1994) proposes that searching for a pure social order is a futile endeavor and that we should be concerned with processes of sociotechnical ordering rather than an order. This concern can be a sociological one among others.

Law (1994) asks what sociological resources are available in light of the task ahead -- the description of sociotechnical processes? His answer is that these are modest endeavors. At best, these descriptions simplify, they tell stories, they are incomplete and they are:

> non-reductionist, concerned with social interaction, empirically grounded, and tend to be symmetrical in their mode of sociological investigation. Finally, they make a serious attempt to avoid starting off with strong assumptions about whatever it is they are trying to analyze.

Along the lines of describing sociotechnical processes Law (1994) posits four "modest" assumptions: symmetry, non-reduction, recursive process and reflexivity. These assumptions inform Law's ethnographic study of a high-energy physics laboratory and continued development of theory.

Law (1994) traces the notion of symmetry to the strong program in that all true and false knowledge is to be explained in the same terms. As Law (1994: 12) puts it:

> the principle of symmetry is simply a methodological restatement of the relationship between order and ordering. It says, in effect, that we shouldn't

> take orders at face value. Rather we should treat them as the outcome of ordering.

In other words, differences cannot be extended as inherent in the a priori nature of things. An important analytical application of symmetry erases the distinction between the macro-social and the micro-social because these divides entertain the assumption that the "macro" is inherently "large" while the "micro" is inherently "small." Conversely, as Law (1994: 11) states "the principle of symmetry suggests that we might treat size as a product or an effect, rather than something given in the nature of things." In short, symmetry helps shape an approach which avoids unnecessary divides between size, distinctions and rigid differences. Law (1994) is suggesting that we look at these phenomena as effects or outcomes of ordering processes.

Law's (1994) second assumption is non-reduction. It is closely tied to the assumption of symmetry. As Law (1994: 12) puts it:

> Reductionism is common in sociology, and, to be sure, in natural science and in common sense. Lying at the core of the modern project, it is the notion that there is a small class of phenomena, objects or events that drives everything else - a suggestion often linked to a belief by the analyst that he or she has understood these root phenomena. Unsurprisingly, reductionism has many enthusiasts.

Clearly dividing phenomena into two classes and assigning causation to a discrete few entities violates symmetry. Hence the proliferation of dualisms. For example as diffusion theory shows, innovations drive communicative processes which lead to adoption or rejection of the innovation. As illustrated in Chapter 3, this form of reductionism is dominant in the sociology of aquaculture and more generally in various sociologies (Law 1994). Law (1994: 13) proposes a project:

> This will be relational, with no privileged places, no dualisms, and no a priori reductions. It will not distinguish, before it starts, between those that drive and those that are driven . . . it will allow that effects, a relative distinction between the drivers and the driven, may *emerge* and be sustained. Note that this is a conditional and uncertain process, not something that necessarily happens, not something that is achieved for ever.

So what do we do with this "precarious place"? Law (1994: 14) suggests "we tell stories, offer metaphorical redescriptions, ethnographies, fairy tales, histories - so called `thick descriptions'." In other words, we look for patterned effects of what comes forward, what stabilizes and what reoccurs.

Law's (1994) third assumption, closely related to symmetry and non-reduction, is that the social is a recursive process rather than a thing. Law (1994) breaks this assumption into two parts, one involving an examination of process and the other to do with recursion. Process is a movement, a verb rather than a noun. Effects conceal processes. For example, an organization is an outcome rather than a structured and stable entity. Structure too, is an outcome along with stability as these are the appearances which effects of process conceal. With recursion, "the social is both a medium and an outcome" (Law 1994: 15). In the social, there is nothing "outside" which drives it. The social generates and re-generates itself. We may be able to discern patterns in the social but "we need to say that *the patterns, the channels down which they flow, are not different in kind from whatever it is that is channelled by them* " (Law 1994: 15).

As Law (1994) emphatically notes, this is an extreme conceptualization because it implies that we do away with the security of many of the fundamental components of sociology! As Law (1994: 16) puts it:

> At best, when we reach this place where there is nothing beyond which goes on, we feel uncomfortable and insecure . . . this fear is right. This is *exactly* what we are doing. It is what we need to do if we are to avoid reproducing the games of classical modernism, and put the experience of hideous purity behind us.

The assumption of recursive process is closely linked to symmetry and non reduction. The critical point is that while process is recognized, recursion isn't. Thus symmetry is violated and we fall back into some form of reductionism. Reflexivity, Law's (1994: 16-17) last modest assumption, is closely related to symmetry:

> in effect it says, that there is no reason to suppose that we are different from those we study . . . and it suggests that if we are engaged in the study of ordering, then we should, if we are to be consistent, be asking how it is that we came to (try to) order in the way we did. In short, together with whatever it is that we write, we are effects as well.

The reflexivity assumption moves us beyond language games and into the realm of *doing* ethnography.

CONCLUSION: ACTOR NETWORKS AND AQUACULTURE R&D

This chapter has traveled far and wide in setting a theoretical orientation for a renewed approach to aquacultural research and development. In sum, diffusion theory's assumptions were found problematic. Moreover, the dominant diffusion of innovations model was found to shore up a previously undisputed status for science as separate from society. These deficiencies are evident in the sociology of aquaculture.

In light of the potential for actor network applications to aquaculture research and development, I envision three thematics which guide the rest of this work. By dissolving a priori categorical divides, actor network theory allows for analysis to (1) extend to non-human actors, within a (2) social historical context, thereby (3) allowing for the reconceptualization of some fundamental sociological categories and relationships.

If sociologists are going to meet new challenges posed by aquaculture biotechnology and genetic engineering, more convincing theoretical and empirical orientations are required than diffusion theory. It is highly problematic to account for transgenic catfish "after the fact" of their construction. Building transgenic fish is also a social process. By extending analysis to non-human actors the scope of studying technoscience at its source of initial production becomes a necessary part of sociology. This "beginning," necessitates the tracing of the origins of earlier social historical associations between humans and non-humans which illustrates the processes of network building and sociotechnical ordering. In moving from networks to ordering, actor network theory further allows us to recontextualize previously divided categorical domains and address fundamental questions concerning how we go about making and ordering our world.

Given this chapter's initiation of an actor network approach, the next chapter turns to an empirical case study of transgenic fish research and development. We begin by "following the actors," initially at the laboratory site, in order to let the stories of humans and non-humans unfold.

Chapter 5

BUILDING TRANSGENIC FISH

INTRODUCTION

The previous chapters have profiled some representative sociohistorical accounts of aquaculture research and development. In sociological and scientists' accounts of aquaculture, diffusion theory dominates applied development settings and academic discourses. In undertaking a theoretical critique of diffusion theory a series of problematic assumptions were traced to ontological monism, language, perspective on tradition, and notably the separation of science from society. These assumptions cohere to exclude the direct examination of technoscience. In sum, questions of how scientists go about doing research and development and how to adequately account for the sociotechnical effects of aquacultural research and development remain unanswered. In order to address these questions, I argued that the sociology of scientific knowledge, and in particular actor networks offers substantive theoretical and methodological resources by which to revitalize the study of aquaculture technoscience.

Actor network sociology avoids a priorism by assuming a symmetrical, non-reductive, recursive and reflexive orientation to the processes of sociotechnical ordering. These assumptions allow us to obliterate a priori categorical divides permitting the direct empirical study of the technoscience whereby the social and natural world are reconstituted, through inscriptions, and "sent back" as heterogeneous ensembles of human and non-human actors. The application of this approach informs the remainder of this volume. Over nine months, I acted as a participant observer at the Auburn Genetics Facility and afterwards conducted face-to-face and phone interviews with the major lab technicians, scientists, and policymakers who shape the field (Appendix B). The results and interpretation of the fieldwork feature in this chapter. Importantly, I found that everyday laboratory activities were inseparable from network building outside of the laboratory proper. Where applicable, reference to these associations are incorporated to situate the laboratory fieldwork within a broader sociotechnical ordering of the field.

In the first section, a note on actor network methods and principles outlines my ethnographic position. As an observer, I became aware that the "inside world" of the laboratory consisting of instruments, transgenic fish, gene constructs and lab staff was inseparable from an "outside" world of the Principal Investigator (PI), collaborating scientists, policymakers and texts. The methodological point of interest, which goes beyond a specific lab study, pertains to symmetrically accounting for both the "inside" and "outside" *of technoscience in the making.*

In the second section, I present an account of fieldwork which took place at Auburn University's Center for Fisheries Genetics Research. First, I describe the physical site of intertwined non-human and human associations imposed by the facility's ordering effects. Second, I situate my initial position among three actors, transgenic fish, the lab technician and the PI. This situatedness allowed an interpretation to emerge which clarified the inside and outside movement of technoscience in the making. I found that the facility occupied a strategic position in a transgenic research community of collaborating scientists which instigated further following the actors along the length of the network. Third, research projects intertwine lab associations and the transgenic community. The effect is that through projects, transgenic fish move from concepts in paper proposals to figures in texts and to objects in ponds. These interventions order action whereby technoscientific knowledge is exerted beyond the laboratory.

In the last section, I examine cumulative modes of organizing and sociotechnical ordering. Beginning from an earlier historical position at the lab bench, an account of the organizing of material associations leads to tracing the production of inscriptions which emerge as the carriers of ideas, concepts and theories about transgenic fish into broader sociotechnical ordering. Technoscience must entail *action at a distance*. Inscriptions are the devices which distill these moves to the outside. Without action at a distance, outcomes are local and thus do not constitute technoscience.

METHODS: FOLLOWING THE ACTORS

To reiterate, my questions concern aquaculture technoscience *in the making* not technoscience *made*. Thus, the fieldwork I conducted at the genetics facility provided an initial point of departure to methodologically "follow the actors." In sum, observations revealed the ongoing construction of "associations" and "competencies" within a range of "possible configurations of the action" (Callon 1998:1). An initial problem pertained to the "radical indeterminancy of the actor" (Callon 1998:1). Compounding actor indeterminancy were ethnographic choices as to *which actors* and to *what length* I would follow them.

In resolving this ethnographic position three related insights were generated. First, I brought questions in sociology to bear on the study of a laboratory and a field of research. My intent was to address questions concerning sociotechnical ordering that unfold in the recursive processes of a laboratory and research field. Second, I attempt to employ Knorr Cetina's (1981) call for a "sensitive" methodology by imputing multi-vocality to *others* and their efforts to fabricate an ordering of the social. What I observed in the laboratory was the heterogeneous engineering of actants in order to overcome their resistance. Once stabilized, the contingent processes and products of the laboratory are extended through social ordering by means of inscriptions. Third, while initially focused on the Auburn actors, the position I took during fieldwork clearly underscored the observation that technoscience has an inside because it has an outside. I argue that inside-outside associations constitute a major and inseparable dynamic of technoscience in the making.

Rules of Method

In resolving ethnographic positioning, Latour's (1987) rules of method and principles informed this account of fieldwork. Latour's (1987: 17) methods:

> mean what a priori decisions should be made in order to consider all of the empirical facts provided by . . . the domain of 'science, technology and society' . . . With them it is more a question of all or nothing, and I think they

> should be judged only on this ground: do they link more elements than others? Do they allow outsiders to follow science and technology further, longer and more independently?

These seven rules of method, Table 5.1, and six principles, Table 5.2, were helpful in turning perceived weaknesses into methodological and contextual strengths.

Table 5.1-Rules of Method.

#	RULES OF METHOD
1	We study science in **action** and not ready made science or technology; to do so, we either arrive before the facts and machines are **blackboxed** or we follow the controversies that reopen them.
2	To determine the objectivity or subjectivity of a claim, the efficiency or perfection of a mechanism, we do not look for **intrinsic** qualities but all the transformations they undergo **later** in the hands of others.
3	Since the settlement of a controversy is the **cause** of Nature's representation, not its consequence, we can never use this consequence, Nature, to explain how and why a controversy has been settled.
4	Since the settlement of a controversy is the **cause** of Society's stability, we cannot use Society to explain how and why a controversy has been settled. We should consider symmetrically the efforts to enrol human and non-human resources.
5	We have to be as **undecided** as the various actors we follow as to what technoscience is made of; every time an inside/outside divide is built, we should study the two sides simultaneously and make the list, no matter how long and heterogeneous, of those who do the work.
6	Confronted with the accusation of irrationality, we look neither at what rule of logic has been broken, not at what structure of society could explain the distortion, but to the angle and direction of the observer's displacement, and to the **length** of the network thus being built.
7	Before attributing any special quality to the mind or to the method of people, let us examine first the many ways through which inscriptions are gathered, combined and tied together and sent back. Only if there is something unexplained once the networks have been studied shall we start to speak of cognitive factors.

Source: Latour (1987: 258).

Aquaculture technoscience in the making involves a methodological focus on the controversies, contingencies, trials, tinkering and tribulations which constitute *action in the effort to assemble a network* (Rules 1, 2, 6). By problematizing sociological and scientists' accounts of aquaculture R&D (Chapter 3) neither appeals to Nature or Society can be established as *causes* for particular *consequences* (Rules 3 & 4). Moreover, we need to *symmetrically* consider *how* Nature is represented by the actors and *how* Society's *stability* frames efforts to enroll actors (Rule 5). We look to the fate of transgenic fish as they undergo *transformations* in the hands of other actors which center on, for example, policy and the environment (Chapter 6) (Rule 2). Thus we observe the *length* of the network being built (Rule 6). In network building we follow the inscriptions: "an instrument . . . any set-up, no matter what its size, nature and cost, that provides a visual display of any sort in a scientific text," which are gathered, combined, tied together and sent back (Rule 7; Latour 1987:68).

Principles

Along with the rules of method, Latour (1987) lists six principles as shown in Table 5.2 below. For Latour (1987), the six principles summarize *his* general observations of "science, technology and society." In part, they suggest attention to a history of technoscience. While subject to modification, these principles allow for a fuller consideration of the inside-outside transformations, the indeterminate actors and outcomes extending along the emerging transgenic network. Importantly, I also conclude that where applicable reference to a "history of traces" -- the earlier efforts at resource mobilization along the network, is required to amplify this account of fieldwork as well as anticipate future trajectories and outcomes. An advantage is that the transgenic fish network is relatively short as the field has only begun to cohere over the last decade. Thus earlier efforts at resource mobilization provide examples which crystallize network building in its present state.

Table 5.2- Principles of Method

#	PRINCIPLES
1	The fate of facts and machines is in later users' hands; their qualities are thus a consequence, not a cause of collective action.
2	Scientists and engineers speak in the name of new allies that they have shaped and enrolled; representatives among other representatives, they add these unexpected resources to tip the balance in their favour.
3	We are never confronted with science, technology and society but with a gamut of weaker or stronger **associations**; thus understanding **what** facts and machines are is the same task as understanding **who** the people are.
4	The more science and technology have an esoteric content the further they extend outside; thus, 'science and technology' is only a subset of technoscience.
5	Irrationality is always an accusation made be someone building a network over someone else who stands in the way; thus, there is no Great Divide between minds, but only shorter or longer networks; harder facts are not the rule but the exception, since they are needed only in a few cases to displace others on a large scale out of their usual ways.
6	History of technoscience is in large part the history of the resources scattered along networks to accelerate the mobility, faithfulness, combination and cohesion of traces that make action at a distance possible.

Source: Latour (1987: 259).

It became apparent that during fieldwork the outcomes of transgenic fish R&D has rested and will rest in the hands of others (Principle 1). Consequences rest on the ability of a spokesperson to *represent* new allies they have enrolled in their network (Principle 2). For example, fish farmers were not interviewed in this study because I found no strong associations between farmers and transgenic fish. Scientists, however, often spoke *on behalf of* fish farmers, consumers and the world's population in terms of the benefits of transgenic fish for aquaculture. However, it remains to be seen whether farmers, consumers and the world's population will be enrolled in the human and non-human *associations* defined by the scientist spokesperson (Principle 3). Overall, the transgenic fish network is relatively short but associations with new actors and harder facts will lengthen it (Principles 4 & 5).

Finally, I argue that in addition to examining single sites, the making of technoscience simultaneously takes place at multiple sites which powerfully illustrates the construction of technoscientific knowledge and application *at a distance* (Principle 6). Thus it is critical that analyses of the heterogeneous associations extend beyond a single laboratory -- to other sites and to past efforts at resource mobilization to better account for the network effects of sociotechnical ordering. Thus fieldwork involved tracing associations between the laboratory and the transgenic research community, projects and past efforts at resource mobilization.

Non-Human Actors: The Site

The genetics facility is a built environment of material associations for conducting traditional and genetic engineering research. The facility *acts* through these material relationships by ordering certain actors while simultaneously excluding others. Essential non-human actors such as host genome DNA, instruments, transgenic fish, electric fences, containment ponds, and gene constructs are defined, enrolled and mobilized in daily trials of strength. These entities also act to exclude non-essential others such as predators, unauthorized personnel, contaminants and flood waters. These trials are situated within physical, chemical, biological and social *barriers*. As Latour notes (1987: 259) "understanding *what* facts and machines are is the same task as understanding *who* the people are." Thus the facility ties together non-human and human associations. In building transgenic fish, actors are progressively defined, enrolled and transformed within a research and development network.

By sheer force, the facility's physical environment restricts, controls and orders the movements of actors. For example, all water flows through a series of specially designed outlets, drains and catchment basins to prevent the escape of transgenic fish. In the lab, technicians exclude contaminants by carefully monitoring for them when screening DNA samples. Officers from the Institutional Biosafety Committee periodically "challenge" transgenic pond security by getting out of their vehicle and walking towards the containment ponds. Invariably they are met by facility staff. By reducing, restricting and replacing natural and social phenomena with strictly defined human and non-human associations, the initial sociotechnical effects of building a transgenic fish network fit local time and place.

The facility proper consists of experimental ponds, a laboratory and hatchery. There are seventy ponds of which fourteen are USDA approved transgenic research ponds. These ponds are an organized assemblage of materials which approximate "natural" or "rearing" conditions. For traditional genetics research, pond sizes are uniform to allow for experimental replications. In particular, the contained transgenic research ponds are a consequence of a debate which was shaped by earlier attempts to move the fish outdoors (see Chapter 6). These debates over the escape of transgenic fish have subsequentially shaped the pond containment facility and the overall field. The debate over the outdoor containment ponds represents an extension of the network (Figure 5.1 below).

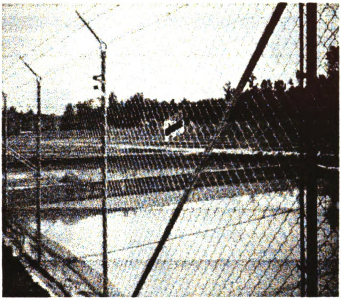

Figure 5.1 - Contained Transgenic Research Ponds.

Containment ponds are fenced, locked and covered with netting to exclude birds and other animals. Moreover, a poisoning system would be activated in the advent of a flood. Access to the area is restricted and continuously monitored by authorized staff. Finally, discharged containment pond water passes through physical barriers designed to minimize escape. Hence, the ponds intertwine the participation of human and non-human actors into an association comprised of the debates and anticipated outcomes within the material environment of the facility.

A 6,500 square foot biochemical genetics laboratory consists of a computer room, main laboratory (radioactive safety approved), dark room, refrigerated room, and tissue culture room (Figure 5.2).

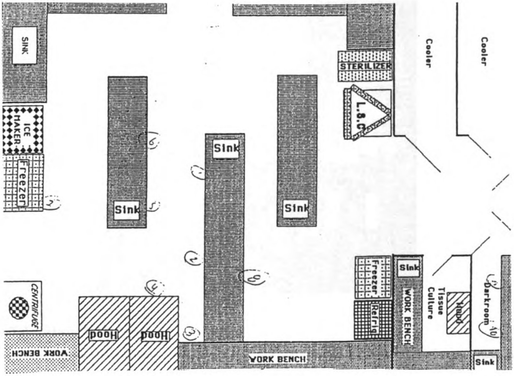

Figure 5.2 - Biochemical Genetics Laboratory Diagram

Large windows face the containment ponds to allow for continuous monitoring. The main lab work area and equipment are devoted to molecular genetics research (Figure 5.3).

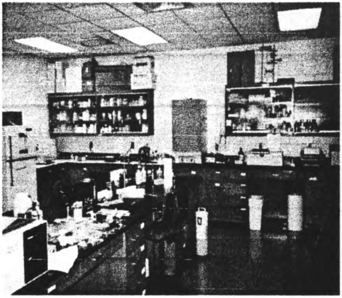

Figure 5.3 - Main Lab Area.

For recombinant DNA work, gel apparati, freezers, centrifuges, PCR (Polymerase Chain Reaction Thermal Cycler), incubators, water baths, autoclave, vacuum pumps and shakers equip the laboratory (Figure 5.4). Through the use of these instruments, materials are transformed and presumptive transgenic fish are inscribed with a visual shape and form which are "direct indicators of the substance under study" (Latour and Woolgar 1979: 63).

Figure 5.4 - Recombinant DNA work station.

A 6,500 square foot hatchery with 300 tanks for indoor spawning, incubation and evaluation of transgenic catfish fry round out the facilities. In the hatchery a series of marked nursing troughs are utilized for the early rearing of presumptive transgenic fish fry. Work stations for microinjection or electroporation of fertilized fish eggs are centrally located on work tables. Aquaria contain brood catfish for induced spawning during the spring and early summer. All discharged water from the facility is filtered five times, the last filter being a french drain which leads into a seepage pond. The drains and filters act as physical barriers to minimize the escape of transgenic fish from the ponds and hatchery (Figure 5.5).

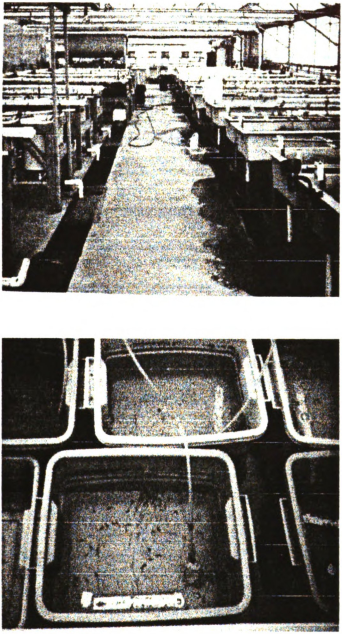

Figure 5.5 - Indoor Hatchery (top) and Nursery (bottom).

Overall, genetic engineering research occupies a significant portion of the facility. In addition to the fourteen containment ponds, most of the laboratory and equipment is specifically used for genetic engineering work. The laboratory is where the core molecular work is conducted on transgenic fish. The ponds and hatchery can be viewed as supplying raw materials for molecular lab work. In the laboratory, presumptive transgenic fish are reduced and transformed through instruments and inscriptions which eventually circulate beyond the laboratory walls.

As previously mentioned, I was attracted to this field by Fischetti's (1991) article on the "carp panoptic." Through observation at the lab, I found that the article had distorted work at the facility. In the following interview excerpt, the Principal Investigator stressed that *both* traditional breeding and genetic engineering research were conducted:

> There is *NO* emphasis on transgenics . . . and that is a misperception because in the popular press and the university that's something that's . . .
>
> MS: Glamorous?
>
> Glamorous. It receives a lot more publicity than the traditional but I would say if you look at our total program I feel that it is quite balanced as far as expenditures and effort . . . space . . . time. Devotionally we put just as much effort into the traditional selective breeding processes as we do the genetic engineering . . . we probably are a bit better in the gene transfer research because of that quote "glamorous" type research -- it's much easier to obtain federal funding for that research than it is for traditional selective breeding.

The above sequence illustrates why it is important to directly study technoscience. Only by following the actors was I able to gain a more multi-faceted understanding of laboratory life by grounding inquiry into the daily social context of laboratory research on the inside and outside of the laboratory proper. However, I found that transgenic fish research entails a much more elaborated network. Transgenic fish research is clearly differentiated from selective breeding by the *length* and *composition* of its network.

Human Actors: Social Organization

Actor networks consist of non-human and human associations. An observer confronts, as Latour (1987:259) puts it, "a gamut of weaker or stronger *associations*; thus understanding *what* facts and machines are is the same task as understanding *who* the people are." It follows that understanding the "social organization" of the genetics facility is the same as understanding the site and what its components and associations are. At the genetics facility, human actors and non-humans engage in building, monitoring and evaluating transgenic fish in the lab, pond and hatchery environments. Like transgenic fish, the facility and its components *defines* and *endows human actors* to do so (Latour 1987). In short, actors are mobilized and act to produce the desired sociotechnical effect of transgenic fish.

From fieldwork, a good everyday example pertains to a detailed set of written instructions for monitoring, maintaining and securing the outdoor containment ponds from intrusion by non-essential others. The instructions organize, define boundaries and mobilize the participation of humans and non-humans. The instructions set boundaries and parameters as to how people and things *act* thus maintaining stable associations. For the transgenic containment ponds, facility staff undertake a daily fifteen point monitoring procedure which includes visual observation of gates, netting, water inlets, pond water levels, screens, levees, fish behavior and catchment ponds. Termination procedures are also outlined in case of contingent circumstances such as an accident or flood (Anon. n.d.). This example illustrates how human and non-human associations are defined, enrolled and stabilized into organizing and ordering of the facility's social time and physical space.

Likewise in the laboratory microworld, human and non-human associations are also defined, enrolled and stabilized into organizing and ordering of social time and physical space. For example, transgenic work occupied a "serious" half of the main lab area. This designation was attributed to a former lab scientist who "revered" the work. It was also the area where low level radioactive materials are utilized. Maintaining stable associations between people and things extended to feeding fish, upkeep of equipment, stocking chemicals, cleaning work spaces, and locking doors and gates when leaving the facility. For the most part, these relations were implicitly embedded in the everyday work cycle of organizing and ordering the social time and physical space of the laboratory microworld. Throughout fieldwork there were few observed transgressions regarding the written instructions or in laboratory procedures.

On a daily basis, lab actors were subjected to the exertion of organizing effects comprised of human and non-human associations. Generally, actors reenforced these effects by participating within sociotechnical ordering patterns. These patterns however, were subject to contingencies which elicited alternative mobilizing and restabilizing efforts. For example, a disease outbreak could occur at any number of points such as in the ponds, hatchery, or nursery. As a consequence, chemical treatment and monitoring of the infected fish would take precedence offsetting other priorities. In another case, analysis of DNA samples showed little amplification resulting in a two week repeating of the lab techniques to trace the point where errors had occurred. In sum, the daily activities conducted at the genetics facility involved a degree of contingency based organizing and ordering to bring forth the desired effect of transgenic fish.

Lab Techs and Principal Investigators

As an "outside" observer, I was *also* subjected to the defining, enrolling and stabilizing actions of pre-existing human and non-human associations intertwined with the facility. As an "outside" observer, I found that entry into the facility required definition and negotiation into ongoing network building which patterned my everyday activities. As a consequence, I was enrolled into a particular human and non-human association among many others potentially available. This enrollment translated as directly working and observing with the key lab technician who worked on the "inside" and who conducted the everyday transgenic research at the facility. As a consequence, my observations were filtered, organized and ordered around this positional association that has thus influenced this account of fieldwork.

More broadly, this account of fieldwork is primarily derived from an association involving three key laboratory actors, transgenic fish, the lab technician and the Principal Investigator. First, transgenic fish are the central actors in this network. Building transgenic fish interests and ties together all the actors, including me as a sociologist. At this particular sociotechnical juncture, I conclude that after a decade's time, the transgenic network is relatively short. In brief, the promises of transgenic fish for aquaculture have not been fulfilled and the extension of the network has been shaped by controversies. Hard facts are few and far between (Latour 1987). Moreover, since the first gene transfers only occurred in the late 1980s, scientists caution that it will require successive generations to stabilize the transgene in the host fish genome. Thus, transgenic fish can presently be described as a concept-object with future mobilization directed towards; (1) further defining, enrolling and stabilizing the object, (2) closure of controversies resulting in the hard facts of technoscience made, and (3) extending the object into a wider sociotechnical ordering.

By an everyday working association with the laboratory technician, I was simultaneously positioned along an inside-outside association directed by the PI who rarely came to the facility. The PI, however, acted and spoke on behalf of an extensive "outside" transgenic fish network. The advantage that this association held for fieldwork was twofold; (1) the inside-outside association between the lab tech and PI identified some preliminary components of how action at a distance takes shape and constitutes technoscience in the making, and (2) allowed for access to other laboratories, scientists and decision making circles through association with the Auburn PI and facility.

I found that laboratory technicians were indispensable for the building of transgenic fish. At the lab bench, they "figure out" techniques, operate instruments, produce inscriptions and manage the research projects resulting in the cumulative network effects of building a transgenic fish microworld. Laboratory technicians act as intermediaries between the PIs on the outside and the other actors on the inside. As put by one lab technician:

> the PI's are so busy and so important what happens is you only report to them when you have final data, or a major problem going on that's holding things up or you think you have an idea for taking a different direction in a project.

> The day-to-day process of working out the bugs, which data needs to be prioritized over what, that's really left between A [collaborating lab technician] and I.

In short, laboratory technicians do the daily and seasonal *work*. In the Auburn case for example, a lab technician was even responsible for designing the entire laboratory:

> S says "We need a building, we want it this big, what do you want in it, design it." I, a biology student working in genetics, is suddenly designing a flippant building. I know more about fume hood installation than anybody else on campus! I know how to get yours certified and passed through the board. Me and the Kiwani people are like this (crosses fingers).
>
> MS: Kiwani?
>
> Kiwani fume hoods, the top of the line fume hoods. I know about duct work, electrical engineering, plumbing, what kind of toilets that we had to have, the type of faucets. I feel like I did everything but cement the bricks together. I went around to different labs on campus, picked the designs I liked, talked to people who worked in labs to see what worked and what didn't work. I went to the big meetings. I had to sit on the bid openings, read the bids. I had to pick out the cabinet makers, the counter-tops. I had to know exactly what materials we wanted, where, what flooring we needed, what substances we worked with so I knew what types of grades and counter-top surfaces we needed. I did a lot. S and I would sit in the bid meetings and he would hand me a bid and say "Is this what we want?" And I would read through the bids and I'd say that's what we want or that's not what we want or we have to fight back with this or we need this . . .
>
> MS: So they really relied on you for everything.
>
> At the same time I was still doing all the research for R. At the same time I STILL had to figure out the transgenic stuff, we also had all the isozyme stuff running. I was trying to do some transferring work. We were breaking ground in several new areas.

From the lab bench, this sequence illustrates the central organizing role played by lab technicians in running a laboratory which even involved designing one. The notion of "what works" and "what doesn't work" extended to even the most innocuous materials used to design and organize the physical facilities as well as "breaking ground in several new areas." Lab technicians organize disorder into a microworld of ordering. In this regard, to solely characterize research as the diffusion of ideas or the scientific method misses the content of daily scientific work and the organizing and ordering processes which cumulate as a product of scientific knowledge production.

During fieldwork I observed that the everyday lab work involved the *local* displacing and organizing of actors into heterogeneous associations through *techniques and routines* in order to stabilize them so that they acted in a desired manner. More concretely, lab techs ultimately "make things work" by overcoming obstacles, aggregating data and managing multiple projects. While the PI sets the overall agenda, the technician organizes the participation of actors at the local facility. At the genetics facility, one permanent laborer (M.Sc. degree) and some temporary labor may be hired depending on how urgently analysis of DNA samples is needed for an upcoming conference, grant submission or journal publication. Graduate students (M.Sc. and Ph.D.) are assisted by the technician in the analytical laboratory portion of their degree work. Much of this lab work is routine and highly repetitive, typically involving the screening and analysis of presumptive transgenic fish tissue samples.

While often mundane and repetitive, lab technicians find it necessary to innovate in this microworld. For example, in a manner which strengthens and amplifies the network effect by increasing the number and reducing the time required to screen fish tissue samples, one lab technician modified a technique which was then routinized at all collaborating labs. In the words of a technician, prior to the use of PCR, samples were analyzed as following:

> you would purify the genomic DNA which took two to three days as opposed to four hours and then you had to determine the concentration of DNA so that you could blot a fixed genomic amount onto a membrane, probe that with P-32 and then that of course is not as sensitive as amplifying the region of interest.

As the number of samples from parent and presumptive transgenic progeny grew exponentially a mass technique for analyzing thousands, not the earlier hundred or so fish tissue samples was necessitated. As put by a lab technician responsible for developing the mass sample analysis technique:

> It used to be a very time consuming and tedious process . . . So what happened was well I just can't do this for thousands of fish because I had all these tissue samples and K, who was before A had all these tissue samples down at Auburn. So I saw an article in Biotechniques and that's mainly how you get most of your information.
>
> MS: What was the article about?
>
> That was about a quick and easy way to extract genomic DNA from a drop of tail blood of transgenic mice.
>
> MS: And what was the technique?
>
> That technique was basically take a very small amount of tissue or cells and put it in an Eppendorf tube, add lysis buffer and some proteinase-K to break down the cell membrane, vortex it, dilute it with water and then take an aliquot of that and perform PCR on that aliquot.
>
> MS: So PCR was key to that step then?
>
> Right. PCR was key to the step.
>
> MS: And then you were able to develop the technique whereby you could utilize a very small amount of a given sample, put it in the PCR and be able to amplify that?
>
> Right. So the outcome of this technique was first of all it didn't work as it was outlined in the article. We found out that we had to do like two extraction steps, the phenol and chloroform extraction and ethanol

precipitated, because apparently in fish fin clips there is a little bit more involved with the tissue a lot more cartilage and everything. But it cut down the time it took to process samples.

This sequence illustrates that a modification to an existing technique enabled the analysis of many more tissue samples. This was accomplished by using an instrument (PCR) and tinkering with a previous method and overcoming the double resistance posed by increased numbers of samples and bony fin tissue. The desired effect of being able to analyze thousands of samples represents a translation of an obstacle into a routine. A stronger association was created by overcoming the resistance of the non-human actors by enrolling them in accord with the desires of the human actors. As a consequence, thousands of samples could now be mobilized in support of the knowledge claims and extension of the transgenic fish network. In short, competent lab technicians organize laboratory microworlds out of disorganization, and ordering out of disorder by making things work; through displacing natural and social phenomena by defining, enrolling and mobilizing these heterogeneous actors into stabilized local associations.

At the genetics facility and collaborating laboratories, lab work is closely linked to controlling temperature by freezers while the actual fish are highly dependent on outdoor water temperatures and biological factors over which there is no control. As a consequence, hatchery work peaks during a time of rising outdoor water temperatures -- the spring and early summer spawning period. Raw materials from these pond and hatchery processes flow into the laboratory during the fall and winter where materials undergo translation into new substances and inscription devices which bring forth the object in shape and form as a transgenic fish. Lab processes such as tissue sample preparation, cloning of gene constructs, amplification of DNA, the reading and writing involved in tabulating data are translated into inscriptions. Some of these inscriptions may leave the lab where the PI further analyzes, refines and circulates them as knowledge claims -- to be inserted into scientific journals.

Transgenic fish research has changed and will continue to be shaped by the advances and the ensuing controversies which comprise the field. From humble beginnings involving borrowed equipment and space at other facilities, Auburn's transgenic fish researchers have built the only North American outdoor facility which conducts, in significant proportion, research on the genetic engineering of fish. As the research levels out from the initial gene transfer phase, narrower and more specific questions are being asked about the molecular mechanisms of gene expression and the environmental impacts of transgenic fish. The research is being evaluated on its merits rather than the former application of a novel technique. Those laboratories and facilities such as Auburn's which entered the field during its inception can now restrict new entrants. At the same time these programs are under more pressure to produce tangible results and objects -- to extend the network. As a consequence, the development cycle has intensified. More mobilizing of additional resources is required by the actors who shape the field. This intensification is leaning to research where more advanced molecular genetics capacity in the labs and more environmentally-oriented experiments in ponds are required to answer critics, stay ahead of the competition and attempt to bring all the controversies to closure.

While lab technicians had previously anchored much of the daily work requirements at the genetics facility, the need to build more independent and advanced molecular biology capacity became evident. In part, this was due to the breakup of Auburn's major collaborating laboratory where advanced molecular analyses were done because the PI was leaving to become the administrative director of a recently established biotechnology center. At the end of my fieldwork a tenure track Ph.D. lab scientist was hired to work at the genetics laboratory. Much more is being demanded from the laboratory research than the earlier application of a novel technique such as gene transfer. As a consequence, the addition of a molecular biologist will strengthen the independent capability of Auburn's laboratory work beyond the earlier lab technician-PI association.

At the genetics facility, all research fell under the responsibility of the founding Director who also acted as the PI for the collaborative research projects. In contrast to the inside work conducted by the lab technician, the PI operated almost exclusively on the outside. Within the emerging shape of a broader sociotechnical ordering, the Director envisions advances and attempts to settle controversies over the *length of the whole network*. In contrast, the lab technician is restricted to building *shorter networks in the laboratory*. The major difference between the lab technician and Director is that the latter acts as a *spokesperson* for all the actors along the length of the whole network. The lab technician only acts *locally* representing the lab actors alone.

Over the course of my fieldwork, the PI conducted no lab work and rarely came to the laboratory. His major mode of communicating to the laboratory staff would be through telephone calls to the technician who ran the genetic engineering lab work. Another arrangement observed at a collaborating laboratory had the PI maintaining an office in the lab simply in order to avail himself of staff. He also did not directly undertake any lab work.

In interviews, lab technicians often remarked on the "hands-off" approach that PIs would take in laboratory work. One technician remarked that "I was his [PIs] hands" for the research. Indeed, much like Latour's (1987: 153-155) hypothetical "boss," PIs are indeed busy on the "outside" -- writing grants, answering correspondence, administrating, analyzing data, attending conferences and publishing papers. At the same time, the bench scientists, graduate students and technicians conduct the inside craft work entailed in everyday laboratory tinkering which culminates in organizing and ultimately ordering technoscientific knowledge. Knowledge claims are backed up by the real objects and inscriptions in the shape and form of transgenic fish. If *successful*, the "insider-outsider" effect is a solid publication record and a well funded laboratory, with bench scientists going about the daily business of producing stable microworld associations and inscriptions through the heterogeneous engineering of stronger associations between them.

On the outside, PI's are simultaneously engaged in bringing in more resources by "interesting" external clients in the importance of the lab's work. The PI represents transgenic fish to a clientele such as the USDA (United States Department of Agriculture). The PI ties together USDA's interests with those of the laboratory and collaborative research program through the funding of the paper projects in real material terms. These intertwined interests become indispensable for all actors. A *successful* PI translates the roles of actors by defining and enrolling them into a particular program of research and development both inside *and* outside the laboratory. Successful PIs orchestrate this double move between the inside and outside and as a consequence strong but tenuous networks emerge through modes of accumulating, organizing and ordering.

In brief, a technoscientific network cannot be separated between the inside and the outside of the laboratory. Networks are situated in the discursive field of "science, technology and society" (Latour 1987). The PI, lab technician, laboratory, ponds and transgenic fish illustrate one set of associated entities which brings forth an object of interest on the inside as well as the outside. From daily fieldwork, it became evident that the laboratory was situated in a broader sociotechnical ordering. For example, collaborating PIs and lab technicians from across North America frequently contacted the laboratory to inquire about their gene constructs, tissue samples and overall progress of the collaborative research. By further following the collaborating actors, the outlines of a scientist-identified "transgenic research community" allowed for the further situating of the facility into a broader sociotechnical effort at ordering.

THE TRANSGENIC RESEARCH COMMUNITY

Since the inception of the genetic engineering of fish in the late-1980s, transgenic fish research has entailed growing collaborations among a broad based scientist-identified "community" of researchers. The earliest collaborations involved actions such as borrowing equipment, the training of aquaculturists in advanced molecular biology labs, and the joint authoring of grants and papers on the first gene transfers in cultured fish species (e.g. Dunham et al. 1987; Zhang et al. 1990). From these beginnings a decade ago, the transgenic network has enrolled many more actors. The network has become longer. As a consequence, the field is more complex, diverse and multi-vocal as the network has extended into broader non-laboratory settings.

I characterize the current transgenic research community as linked together by multiple research questions, applications, materials and controversies centered around the building, measuring and performance of transgenic fish. These questions pertain to aquaculture applications as well as theoretical ones regarding immunology, growth regulation, evolution, population genetics and the environment. In interviews, scientists often described the social relations of their work as situated within a "transgenic research community." Worldwide, scientists in the field communicate with each other. They compete, debate, collaborate, exchange materials, share grant monies and jointly publish articles. On the surface, or if one reads popular accounts, the designation of "community" implies a seamless uniformity, allegiance and boundedness among its members. In contrast, the transgenic fish research community draws together a relatively diverse array of heterogeneous actors, materials, locales, abilities, interests, questions and activities. Defining, enrolling and intertwining these actants together in stable associations has given the network its current shape, form and trajectory.

Most obvious were aquaculture scientists such as those at Auburn. Their objectives were to produce improved lines of catfish broodstock for aquaculture through a combination of selective breeding and genetic engineering techniques (Dunham n.d.). Less obvious were an array of collaborating scientists and laboratories whose programs were organized around other questions concerning evolutionary biology, the molecular mechanisms of growth regulation, and immune recognition in lower vertebrates. One scientist expressed his reasons for collaborating with Auburn's genetic engineering program:

> It was the next logical step in the development of my work. It would enable me to answer questions that otherwise I couldn't have worked out . . . A number of the questions we are trying to answer concerning the function of the gene we dissected out in the lab and studied . . . can be appropriately investigated at the whole animal level by transgenic approaches . . . there's a logical extension of allied lines of research.

The effect is that a series of collaborations between diverse actors constitutes the transgenic fish research community through the building of a relatively stable but ever tenuous network.

I found that extensive collaborative arrangements in the transgenic fish community were unique to the field of aquaculture. In agreeing with this assessment, the rationale for these collaborative arrangements was put by a leading scientist:

> That's because so many skills are required. Look at how different are skills from cloning and sequencing a gene, finding its key regulatory element that's putting down its different expression vector; how different is that from spawning the fish and putting the gene in the young; how different is that from taking the data . . . how hard it is to take growth data from fishes and extract how much is genetic and how much of that is environmental . . . that's a real skill. If you look at the classical C-D-P [three PI's] collaboration; C does a lot of the building of the vectors, D produces the fish, and P's group has done a number of things involved with regulation and growth factor identification.

In short, aquacultural scientists were able to take advantage of opportunities to access resources such as grant monies, laboratories, equipment, techniques, biological skills and publishing outlets by extending their network in a manner clearly not evident in more applied lines of production-oriented aquacultural research. At the same time, collaborating non-aquacultural scientists found that in order to pursue their interests and opportunities, an applied objective of producing faster growing fish through genetic engineering enhanced their ability to address their own questions and sustain their particular research agendas. By collaborating where their interests overlapped, both groups could enroll relevant others such as funding agencies and journal editors through an "applied" linkage with aquaculture.

Collaborative networks are powerful because they extend and multiply sociotechnical effects. The broader they are the more advantages they hold for advancing the research network. As a leading scientist noted:

> Look at who are the most successful groups in the United States. It's those two who have very broad collaborations. Other groups and I won't mention names so as to not embarrass them, one person labs or maybe one aquaculturist and a molecular geneticist just haven't had the horsepower to come into the lead. They just don't have those different points of view being brought to bear. They don't have the resources and connections.

In the case of transgenic fish research, Auburn's genetic engineering facility works with an international array of collaborating scientists. As the only outdoor testing site in North America, the facility's containment ponds have intertwined aquaculture, molecular genetics and the environmental interests of the transgenic community and others. The justification was put by Chen and Powers (1990: 214) during an earlier move towards outdoor testing:

> In order to achieve the maximum potential impact of the foreign genes in transgenic animals, it is essential to study the physiological, nutritional, developmental, immunological and reproductive responses of transgenic fish in the simulated wild type environments (i.e., outdoor ponds with proper containment), where model environmental studies can be carried out.

These external collaborators have strengthened Auburn's limited capacity in molecular genetics. Moreover, a molecular biology capacity complements Auburn's expertise in aquaculture genetics. Conversely, non-aquaculture collaborators are able to test the objects within a contained setting which simulates "natural" aquatic environments. Chen and Powers (1990:214) illustrate these intertwined interests:

> For example, it is important to study the growth characteristics of transgenic fish that produce elevated levels of GH under typical aquaculture food saturating and under conditions of food variability such as are experienced during seasonal changes in the natural environment. Will these transgenic fish starve when food is limited, or will they out-compete wild stocks? These and other critical pond experiments, must be done in order to assess the environmental impact of transgenic fish.

With the growing development of the field, the advancement of these interests, however, did not go uncontested. In contrast to the above quoted necessity of moving to "critical pond experiments," another group of scientists in the transgenic field advised caution in this matter. As a consequence, a protracted controversy broke out over the environmental safety of pond experiments involving transgenic fish (see Chapter 6).

Collaborative networks, while defining, enrolling and intertwining the interests of the actors, however, are never static and are further shaded by controversy, uncertainty, competition, and a desire for independence. The Auburn PI summarized the relative strengths and weaknesses of collaborative work:

> the weakness behind any collaboration is that obviously each independent program has its own agenda . . . so your collaborator can't address all the things you'd like to and on certain occasions they're going to have other priorities. So another purpose of our having our own molecular geneticist is so that we have the independence to address what we want to, when we want to, without having the constraints of a collaboration. And our long term goal of course isn't to be totally independent but to have a combination of collaboration and independence to take advantage of the abilities of other people and resources.

As a case of technoscience in the making, the transgenic network never exhibits total stability. Against the backdrop of earlier novel successes in gene transfers, a general consolidation in the field, growing controversies in non-laboratory spheres and increased competition for resources, a new set of concerns and trajectories became evident. For example, scientists often mentioned that transgenic fish research was a long-term process which would require sustained commitment by funding agencies. In a funding era which scientists characterized as having a short-term horizon the uncertainty of sustained funding at both the federal and state agency levels created concerns. As one PI put it:

> I think the commitment of the federal government to supporting transgenic fish research and funding is gradually weakening. It wouldn't take much for it to disappear.

This sentiment was also expressed by another scientist who commented on the changing priorities of funding agencies:

> I think in the United States the funding is less and less. I think funders want to see results quickly. Gene transfer is long-term. We have had problems with [agency X] funding gene transfer projects . . . they are not interested anymore.

In another twist, two scientists discontinued transgenic laboratory research and entered into national and international aquatic GMO policy formation. As a consequence, they often found themselves at odds and at the center of a protracted debate with their colleagues concerning the potential environmental impacts of these novel organisms.

The collaborative relations within the transgenic fish research community provide good examples of the positioning of actors and laboratories within the plural processes of sociotechnical ordering. As the network lengthens, actants are mobilized, stabilized and combined to act at a distance (Latour 1987). For example, materials such as fish tissue samples can be sent to other labs for advanced molecular analysis. Conversely cloned gene constructs can be sent to the Auburn lab for insertion into fish and then tested in outdoor ponds. Through mobility, stability and combinability a greater range of productive power effects are exerted through the network. In this regard, the genetics facility critically facilitates this move through the outdoor containment ponds thus simulating the "natural environment." There are no other simulated natural environments. Due to these ponds, the facility acts, in part, as a "centre of calculation" - a point in the transgenic network which allows it to act at a distance on other associated actors (Latour 1987).

Clearly, the inside-outside association between the facility and the transgenic research community allows for cycles of accumulation resulting in action at a distance -- key network dynamics of technoscience in the making. From laboratory fieldwork, one important device which directed actions and gave a sense of organizing and ordering to all the inside-outside associations were the collaborative research projects. As discussed in the next section, the research projects provide another important dimension to the building of the network.

Paper Proposals

Research projects begin as stories. If convincing, that is if these proposals progressively define, enroll and mobilize the required resources, they become established by acting to produce the desired objects, in this case transgenic fish. Projects accumulate by amplifying the associations entailed in the building of the transgenic fish network. Latour (1996: 23-24) notes that:

> a technological project is a fiction, since at the outset it does not exist, and there is no way it can exist yet because it is in the project phase . . . In the beginning there is no distinction between the project and the object.

In these projects, scientists "pass progressively" from "signs and things" and "projects and objects" to one or the other (Latour 1996: 24). Clearly, transgenic fish are passing from projects to objects, from signs to things. But the movement from local circumstances to action at a distance has not reached a definitive closure: many partial accounts still permeate the projects and the quasi-objects. Despite spokesperson's claims about the potential of transgenic fish, these quasi-objects only exist as prototypes. We do know that (1) gene transfer has been accomplished, (2) prototype transgenic fish exist, but (3) the aquaculture potential is far from becoming a fish farmer's reality. With regard to these "objects," much remains unknown about their genetic expression. At the same time, how these "objects" would act in the environment has become central in new controversies and the subject of widespread speculation.

From my position at the lab bench, the sequencing of projects into actions was never made overtly manifest but was couched in seasonal cycles and as the everyday laboratory processes, techniques and routines of "piecing it together," and "making it work." Perhaps what is termed the "research and development cycle" was best put by one scientist who stated, "science and learning is kind of an *accumulation*, an accumulation day by day, year by year." A similar sentiment was expressed by a lab technician:

> Well one experiment just builds on another. If you break it down into one experiment like is the gene going to be incorporated into the egg? Into the fry? Then that's this year . . . That's the best way to look at it because it's too overwhelming.

Transgenic fish stories and potentials are kept alive by the PI-spokesperson. In broad terms, a spokesperson constructs a "society" where transgenic fish fit into sociotechnical ordering.

The spokesperson extends the network. The spokesperson claims that by overcoming the resistance posed by fish genes, transgenic fish can be engineered to perform in a very precise human designed manner (e.g., disease resistance, faster growth, freeze tolerance). These fish, they claim, will benefit humans in terms of food consumption, economics and the environment. It remains to be seen whether or not everyone and everything will be convinced by these arguments and whether or not the spokesperson can turn them into facts. However, what we witness are efforts to mobilize, stabilize and combine heterogeneous actors resulting in the cumulative modes of organizing and ordering of the sociotechnical.

At the genetics facility, projects were organized around seasonal cycles. There are two major "seasons" at the genetics facility. During the fall and winter when pond temperatures are low laboratory work features tissue sample extractions, screening, amplification and identification of transgenic individuals. With rising water temperatures in the spring, preparations are made for gene transfer. For laboratory workers, this is the most demanding time of the year. In the lab, foreign genes which originated at other laboratories are cloned and then microinjected into fertilized fish eggs which have to be synchronized with the spawning. After spawning, fry are nursed in the hatchery and need to be constantly monitored for growth, development and disease outbreaks to ensure that the required number of individuals are produced for the new round of projects. Not all fish spawn at the same time so there are back-up numbers of brooders to ensure that adequate numbers are produced to meet the requirements of the collaborative projects.

In broad terms, the genetic facility runs as a project cycle. From 1987 to 1996, I traced seven project grants listed in Table 5.3 below:

Table 5.3 - Transgenic Fish Research Projects (1987-1996).

Project Title (Funding Period)	Amount ($)
Development of Center for Genetics Breeding and Genetic Engineering of Warmwater Fish (King-Mellon Foundation: 1987-1992).	1,270,000
Gene Transfer and Expression in Farmed Fish (BARD-USDA: 1989-1991).	250,000
Transfer, Expression, Inheritance and Effect of Trout Growth Hormone Gene in Catfish (USDA-CSRS: 1991-1993).	200,000
Predator Avoidance, Spawning and Foraging Ability in Transgenic Catfish (USDA-CSRS: 1992-1995).	200,000
Gene Linkage Maps in Catfish (USDA-CSRS: 1993-1994).	200,000
Gene Transfer in Catfish (USDA-CSRS: 1993-1994).	15,000
Improvement of Growth by Expression of rtGH and Selection in Transgenic Catfish (USDA-CSRS: 1993-1996).	230,144

With the exception of the original King-Mellon center development grant, all projects were collaboratively funded by the USDA. The other six projects can be viewed as a "chain of translation" (Latour 1996). Outside of the original King-Mellon infrastructure grant, the most important project was "Gene Transfer and Expression in Farmed Fish" because a set of founding innovations came "from a blending or redistribution of properties that previously had been dispersed" (Latour 1996: 36). This project established the assumption that transgenic fish can be created and grown faster than non-transgenic siblings. Moreover, PIs argued that transgenic fish could increase aquaculture production thereby solving problems which could not be *better* solved by competing approaches.

Sociologically, it doesn't matter if everyone believes the transgenic fish stories. However, it is important that the USDA became interested in what the spokesperson claimed about transgenic fish. It is even more important that USDA funded the paper projects that the spokesperson submitted to them because this ties their interests together in real material terms. The USDA support reveals their sustained but silent interest in supporting the production of transgenic animals and the spokesperson. As put by one scientist, "If you go over to USDA, their goal is to have transgenic stocks of animals. It's a priority. They say that behind closed doors."

The USDA has been a major "outside" actor in building, funding and later regulating the transgenic fish network since the field's inception. Without this primary source of support for development, the network would simply collapse. The tie with USDA made transgenic fish partially real because they became quasi-objects or prototypes and further animated the stories behind the development cycle of projects. Yet, transgenic fish partially remain partially confined to paper because the projects have not delivered the desired performance that the spokesperson claims. The host genome, promoters, growth hormone and cells resist full integration and the associated interests of the spokesperson.

Chronologically, the previously listed projects provide an account behind the steady emergence of transgenic fish as objects and things. For example, "Gene Transfer and Expression in Farmed Fish," involved an early collaboration between scientists from the United States and Israel under the Binational Agricultural Research and Development Fund (BARD). This project established an orientation for all subsequent laboratory research. A founding chain of translation was established through some innovations (Latour 1996). The final report summarized the accomplishments over the two year (1989-1991) project period; (1) gene transfer efficiency was enhanced and evaluated in parental and sibling stocks of carp, (2) electroporation techniques allowed for greater numbers and better integration rates of rtGH1 cDNA (rainbow trout growth hormone), and (3) families of transgenic carp were found to grow at variable rates. Variable growth was traced to possible differences in copy number, level of expression, insertion site, genetic background and epistasis.

Another project, "Gene Transfer in Catfish" (1993-1994) requested a Baekon 2000 apparatus for electroporation of fertilized fish eggs with foreign gene constructs. Moving away from the tedious and inconsistent microinjection techniques, the Baekon 2000 apparatus allowed for many more fertilized eggs to be consistently incorporated with foreign growth hormone genes. Because a microinjector is hand and foot operated, only a small fraction of the eggs hatched and survived. As a result, the gene construct was integrated in only a small percentage of the survivors. With the electroporation instrument, many more eggs survived and the integration rate was significantly higher. Again, a constraint was removed and the procedure was turned into a routine whereby more materials could be processed in much less time thereby allowing for accumulation of more entities into the network.

These two representative projects accumulated entities necessary to partially translate the interests and ideas of the scientists into objects and things. If successful, tangible objects emerge and the chains of translation become longer. If the projects fail, then the objects are no more real than the paper they are written on (Latour 1996). What is at stake in this technoscientific endeavor is "defining the human form of a nonhuman and deciding on the limits of its freedom" (Latour 1996: 62). In transgenic fish research the gene transfer has been the real achievement. From there, the impression is one of many more uncertainties and specific questions pertaining to the interaction, determination and control of genetic expression at the molecular and environmental levels. As a result, reality could recede and the network could collapse if the scientists are unable to limit the freedom of the object.

With debates over the potential environmental risks of aquatic GMOs significantly shaping the field, "Predator Avoidance, Spawning and Foraging Ability in Transgenic Catfish" (1992-1995), proposed a series of outdoor pond experiments to determine the genetic risk of transgenic channel catfish with the rainbow trout growth hormone gene. For the first time, transgenic fish were evaluated for predator avoidance, foraging ability and spawning ability under outdoor pond conditions. These traits are critical for assessing the survival and competitiveness of transgenic fish in the wild -- a major focal point in the debates over the environmental safety of these organisms. These experiments were conducted in confined ponds at the genetics facility rather than aquaria or tanks because of the major assumption that "ponds can more closely represent the ecological complexity and diversity of the natural environment" (Dunham 1992 et al. : 5). Moreover, the ponds allow for the accumulation of environmental risk data. Critics do not have this source available to them. In short, this line of research seeks to address possible scenarios brought on by the escape of transgenic fish into uncontrolled environments and to answer critics who have raised environmental concerns regarding the establishment of transgenic fish populations in the wild.

Through these projects future scientists are trained and skills, values, and knowledge are transmitted through scientific practices. Future scientists at the genetics facility are trained within an aquaculture degree granting program. This program requires coursework and especially involvement in the research projects. The focus of training is on the applied aspects of aquaculture. In interviewing aquaculture and molecular biology graduate students, like the PI spokesperson, they often spoke on behalf of "science," "farmers" and the fish. Like the spokesperson, they argued that if the "public" would fully understand and negotiate their program of investigation they would clearly see the benefits. In sum, the development cycle trains future scientists to act as sociologists, as spokespersons for humans and non-humans.

Projects sustain the transgenic fish development cycle and promise future payoffs for aquaculture development and understanding genetic expression in aquatic organisms. Indeed, the projects have developed prototypes but a decade-long effort has been exerted to progressively pass to real objects. The projects which add up to the field's development sort through and accumulate relevant entities which have been subjected to organizing for an ordering effect in accordance with human desires. The momentum for the projects is maintained by interesting others with the promised payoffs for a "society" which the spokesperson has created in which to insert the products. At best, transgenic fish are prototypes and all the human and non-human resistances have not been overcome to achieve an ordering which is stable and in accord with the claims of the spokesperson. Nonetheless, those who need to be convinced have remain convinced by the spokesperson as the research and development continues.

Throughout fieldwork and later in interviews, I witnessed innumerable actions, listened to a variety of stories and observed the daily work undertaken at a fish genetics laboratory. In organizing and ordering this account I came to discern some patterning effects of technoscience in the making. In addressing how scientists go about doing research and development, I found that the inside-outside associations between the lab and field were inseparable. Moreover, by following the actors in the research and development process, modes of accumulation, organizing and ordering emerged as a set of intertwined associations upon which knowledge claims were asserted beyond the confines of a particular locale. In other words, by accumulating, organizing and ordering associations into a relatively stable configuration best captured in an inscription, action at a distance emerges which shapes the social. These cumulative modes are examined in the next section.

MODES OF ACCUMULATION, ORGANIZING AND ORDERING

Within the transgenic community and the emerging shape of the social, the genetics facility acts as a prominent center of calculation. This is due to the *strategic position* the facility occupies in the transgenic network which distinguishes it from other centers such as the collaborating molecular biology labs. First, the outdoor containment ponds are situated at the center of the knowledge claims and controversies to extend the fish into a wider sociotechnical ordering. Second, the production of transgenic fish for aquaculture brings together collaborating scientists who have begun the process of measuring and refining the performance of the fish in the laboratory *and* simulated "natural" conditions. Third, the applied aquaculture potential of these novel organisms, reenforced by questions concerning gene expression in fish and the environment, interests relevant others who sustain the program of investigation in the labs and ponds. As a consequence, transgenic fish have become real objects, currently positioned for further extension into sociotechnical ordering -- as products and as knowledge claims.

As a center of calculation, the facility acts on distant points in the network. The actors at the facility build a local microworld by displacing natural phenomena through engineering heterogeneous ensembles of new human and non-human associations. These ensembles are tied to social time and place. With their collaborators they lengthen the network. Through organizing and ordering a widening cycle of accumulation begins to take shape whereby transgenic fish emerge as products of scientific knowledge and practice. As a consequence of these associations, transgenic fish exhibit movement towards greater mobility, stability and combinability whereby they "act at a distance on unfamiliar events, places and people" (Latour 1987:223).

At this juncture, some the earliest efforts at building transgenic fish from the lab bench provide a tracing of some cumulative effects of organizing and ordering which have resulted in the emerging products and knowledge claims concerning transgenic fish. These practices at the lab bench dispel notions of "great ideas," "discoveries," and "internalist views of science," as the driving force behind technoscience and are replaced by the direct observation that technoscience in the making is a steady cycle of accumulation involving the tedious organizing and ordering work of everyday laboratory practice.

Beginnings at the Lab Bench

In the late 1980s, Auburn's genetic engineering program began in an unairconditioned storage room in a run-down makeshift laboratory-hatchery, located at the main research station. A former lab scientist recalled the inception of genetic engineering of fish in the late 1980s:

> MS: Where did the idea for undertaking this line of research come from back in those days?
>
> It came through R [the Director-PI]. He had been reading about it... he's got a very dynamic sense of potential and future . . . a progressive attitude towards technology and its application towards agriculture and aquaculture.
>
> MS: So he was an instigator or catalyst for taking on this line of research then?
>
> (Laughs) of saddling us with it. He went out and said "You guys learn to do this -- this is what I want to do, now you guys figure out how to make it work." That's how the whole idea of the lab usually runs. R comes up with an idea but then you have to figure out how to make it work.

A group of outdoor chain-linked fenced ponds for transgenic offspring were also set up at the main station. These ponds were situated next to a drainage creek which flowed into a tributary stream. At this site, biosafety was eventually determined as inadequate by Federal authorities because of the proximity to the creek (see Chapter 6). While the genetics group awaited the completion of the new facility, they initiated the work. Amidst much external scrutiny they began "figuring out" how to run a molecular fish genetics laboratory and "piecing together" the tedious process of gene transfer and pond rearing of transgenic fish.

In contrast, the published literature erases these grounded accounts of technoscience in the making. In published texts there is no trace left of the early trials, tribulations and tinkering which underscored the development of the laboratory or techniques involved in *organizing* the first gene transfers, the watershed event of the field. As will be illustrated in the next section, there are only inscriptions. For Auburn lab technicians, learning how to run a molecular genetics laboratory first required training in other laboratories. As a former lab technician recalled:

> You have to figure out how to best do it and to work in somebody's lab you cut down a tremendous amount of learning time. You can get your lab up and running and doing those projects so much faster than having to reinvent. You can read a paper on the simplest form like starch electrophoresis and it can take you a year to get your electrophoretic lab up and running to where you are getting consistent data or you can spend three weeks in somebody's lab and have yours up and running in another week. So the time is just tremendously different.

Once training was finished, bringing the techniques "back home" and "piecing it together," required trials and tribulations at the makeshift laboratory and ponds. At this time, "piecing it together" entailed learning how to microinject DNA into catfish eggs (Figure 5.6).

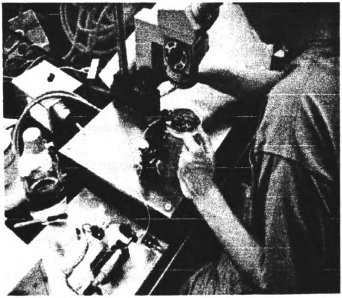

Figure 5.6- Microinjection of Fish Embryos with cDNA.

As a former lab scientist recalled early efforts at microinjection of human growth hormone into catfish and carp eggs:

> There are a lot of things people do in a lab that's not written in a paper . . . We had our little microinjector unit and fit in that unairconditioned room at the time and just basically started piecing it together. There was everything to figure out. You had to figure out how to make the needles, you had to figure out how the diameter of the needle would successfully get into the egg without rupturing the egg, how much you could inject into the egg without exploding the egg. The timing of the cell stage came down the road simply because there was so much to figure out ahead of that . . . how to get your gene, how to make it liquid enough in a solvent enough state to pass through the needle but not too dilute so that you weren't getting soluble amounts into the egg.
>
> MS: And now it's all standardized.
>
> See this is my problem with the whole lab up there . . . all these people walk in and we have everything cookbook and they have no idea what its taken just to get it to that point.

This sequence illustrates that organizing disorder does not entail following a pre-existing cookbook or having a "Eureka" experience, but involves the daily piecemeal trials and tribulations of building heterogeneous associations of malleable materials which overcome their resistance. In the above example, the eggs initially resist until the lab workers "figure out" the right needle diameter, solution amount and timing of the injection. The lab workers engineer a new heterogeneous association between humans and non-humans. By, "making it work," they displace natural and social phenomena through organizing things and people for a desired effect and ordering them to fit social time and place. If "it works" the trials and tribulations of earlier piecemeal efforts at organizing fade into the realm of routinized "cookbook" techniques. If "it works" an ordering of the laboratory microworld is a result.

As a consequence, a cumulative ordering of the local laboratory microworld sets the stage for extending into the social.

In the everyday laboratory we enter a world never directly manifested in scientific texts. As Rouse (1987: 224) summarizes "scientific practice introduces order into the phenomena it describes; it does not just find order there." At this juncture we find the "stuff" of daily technoscientific practice in its fundamentally disordered state. Hence, for the lab technician, the ground task is to construct a microworld by organizing disorder into an ordering. From the lab bench, the patterns are those of displacing, recombining, restricting, and overall tinkering with materials by "piecing it together" and "making it work" -- in other words by organizing disorder. It follows that high value is placed on the literary skills of inscribing and writing which traces the above associations in a distilled and succinct manner (Latour and Woolgar 1979).

Behind the knowledge claims in publications, lab scientists display a "hands on" grasp of the everyday constraints in ordering multiple activities and overcoming obstacles. Lab scientists and technicians "piece things together" and "work things out" through routinizing of human and non-human associations for desired *local* effects. In the above examples, running a molecular genetics laboratory and learning how to microinject laid a foundation for building *stronger associations* in laboratory ordering. Over social time, these events have receded into a wider cycle of accumulation whereby a well equipped and staffed laboratory and facility replaced the makeshift lab and ponds and where more efficient gene transfer techniques such as electroporation replaced the tedious hand and foot operated microinjection apparatus. As a consequence, many more actants were defined, enrolled and mobilized in positioning the products and knowledge claims into the wider cycles of accumulation and sociotechnical ordering.

By observing laboratory activities and by following these beginnings at the lab bench the significance of instruments and inscription devices becomes central in tying together all the heterogeneous associations of technoscience in the making. Through instruments and inscriptions, the daily work in the laboratory becomes focused as it is distilled and circulates as a visual display which is used to *represent* the composition of a knowledge claim and field. A focus on the manufacture of inscriptions allows us to follow the seamless weaving together of all the actants on the inside and outside of the laboratory as the socially ordered products of scientific practice and knowledge.

Following Technoscience Through Inscriptions

When we follow texts to the laboratory where they are produced "we are at the junction of two worlds: a paper world we have just left, and one of instruments that we are just entering" (Latour 1987: 65). In the everyday setting of a laboratory, an observer stands at a bewildering crossroads between ordering, disorder, texts, instruments, scientists, technicians, and fish endowed with human-designed properties and those that swim in the wild. On the surface daily laboratory activity can seem to be in a state of disorder: an urgent phone call puts tissue samples back into the freezer and sends lab workers to notebooks to tabulate growth averages and standard deviations on groups of transgenic fish; Southern blots are not amplifying the transgene thus delaying the making of solutions for gene cloning; a whole day is spent simply labeling hundreds of plastic vials for tissue samples.

From the above, how does one make sense of such a state of affairs? What are scientists doing? In this respect, Latour's (1987: 64) definition of a laboratory as "the place where scientists *work*," provides the visible cues to proceed into this labyrinth and out of it. A visual examination of the laboratory (see Figures 5.2 and 5.3) shows that it consists of work benches, storage cabinets for chemicals, a lab worker and the central element in producing technoscientific products in the lab and outside it -- instruments and inscription devices.

Instruments are central to building technoscientific networks. *Scientists work with and from instruments.* In the hands of a scientist, instruments are capable, alone or as a particular configuration, of creating new material substances and producing visual displays in the form of a highly valued graph, picture or map which is then circulated. As Latour and Woolgar (1979: 51) put it:

> particular significance can be attached to the operation of apparatus which provides some kind of written output. Of course, there are various items of apparatus in the laboratory which do not have this function. Such 'machines' transform matter between one state and another . . . By contrast, a number of other items of apparatus . . . transform matter into written documents.

Centrifuges, PCR, microinjectors and the Baekon 2000 apparatus are examples of instruments which in themselves do not directly produce written output. They transform matter such as solutions and fertilized fish eggs into other substances. Latour and Woolgar (1979: 51) define instruments which transform matter into written documents as inscription devices which are:

> any item of apparatus or particular configuration of such items which can transform a material substance into a figure or diagram which is directly usable by one of the members of the office space.

In the biochemical genetics laboratory, the closest example of an inscription device is the Southern blot hybridization apparatus. By pouring PCR products onto an electrified gel-plate, banding patterns may appear which are photographed and interpreted as to the existence of a transgene. Other instruments such as PCR, are "part of a configuration" of items of apparatus which produce the picture. In a textual display, the picture can be further modified and serve as the basis for an argument (Latour and Woolgar 1979).

By following instruments and inscriptions through the laboratory and into a text, an end point of sorts is reached which culminates in a *visual representation* of evidence that the transgene is present in the fish. From Chen et al. (1995: 913), a key inscription from the transgenic fish literature is reproduced in Figure 5.7 below. This figure visually displays the identification of a transgenic fish by means of semiotic molecular measurement and words.

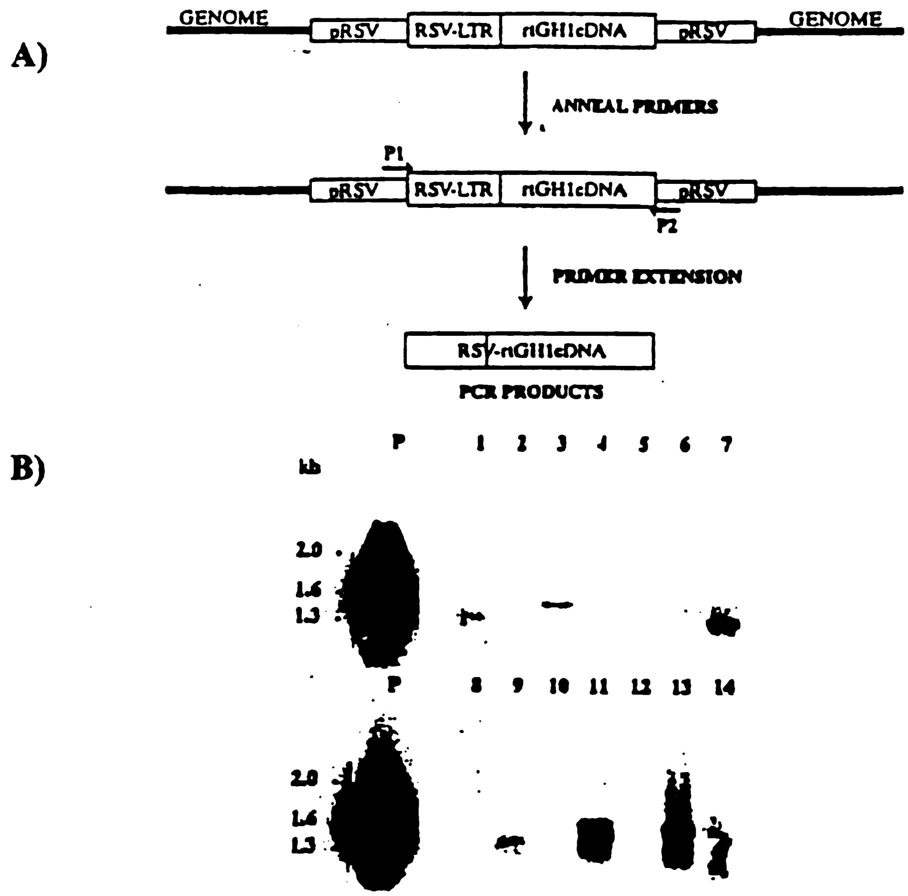

Figure 5.7-Identification of Transgene in the Presumptive Transgenic Fish by PCR and Southern Blot Hybridization.
Source: Chen et. al. (1995: 913).

The "(A)" frame represents the PCR amplification strategy. The PCR instrument amplifies small quantities of targeted DNA into larger quantities of analyzable materials. Koshland (1989: 1541, quoted in Rabinow 1996) provides a good summary of PCR:

> The starting material for PCR, the "target sequence," is a gene or segment of DNA. In a matter of hours, this target sequence can be amplified a millionfold. The complementary strands of a double-stranded molecule of DNA are separated by heating. Two small pieces of synthetic DNA, each complementing a specific sequence at one end of the target sequence, serve as primers. Each primer binds to its complementary sequence. Polymerases start at each primer and copy the sequence of that strand. Within a short time, exact replicas of the target sequence have been produced. In subsequent cycles, double-stranded molecules of both the original DNA and the copies

> are separated; primers bind again to complementary sequences and the polymerase replicates them. At the end of many cycles, the pool is greatly enriched in the small pieces that have the target sequences, and this amplified genetic information is then available for further analysis.

The PCR apparatus is used to screen for presumptive transgenic individuals which often involve thousands of samples (Chen et al. 1995). A lab technician routinely programs the PCR instrument which results in greater quantities of targeted DNA. The finished PCR products are then subjected to Southern blot analysis. In short, amplification products are separated on agarose gels by electrophoresis, transferred to nylon membranes and probed with 32P- labeled RSVLTR-rtGH1 cDNA. From there a banding pattern will appear and after a picture is taken, the patterns are interpreted to indicate the presence or absence of the transgene. In Figure 5.7, the section marked "(B)" represents a Southern blot analysis of PCR amplified products. The marks in lanes 4, 6, 8 and 12 indicate positive for transgenesis. The marks in lanes 1 and 7 are the rainbow trout gene constructs (RSVLTR-rtGH1 cDNA).

For the reader, Figure 5.7 distills a long chain of translation which masks the building of the construct, cloning it, injecting it into the egg, rearing the fry, monitoring the confined ponds, preparing the tissue sample, and subjecting the displaced and recombined matter to PCR and Southern blot hybridization techniques. In place of all of these organizing and ordering processes, a simple inscription is produced which is "regarded as having a direct relationship with the original substance" (Latour and Woolgar 1979: 51). The inscription is the basis for a text which conveys the "ideas, concepts and theories" behind transgenic fish (Latour and Woolgar 1979: 63).

Getting to the point where an inscription serves as the basis for ideas, concepts and theories, requires a further elaboration of the hidden trials and tribulations of the everyday organizing and ordering of laboratory work. As a generalized example, over a two month period we encountered a series of problems in getting amplification in the laboratory. In the words of the lab technician:

> During the end of January there were a few runs of different amplification and nothing came up . . . At this time we ran out of primers and I ordered new ones. When they came I still didn't get amplification.
>
> Obviously something was wrong before we got the new primers -- the primers were too concentrated. Too much primer inhibits PCR reactions. So, I set up one reaction with a lot of different variables and out of this I did two amplifications 10-12 tubes (50 and 100 microliters). Only one set worked at 50 and 100 microliters. "Worked" means I obtained amplification.
>
> So, that means we switched everything to follow those reaction conditions. We got one amplification. Then we ran a mini-gel on Monday and only one amplified (PHONE CALL INTERRUPTS).
>
> (RETURNS) Where was I? We ran a gel and out of 4, one amplified. So that means we have two out of four because one worked the day before.
>
> The next thing we tried, yesterday evening... I figured out how much of each DNTP would have to be added from each DNTP tube to give proper DNTP concentration therefore bypassing the DNTP master mix. And we got no amplification. I thought here is where the problem lies.
>
> This afternoon I ran a mini-gel with all the positives and the negatives just in case someone put the positive template in the negative control tube (it just has water in it), and unfortunately or should I say fortunately nothing came up at all. So tonight I am setting up another PCR run with 4-5 different variables and we'll see what happens.
>
> The problem could be any of the following (1) template DNA has degraded but we've used old and new templates. It's doubtful, (2) Possibility that maybe not taking time in pipetting and not getting enough reagents, (3) Another possibility is that the positive DNA was not put into the positive control DNA tube, (4) Another possibility is that reagents are bad. I doubt

> that. The four N did one turned out. If the last one turned out we can eliminate bad reagents, (5) If no luck, I'll call some tech lines and friends.

Even more problematically, the amplification problem had backed up other pressing work. Three other major activities were put on hold; (1) cloning genes, (2) interphase blood smears, chromosome smears to see on the chromosome where on which gene the transgene had been inserted, and (3) "southerns," cutting DNA with two restriction enzymes to see if the gene had been integrated.

A few days later, the lab technician announced that the amplification problem had been solved:

> I set up different trials using different things to find out what was happening. It's in my other notebook (goes to retrieve notebook). It might have been a problem with who was setting up . . . poor lab techniques. Certain things continued to reiterate such as checking the solution for floaters, and sterile techniques... changing the god damn tubes. We get two primers that work and then three that don't. How do you figure that out?
>
> So I amplified twelve samples. I only amplified the plasmid, the gene using these different things. When I sat down to make up these samples, the water N was using was cloudy so I changed what I planned, adding more samples and involving N's water and fresh water. And those were the ones that didn't work.
>
> MS: What is meant by the "water"?
>
> The DNTP master mix. The four DNTPs and water. We aliquot it out. There was mixing in the same tube. [The problem] was a combination of things, getting new primers and then THIS.

In the literature, amplification techniques are currently considered routine and merely mentioned in Figure 5.7 as "by PCR and Southern Blot Hybridization." However, in the laboratory example above, non-amplification was a major time consuming problem which required extensive tinkering and trials until the desired effect was obtained.

During these amplification trials, I obtained a picture from one of the gel runs (Figure 5.8 below).

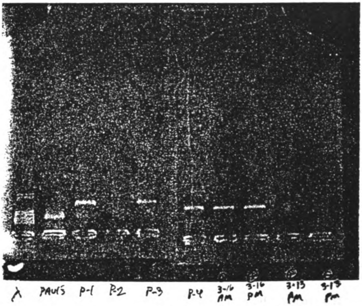

Figure 5.8- Southern Blot Amplification of Plasmid DNA.

I asked the lab technician for an interpretation of the picture:

> Lambda is the DNA ladder. Lambda is viral DNA, 50 kilobase and circular. The DNA is cut with restriction enzyme HrndIII which gives 9 bands of different sizes ranging from 150-200 bp to 25 kb (2,500 bp).
>
> DNA that P asked me to run is labeled P-1 to P-4. P-2 did not amplify.
>
> These samples were different gene cocktails and were left overnight in the fridge after being set up for PCR to see if they would work. This trial was to see if we could use half the taq (polymerase) we are currently using as it is very expensive.
>
> 3-16 am and pm are both positive. These samples amplified. They are the

> positive controls (they have the plasmid DNA, the gene we inject into the fish) for the regular fish DNA.
>
> 3-13 pm (+ -) did not amplify. 3-13 pm (-) did not amplify. This is the negative control ran on the gel to see if N had mistakenly put the template DNA in the wrong tube.

A comparison of the two inscriptions (Figures 5.7 and 5.8), allow for a paradoxical contrast between the laboratory, its position in the network and sociotechnical ordering. In Figure 5.7, the laboratories, processes and material associations fade into a series of blots which represent the presence (or absence) of the transgene. In contrast, Figure 5.8 and the technician's struggle to clear up the amplification problem is the outcome of local trials and tribulations in the laboratory. Once the problem was corrected; the inscription no longer matters, there was no accompanying text and it was not circulated beyond the laboratory.

In the text that subsequently developed out of Figure 5.7, the trials, tribulations, organizing, ordering, material substances and even the laboratories that were involved in producing it have been erased. Moreover, Figure 5.7 is widely circulated in the network as a basis for a text which carries with it *not* these trials and tribulations of local ordering but the ideas, concepts and theories about transgenic fish. In other words, Figure 5.7 serves as the source of knowledge claims which "facilitate a swift transition from craft work to ideas" (Latour and Woolgar 1979: 69).

The difference lies in the contextual linkages behind each inscription. Figure 5.8 represents the craft work of "figuring it out" within the *local* environs of the laboratory. Hence it is relegated to the mere "technical" and eventually forgotten. This figure carries no accompanying text which asserts ideas, concepts or theories. "It" builds no external linkages and merely signifies the correction of a problem within the local ordering of the laboratory. In contrast, Figure 5.8 *represents* to society; (1) a direct link to the substances and, (2) evidence for the assertions about transgenic fish in order to persuade others. These assertions are strategically circulated and embody linkages to other texts, work and institutions (Callon et al. 1986). The effect is that transgenic fish are poised for extending into a broader sociotechnical ordering *if* the spokesperson is persuasive and *if* no dissenters wait in the wings.

In illustrating this move, Latour and Woolgar (1979: 63) capture the critical significance behind an inscription. In a text, an inscription becomes:

> the focus of discussion between participants, and the material processes which gave rise to it are either forgotten or taken for granted as being merely technical matters. A first consequence of the relegation of the material processes to the realm of the merely technical is that inscriptions are seen as direct indicators of the substance under study . . . A second consequence, however, is the tendency to think in terms of confirmation, or evidence for or against, particular ideas, concepts or theories.

Herein lies the value of inscriptions. They provide a transition point from the inside "technical" work of the laboratory, which is erased and transformed into the broader realm of ideas, concepts and theories. Indeed, the success of gene transfer in fish, represented by an inscription, carries a broader set of ideas, concepts and theories as to how these novel entities would act at a distance. As such, texts:

> make possible the construction of linkages between existing entities and the formation of novel entities and, if persuasive, thereby constitute an important method for attempting to control the environment (Callon et al. 1986: 11).

As a consequence, there "thus occurs a transformation of the simple end product of inscription into the terms of mythology which informs participants' activity" (Latour and

Woolgar 1979: 63). Hence, the basis for the astounding claim by scientists that transgenic fish will indeed "feed the world."

Inscriptions are a transitional "end result" of the laboratory as the source of technoscientific production which erase and reassert a representation of lab production in terms of facts in a scientist-envisioned "society" (Latour 1987). Following technoscience in the making through the construction of inscriptions allows us to trace the activities in the laboratory to the strategic position a text plays in envisioning a sociotechnical ordering. While a transgenic fish is nothing more than a heterogeneous association of material substances which travels through instruments and leads participants to produce a text, "it" further informs participants' activity because as a text links with other texts, work and institutions are forged. Hence, the importance of an inscription device, "is that none of the phenomena `about which' participants talk could not exist without it" (Latour and Woolgar 1979: 64). This talk is about creating and controlling actants, persuading others and building a world beyond a mere laboratory through action at a distance.

CONCLUSION

This chapter addressed the question: How do scientists go about doing research and development? Through a case study of a laboratory, a variety of everyday trials in the organizing and ordering of a local microworld were detailed in the heterogeneous association building of a transgenic network. Throughout this depiction of the transgenic network, the inside-outside association remained a prominent feature of fieldwork. In tying together the moves from the laboratory to a broader sociotechnical ordering the creation of an inscription distills the cumulative actions of a laboratory on the inside as well as the outside.

In conclusion, scientists go about doing research and development by working with and from instruments. They produce inscriptions, some of which circulate beyond the laboratory. These inscriptions carry the ideas, concepts and theories concerning transgenic fish. These stories inform the participants' activity which seeks to extend the products of technoscientific practices. At this juncture in the broader sociotechnical ordering, the laboratory fades from view, and the social positioning of transgenic fish in the lengthening network undergo transformations in the hands of others. The next chapter details the strategic political moves to go beyond the laboratory walls and their effects.

Chapter 6

MOVING FROM THE INSIDE TO THE OUTSIDE

INTRODUCTION

The last chapter depicted a laboratory's efforts at organizing and positioning into a broader sociotechnical ordering. While many daily lab activities remained local, the building of heterogeneous associations and subsequent representation of transgenic fish in texts and also ponds signaled an extension of the network through action at a distance. In particular, the centrality of instruments and the value of inscriptions provide the transformative base from everyday laboratory craft work to widely circulated assertions in texts which envision an ordering of the social. As a consequence, the laboratory fades from view and other actors, contexts and controversies emerge over the movement of transgenic fish out of the laboratory and into a wider sociotechnical ordering.

In order to facilitate this move, scientists must envision a society to extend their assertions and novel lab-created objects. This is so because in the laboratory scientists enculturate natural objects to fit social time and places. Through this simultaneous "double move" from laboratory to non-laboratory environs, scientists attempt to heterogeneously engineer a longer network by building a society. Without "a society" the assertions and objects would simply remain in the laboratory. As a result of these machinations, the divide between science and society becomes obscured within cultural practice. Thus, "science" and "society" emerge as intertwined network effects of sociotechnical ordering.

The last chapter alluded to the controversies concerning the extension of transgenic fish into sociotechnical ordering. In this respect, actors supported or resisted the efforts of scientists and others to extend the network outside of the laboratory. Scientists argued that transgenic fish models offered fundamental insights into the mechanisms of evolution, growth regulation and immunology of lower vertebrates. Moreover, scientists attempted to persuade relevant others that the commercial culture of transgenic fish could alleviate world food problems. In contrast, environmental groups argued that the work on transgenic fish was premature and serious environmental problems were a likely consequence of an extended network. They challenged the scientist-advocates with the question: How would transgenic fish act in the wild?

This chapter begins with a proposal to move transgenic fish, a few hundred feet, to minimally secured outdoor research ponds at Auburn. An ensuing controversy developed which brought many more actors into the network. Both advocates and dissenters posed "obligatory passage points" -- whereby they defined problems in their own terms or resisted enrollment efforts in order to resolve or block the movement of other actors (Callon 1986). In brief, the forces of dissent were defeated over the local issue of outdoor pond research by a hypothetical scenario constructed by advocates which argued that: (1) the possibility for a "catastrophic" transgenic fish escape from the *new genetics facility* would be "virtually impossible," and (2) an escaped transgenic fish would face a set of harsh environmental conditions preventing its establishment in the wild.

While the controversy over the local outdoor pond research subsided, a series of consequences arose from this local controversy which had no precedent. First, it became apparent that a national oversight policy concerning aquatic GMOs, consisting of finfish, shellfish and crustaceans, was required which addressed shortcomings in existing federal protocol, acts and guidelines. Second, a movement among scientists and policymakers to address these shortcomings led to the creation of voluntary national performance standards for the safe conduct of research involving aquatic GMOs. However, the creation of performance standards raised many more unresolved concerns and questions over extending aquatic GMOs, including finfish, into new network spheres of commercialization, public acceptance, and research unfolding in other parts of the world.

In order to better convey the jostling and machinations of this actor world, a dramaturgical approach outlines this chapter. The first act reconstructs, in some of the key participants' own words, the controversies involving the move to outdoor research ponds and early aquatic GMO policy formation. The second act involving the creation of the performance standards is an outcome of these earlier controversies. As we move away from the laboratory, the stories that unfold become broader and bolder as transgenic fish extend along the network. Heated arguments take place on pond banks over their width, in administrative offices where careers are at stake, and at international meetings over defining aquatic GMOs and the criteria for performance standards. Moreover, some scientists threatened to move their research overseas rather than comply with any performance standards. In conclusion, no sense of closure is reached because the socially constructed standards have reduced (social) "objectivity" to exclusive biological phenomena and parameters. As a consequence, the performance standards have opened up significant new social arenas of contestation along an extensive international network.

ACT I: AN EARLY SHOWDOWN

Human Actors in Association with the Non-Human Actors below: Administrators and scientists from the Alabama Agricultural Experiment Station (AAES), Auburn's Institutional Biosafety Committee (IBC), scientists from The National Institute of Health (NIH), the Environmental Defense Fund (EDF), Federal policymakers and scientists from the Office of Agricultural Biotechnology (OAB), the United States Department of Agriculture-Cooperative State Research System (USDA-CSRS), and the Agricultural Biotechnology Research Advisory Committee (ABRAC).

Non-Human Actors in Association with the Human Actors Above: Transgenic carp, makeshift transgenic research ponds and hatchery at Auburn, a drainage creek leading into Saugahatchee Creek-Yates Reservoir, the National Environmental Policy Act (NEPA), and the USDA-CSRS (1990a) authored Environmental Assessment (EA) document "Environmental Assessment of Research on Transgenic Carp in Confined Outdoor Ponds."

A Passage Point: How to conduct environmentally safe transgenic fish research in outdoor ponds.

The Plot: In December 1986, AAES submitted a broad genetic engineering proposal to the USDA-CSRS. One feature of this proposal concerned the movement of transgenic carp to outdoor research ponds. There was no precedent to follow in this case. Proactively, the AAES requested a review of the proposal from the USDA-CSRS and the ABRAC who concluded that biosafety measures were adequate to protect human health and the environment. However, in the original proposal Form 62 had not been completed and signed by Auburn's IBC causing a delay which allowed Federal administrators more time to consider all of the environmental ramifications in accord and compliance with NEPA. An interpretation of NEPA raised a number of objections over the environmental integrity of the proposed research site by federal policymakers.

As a consequence of these actions, federal policymakers from OAB and the USDA inspected the makeshift outdoor research site located at Auburn and found it deficient. Members of the AAES asserted that the site was adequate, while one member from USDA-CSRS tenaciously asserted that the environmental integrity of the site was not consistent with NEPA. A controversy erupted which was settled by revising an initial EA (Environmental Assessment) from three to five alternatives with the preferred alternative involving the outdoor rearing of transgenic carp at the new genetics research facility.

Sub-Plots: As transgenic fish became enculturated to fit social time and place, they moved from the laboratory to outdoor research ponds. After much controversy, they overcame a passage point. However, the fish, researchers, USDA and other actors encountered many more passage points along the lengthening network. As a consequence of these ongoing controversies, two members from Minnesota's transgenic fish research group (MTFG) began to address aquatic GMO policy matters (Kapuscinski and Hallerman 1990a; Kapuscinski and Hallerman 1990b; Hallerman and Kapuscinski 1990a; Hallerman and Kapuscinski 1990b). These early efforts culminated in the creation of national voluntary research performance standards involving over two hundred participants. As a result, many more actors became involved in the debates, controversies and policy processes concerning an extension of the network.

"Let me just tell you a little bit about the Auburn thing. They came in with a large proposal . . ."

- an OAB employee

The USDA justifies biotechnology applications in aquaculture and more specifically the genetic engineering of fish as an avenue by which to "produce improved fish that may enhance the U.S. aquaculture industry and help maintain its competitiveness in world markets" (USDA-CSRS 1990a:4). As such, USDA funds biotechnological applications in aquaculture and a modest amount of transgenic fish research and development within an aquacultural genetics and breeding program (Parker et al. n.d.; UDSA 1988; OTA 1995). In December, 1986 AAES submitted a broad proposal to USDA-CSRS for approval of transgenic fish research involving several cloning vectors. A Federal official recalled:

> they came with a very non-specific, kind of raw type proposal that mentioned biotech, and mentioned working with growth hormone genes, a series of growth hormone genes in a bunch of different fish. But it was not specific. Some teams were put together that went down to Auburn to talk about it. The upshot of some of that was that they advised Auburn first to stay away from the human growth hormone gene because of its political sensitivity and they were advised to come in with a very detailed and specific proposal to pull that component, that biotech component out and really define it quite specifically and define very clearly the site where they were going to do it.

As a consequence, AAES submitted a revised proposal to the Director of OAB in February of 1989. In March of 1989, ABRAC reviewed the revised AAES proposal and concluded that biosafety measures described in the AAES proposal "were sufficient to protect human health and the environment" (USDA-CSRS 1990a:8). At this public meeting several environmental groups, representatives of other federal agencies and members of the media were present.

Upon submission of the revised proposal to the Administrator of CSRS, OAB in conjunction with a number of experts drafted an initial environmental assessment. As a former OAB official recalled:

> some people were assigned to work on the original environmental assessment. But the original document, that was done in-house. It was woefully inadequate. I took a look at it and I advised the Director that it was woefully inadequate. I think there were a lot of things that were not done right very early on because of inexperienced people. I think they thought it was going to be a very simple task and breeze through it quite easily when it was really a lot more difficult and complex. That's why we lost some time in the beginning in proceeding more expeditiously.

The AAES proposal was unique because it involved the movement of transgenic fish to outdoor ponds. Did this move constitute a deliberate release? In this case there was no precedent to follow. Moreover, the proposal attracted widespread attention from anti-biotechnology advocates and environmental interest groups. (Hallerman and Kapuscinski 1990a). An OAB employee assessed the overall situation at this time:

> As in anything that is new like this, when you are cutting new ground you've got a lot of stakes involved. You've got the environmental groups, you've got your industry people, you've got Fish and Game people, you've got all sides of the spectrum in the perspective speaking from a sociological standpoint, plus you've got some politics involved with people trying to figure out just what directions should the government be going in this area.

At stake was compliance with Federal Policy and the integrity of the research. As an OAB official recalled:

> Now it's critical to understand in regulatory policy that stuff like the Auburn work that is funded by a federal agency must comply with the National Environmental Policy Act. That means you must consider the environmental consequences of your actions and you have two choices: you can do an environmental assessment and make a finding of no significant impact or if there is some impact you got to do what is called an environmental impact statement -- follow all the rules and procedures in public involvement in doing that . . . very sensitive with the environmental groups and they were very opposed to any fish work getting very vocal and very opposed. They thought it was all premature.

In particular, objections were raised about the adequacy of outdoor ponds and hatchery containment facilities (Hallerman and Kapuscinski 1990a).

As a consequence, AAES modified confinement measures at the makeshift site. This revised set of procedures and protocols became the "preferred USDA alternative" in the initial EA. Three alternatives comprised the scope of this document:

(1) (original AAES proposal) - rearing of 50,000 offspring/fry in older, outdoor research ponds and reducing the number to 3,000 when the fry reach fingerling size.

(2) (Preferred USDA action) rearing the same number of offspring and fingerlings in the older outdoor research ponds "under modified conditions of confinement and mitigation, primarily in the water drainage system and pond levees

(3) (no action) rearing reduced numbers of offspring indoors in a new hatchery facility (USDA-CSRS 1990a:1).

The USDA-CSRS (1990a) published the initial EA in the February 16, 1990 Federal Register (1990b) and invited public comments. Despite USDA's finding of "no significant impact" comments emerged regarding the scope and need for the research. In particular, the management of confinement facilities came under questioning by environmental groups. It was also noted that past research at this facility had led to the introduction of exotic Chinese carp into nearby Saugahatchee Creek-Yates Reservoir. In the words of a former OAB employee:

> there clearly was going to be a problem and it was very important that we very closely follow the requirements of National Policy and do so in a way that if there were a legal challenge we would be in good shape to deal with that challenge. And that was my main concern. I felt that the worst thing that could happen to the Department was to take an action and then have one of those [environmental] groups take it to court and as a result tie up this whole field of research for years and years through the court process.

The major environmental concern centered around the research ponds which were situated next to an open running drainage ditch that flowed into nearby Saugahatchee Creek-Yates Reservoir. The tops of these ponds were less than one foot above the recorded one hundred year flood level. Pond outlets relied on filters which could easily break or clog, allowing fish to escape. Moreover, the hatchery where some of the early phases of the work was to be conducted (e.g., microinjection of fertilized fish eggs, rearing of fry) lacked a secure drainage system.

A Dissenting Voice

At this time, advocates anticipated that full outdoor pond trials of transgenic carp would shortly commence without undue delay. In fact, nine adult transgenic carp were moved to two of the outdoor ponds due to the difficulty of survival indoors. This movement of adult carp had been approved by Auburn's IBC in accordance with NIH Guidelines. Any opposition from environmental groups such as the EDF was relatively muted by institutionally managed concerns directed by the USDA-OAB, ABRAC and the AAES. As the lead agency, the USDA-OAB along with other actors (e.g., ABRAC, AAES, fisheries experts) were overwhelming in favor of quickly approving the research in accordance with alternative two in the initial EA -- the rearing of offspring and fingerlings in the older outdoor research ponds "under modified conditions of confinement and mitigation, primarily in the water drainage system and pond levees" (USDA-CSRS 1990a:1). In fact, the consensus was nearly unanimous as close to fifty experts (e.g., ABRAC, fisheries scientists, OAB) weighed in with the view that the biosafety measures of the research "were sufficient to protect human health and the environment" (USDA 1990a:8).

However, formal approval for a federally funded agricultural research project requires the signature of the USDA-CSRS Administrator. While the consensus was nearly unanimous, one administrative research scientist refused to sign off on the proposal. He recalled his reasons for not signing off:

> At that point when the original Hatch Project came into us there was a form [62] that they filled out that says it is reviewed by the institutional biosafety committee. If that form would have been completed and signed I would have signed off on it. It was our protocol at that point. It was not done and at the same time Auburn proactively came in and got ABRAC involved. See you had ABRAC reviewing things, making recommendations and decisions while the original proposal was on my desk and I was the one who had to sign off on it, *not* ABRAC. That was what held it up on my desk.

In short, to adhere to NEPA and NIH guidelines, recombinant DNA work required that institution's IBC review and approval.

Why didn't Auburn's IBC check off and sign the form? First, the AAES proactively sought input from USDA and the ABRAC. This immediately brought public attention which involved other interested groups and an ensuing national policy debate. Second, given that this was the first time transgenic fish were to be reared outdoors, compliance with NIH guidelines over the matter of whether the contained pond rearing of transgenic carp fingerlings initially constituted a "deliberate release" required more specification. According to an Auburn Biosafety Officer involved at that time:

> What happened was the part that was inside the laboratory really didn't constitute any kind of controversy. That went along quite smoothly. But the non-standard laboratory portion using the containment ponds--there was a lot of public interest. One of the things going on in Washington, I believe, was that the IBC succeeded in convincing the ABRAC that this wasn't a release and therefore wasn't really under its purview. That immediately put it back under the guidelines of the NIH, who had no problem with this, and then I believe we went on from there.

The issue at stake was whether the movement of transgenic fish to outdoor ponds constituted a "deliberate release." Under Section III.A of the NIH guidelines, before a deliberate release can take place the NIH must first publish information on the experiment in the Federal Register and allow thirty days for comment. Second, the Recombinant DNA Advisory Committee of NIH must review the experiment and decide whether to grant approval (NIH 1995). At the same time ABRAC was reviewing the proposal and considering further documentation provided by Auburn's IBC that the outdoor confinement procedures were adequate and in accordance with a proposed revision of NIH guidelines (NIH 1995; USDA-CSRS 1990b).

Eventually the issue concerning deliberate release was resolved. According to Auburn's IBC, the NIH and the ABRAC, moving transgenic fish into modified containment ponds did not constitute a "deliberate release" into the environment. However, the delays and settling of this narrower issue, allowed key officials the time for further consideration of the environmental ramifications and intentions behind the proposed research actions. As put by the USDA-CSRS administrative research scientist:

> I simply asked the question: How many fisheries biologists were looking at the environmental impacts of that proposal? The way it was handled with ABRAC again pointed out the deficiency. You had people who were working with bacterium and plants making comments on facilities for fish. These people understand agriculture but they didn't understand aquacultural systems. If you put a chain link fence around a pond that doesn't mean you are going to keep fingerlings in there. So what? That doesn't mean anything to me as a containment facility. And to say that fish can't get from this pond to this creek, either way, I think there is regular likelihood that somehow they will get there.

Since Auburn's IBC had not signed off, it allowed the administrative research scientist the time to further reflect on and consider the environmental integrity of the research site. He recalled that if Form 62 had been completed:

> We wouldn't have been involved. I wouldn't have seen that *and* all these other issues besides the ponds that pointed out a weakness in our system. And I pointed it out to the ABRAC. There were things that were inconsistent. I've been to the facility. I remember a statement [in the proposal] saying "all of our dikes are four feet wide at the narrowest point in any dike" and I'm saying "Well, I'm sorry they are not." A number of those dikes are caving in. Those dikes, in fact the perimeter dike is actually the stream bank as well. The internal dikes are caving in and there are definitely points where there's less than two feet.

As the lone and key holdout, this individual came under intense career and decisional scrutiny. In his words:

> I was put in a very awkward position and a very stressful position. And it threatened my job. And my position was if he [USDA-CSRS Administrator] disagrees so much with my assessment he can certainly override that but my professional opinion is not negotiable. We can disagree and as he told me he had fifty people telling him to sign it and one person telling him not to. So if I was in that situation I would look at those fifty people and that would be grounds for me to maybe ignore that one individual. But who are you listening to and what is that one individual saying?

In order to expedite a formal decision, the Administrator requested a written and signed review of the administrative scientist's position. As this individual recalled:

> I had a day off. At that point we used to always have every other Friday off. He [the Administrator] wanted me to come in and I told him "Let me work on it at home this weekend." And I really thought through the issues and my position and I signed it and dated it and gave it to him on Monday.

On Tuesday morning, the Administrator called the administrative scientist to say he was coming to *his* office. Thinking "I bet that's how he fires people" the administrative scientist waited for the Administrator.

Upon arriving the Administrator stated that he had fifty people telling him that this administrative research scientist was wrong. In the words of the administrative scientist, the Administrator then announced:

> "I've reviewed your report and I think you're right. And you're actually the only person that stood up to me in this whole debate here. And I think your position will now be the Department's position. And I'll support that. The only thing I'm requesting is that you and I go down to Auburn and look at the facility ourselves."
>
> Because there were things I was saying that actually in my report conflicted with some of the information we had from Auburn.

Due to a connection with the White House, an Air Force One jet was chartered and flew to Alabama. Aboard were five federal officials, including the Director of OAB, an OAB policy analyst, an environmental lawyer from APHIS, the USDA-CSRS Administrator, and the administrative research scientist. Awaiting them in Auburn were members of the AAES, including the Director of the Experiment Station.

How Wide is This Dike?

From the onset, inspecting the Auburn research site involved confrontation. The AAES Director demanded to know *who* was holding things up. In his view, AAES had complied with all the guidelines and documentation necessary for commencement of the outdoor experiments. Moreover, the revised proposal had received an endorsement from ABRAC. On the other hand, the team of Federal administrators and scientists had to adhere to, and more importantly interpret national policy guidelines in a case where there was clearly no precedent.

The Federal inspection team visited the containment ponds and a hatchery -- dubbed the "biotech facility" in the proposal. At the ponds, the team was confronted by the issue of the width of pond dikes with documentation from the University Vice-President stating that they were four feet wide. In the words of the USDA administrative scientist, the following exchange took place between USDA and AAES scientists:

USDA: They are not four feet wide.

AAES: Did you measure them?

USDA: Well, I didn't bring a tape measure.

AAES: Well, why didn't you?

USDA: Hey, I'm not here to measure the facility. I'm telling you there's a problem with the integrity of those dikes. I'd be concerned about it in a routine experiment. And in this case we have to be concerned about pond levels being on a flood plain -- all of that.

AAES: We have a letter from the Vice President, are you right or are you wrong? Or is he right or you wrong? One of you is right. One of you is lying.

USDA: No. I don't think either one of us are lying. Okay? I don't think the Vice President went out here and measured the dikes.

> We went to a point in the dike and I said "Is this four feet wide here? Is it three feet wide? Is it two feet?" (and at that point it was like that) and the Administrator said "No."

The inspection team next visited the run-down hatchery which was designated as the "biotech facility." The inadequacy of this facility was clearly exposed in the following recollection by the administrative research scientist:

> When we went there, the emphasis was on the ponds. I kept on saying all along that the hatchery was a real threat more than anything. If the hatchery and fry are in this facility and that has external drains that go in you have to pay attention. AAES countered by saying "That's not part of our proposal." I said "I'm sorry it's in the proposal. I don't know if we are funding that work or not but that's an environmental issue that needs to be addressed." So while we were down there I suggested to the Administrator that he ask to see the biotech facility. We went there and opened up that gate and the Administrator said "What are we doing here? What is it?" And the Chair of the Institutional Biosafety Committee was with us. And Y was there as well, and either one had supposedly had signed off that this was the approved facility. The question was asked of the Chair: Have you ever been here before? And he said no, it was the first time. And it looked like a garage and I didn't need to know what it looked like inside.

At stake were two different positions. The point of contention between the AAES and the USDA inspection team both involved interpreting and conforming to different sets of regulations which both did. The incongruence of those regulations revealed shortcomings in Federal oversight. Both parties were following the correct protocols. However, the uniqueness of this case exposed gaps in regulation and guidelines especially with respect to environmental safety. As stated by the administrative research scientist:

> We were at opposite sides of the table but agreeing on everything we were saying. Yet we had an experiment station director at the head of the table and a director of an agency at the other end who had already made a decision that we were so far off on we really had a difference of opinion. They had a different set of regs that they had to comply with than me. And again if they wouldn't have used our federal funds they could have done any of the work. We had no involvement. Federal action was the use of our funds and that's

> why we were involved. If they would have done that with State money we don't have anything to do with it.

In short, the site did not pass the passage point posed by environmental containment as conditioned by the use of federal funds and an interpretation from NEPA. In resolving this controversy, the administrative research scientist advocated that the research be conducted at a new and superior facility:

> That was a very painful experience but a growing experience. All that is a big step forward when they acknowledge the deficiency they have when they take on something completely new. We knew they had a plan for the new facility and my opinion was -- this lower facility? No! This is not the model. This research is too important and we have to do it right. Let's work together on the new facility and let that set the standards for others. And that's the scenario that eventually played out.

In sum, if Form 62 had been signed by the IBC on the original proposal, the outdoor experiments would have commenced as envisioned by Alternative Two "under modified conditions of confinement and mitigation, primarily in the water drainage system and pond levees" (USDA-CSRS 1990a:1). Because Federal monies made up a portion of the overall funding, an interpretation of NEPA had to be applied to this case. With no precedent to follow, gaps in Federal oversight policy and guidelines were exposed.

As a consequence of this case four important policy developments were institutionalized. First, interpretations of NEPA and NIH guidelines were used to guide decisions regarding outdoor research on transgenic fish. Second, NIH guidelines were revised to include a section on aquatic systems. Third, direct responsibility for compliance with NIH guidelines concerning "appropriate containment" became vested with the research institution's IBC. Fourth, the incentive for the formation of a special ABRAC advisory group on genetically modified aquatic organisms began to take shape.

Moving From Three to Five Alternatives

In settling the movement of transgenic carp to outdoor research facilities, two additional alternatives were added to the revised EA (USDA-CSRS 1990a:1). The two new alternatives proposed were:

> (4) (USDA Preferred Action) called for "rearing 50,000 offspring/fry in new research ponds of superior design and constructed at a higher elevation than the older ponds, and reducing the number of fish to 3,000 at the fry stage."
>
> (5) called for "rearing 10,000 offspring/fry indoors until they are fingerling size, and then rearing 3,000 fingerlings in the new outdoor research ponds."

At first glance, these two alternatives seemingly represent differences in experimental designs and procedures. However, alternative four, the USDA preferred action represented the views of the USDA and AAES while alternative five was proposed by the Environmental Defense Fund. The differences between the two alternatives are tied to place and *numbers* of transgenic fish under the hypothetical scenario of transgenic carp escaping into natural bodies of water. In other words, an assessment of potential environmental risk underlies the passage points proposed from different scientist-actor standpoints.

In comparing the two alternatives, the USDA argued for Alternative Four. First, USDA established a scenario which implied that there was little chance for fish to escape from the new facility. Of the five alternatives in the final EA, Alternative Four (USDA preferred action) is clearly the most elaborate with very detailed descriptions of the newly constructed genetics ponds and physical barriers (e.g., higher pond elevation, French drainage system, locked chain link fence, bird netting, catch basin), chemical barriers, biological barriers, security and maintenance, monitoring, and hatchery procedures.

Second, in the rare likelihood of a "catastrophic" escape, the number of fish would be insufficient for establishment of transgenic carp in wild aquatic habitats. Noting that an introduction of exotic fish has often involved repeated stockings of large numbers of that species, USDA emphasized that it had no systematic policy to fund future transgenic fish research. Given the unlikely occurrence of an escape, USDA goes on to envision a scenario whereby an escaped transgenic carp would be subject to intensive predation, encounter adverse ecological habitat, and fail to overcome spatial and temporal barriers in the wild. In conclusion, they argued that transgenic carp or the introduction of the rtGH gene into the wild carp gene pool was theoretically limited because:

> establishment of a new genotype within a pre-existing fish population often is the result of a sustained stocking program that involves repeated stockings of large numbers of fish, typically many more fish than will be used in this experiment" (USDA-CSRS 1990a: 27).

Third, the proposed outdoor experiments attempted to simulate actual pond production conditions. In countering EDF's alternative five, obtaining crucial "performance data" would be inhibited because the early growth of the fish would take place indoors thereby not taking into account genotype-environment interactions better simulated in the outdoor ponds. As a consequence, indoor growth data "would be of lesser value in guiding future experimental work" in terms of predicting environmental impacts as well as affecting "the growth relationships seen during the second phase in the outdoor ponds." (USDA-CSRS 1990a: 36).

How Do Transgenic Carp Act?

The final USDA-CSRS (1990a: 34) environmental assessment document contains a very brief section on the "Socioeconomic Impacts" of the proposed research:

> Research on transgenic fish is at an early stage of development. Any prediction of possible commercial application that may eventually evolve from the research would be highly speculative. Assessment of socioeconomic impacts at this time would be premature and meaningless. Experimental carp will be destroyed at the end of the experiment and none will be available for introduction into aquaculture production units.

This statement is revealing in that "socioeconomic impacts" are characterized as "premature and meaningless." Moreover, *ex ante* socioeconomic impacts are only associated with future commercial production of cultured transgenic fish. Given this assessment, it would seem that conventional sociological analyses would be limited putting an end to our stories because science and society are treated as completely separate entities. A hypothetical ecological scenario centered on the life cycle of escaped transgenic carp provides the basis for anticipating how the carp would *act* in the wild. For the authors of the EA, socioeconomic impacts passively arise from ecological interactions involving escaped carp.

However, at this point the advantages of using actor-network theory weigh in by directly extending analyses *to things*. If we extend our analyses to things, a critically important actor emerges which in *association with the human actors* ties everything together -- transgenic carp. From this approach, the EA becomes a highly sociological document where humans speculate on *how transgenic carp will act* if they escape into natural aquatic habitats. *How carp act* brings into play a simultaneous set of associations: human actions, motivations and institutions which are intertwined with the *potential effects* of escaped transgenic carp. In fact, much of the EA can be read in this manner which hypothetically traces effects such as the "fate" of the rtGH gene in wild carp populations, ecological interactions between carp and predators, and the effects of transgenic carp on water quality, aquatic vegetation, indigenous organisms and human consumption. On the surface, the authors of the EA envision an *actor world* constructed around the human engineered transgenic carp and its hypothetical ecological interactions in wild aquatic habitats. However, the potential effects of non-human (transgenic carp) actions are animated by associations with human actions, motivations and institutions which led to an outcome for endorsing the move to outdoor ponds. The EA provides the argument for this outcome.

In constructing an actor world around escaped transgenic carp, USDA elaborated on a series of insurmountable passage points around the actions of hypothetical escapees. Repeatedly emphasizing that the probability of an escape is highly unlikely, even "catastrophic" from the new genetics facility, the authors of the EA nonetheless further envisions the biological life stages of a hypothetical escapee in the wild. At each stage in the carp's life cycle, it faces seemingly insurmountable passage points which terminate any movement towards building a strong network (an established population) in the wild. For example, USDA states that in order to establish a new genotype in a wild population, repeated and massive stockings of that genotype would have to occur. From this point, USDA adds that stockings to establish a new fish species often involve large numbers of fish "many times more fish than will be used in this experiment," and that "carp are not intentionally stocked anywhere in natural bodies of water in the United States" (USDA-CSRS 1990a: 27).

Throughout a section in the EA entitled "Environmental Consequences" USDA builds innumerable passage points around the ecological interactions that would act as obstacles in preventing the establishment of a transgenic carp population or incorporation of the rtGH gene in wild carp populations. The EA notes that despite repeated introductions of other domesticated fish, "domesticated stocks may not affect allele frequencies in natural populations" because domesticated stocks lack survival fitness when compared with their wild siblings (USDA-CSRS 1990a: 27). Nonetheless, USDA-CSRS (1990a: 29) goes on to illustrate that escaped transgenic carp incorporating higher growth hormone levels may display "increased appetite, aggressive feeding, and agonistic behavior" in the wild. As a consequence, these carp could expand beyond the point of introduction. However, the lack of suitable carp habitat, the large number of carp predators and the periodic drawdown of Yates Reservoir water levels would mitigate against the vectors allowing for the spread of transgenic carp.

In sum, the EA envisions a comprehensive but highly speculative scenario which reduces environmental risks posed by escaped transgenic carp. It is clear that the USDA built a case for Alternative Four by forcing out Alternative Five which was proposed by the Environmental Defense Fund and backed by anti-biotechnology advocates (Hallerman and Kapuscinski 1990b). The USDA staged their argument by indicating the unlikelihood of a "catastrophic" escape from the new "superior" facility and then envisioned a genetic-environmental scenario whereby escaped transgenic carp would face innumerable barriers in establishing a population in the wild.

In short, USDA imputes actions to transgenic carp as to how they might behave and interact in the wild. They anticipate and address concerns posed by environmentalists based on the central position of how transgenic carp act. In conclusion, USDA-CSRS (1990a: 36) state that:

> the escape of transgenic carp is highly unlikely. It is even more improbable that any escaped fish would survive to adulthood in the natural environment. The likelihood of successful spawning and incorporation of the rtGH gene in the gene pool may be further reduced by spatial and temporal factors, and differences in spawning preferences between the transgenic and non-transgenic carp. Even though the probability is extremely low that the rtGH gene will enter the gene pool, any effect that theoretically might occur would be limited and there would be no significant impacts due to the nature of the accessible environment.

Indeed, humans envision how transgenic carp act. As USDA-CSRS (1990a; 1990b) envisions an implicit actor world centered around the carp, they construct hypothetical "trials of strength" around the interactions of carp and the environment which keep the carp within the limits of human desires and interests (Latour 1987; 1996). The carp are pronounced as enrolled in the researcher's program of investigation. For their part, on paper and in the confined ponds the carp do not resist USDA-AAES interests. Thus, the cumulative USDA assessment established a finding of no significant impact and endorsed the commencement of outdoor pond experiments at the new genetics facility.

A SUBPLOT IN MINNESOTA

The Auburn controversy was a signal event in the field of transgenic fish research and development (USDA-ABRAC 1995; Hallerman and Kapuscinski 1990b; Kapuscinski and Hallerman 1994; OTA 1995). From the laboratory, transgenic carp moved outdoors by overcoming the resistance of various actors. Overall, this movement resulted in the successful enrollment within the USDA-CSRS led program of transgenic fish research and development. The ensuing controversy and widespread attention this case received has influenced the course of research, development and the crafting of a policy direction. As a consequence, transgenic fish entered into wider sociotechnical ordering and the ensuing point of collective contention turned to policy oversight matters and creating the necessary controls for the environmentally safe conduct of this type of research.

In this respect, parallel to the Auburn case was the development of a strong policy oriented focus at the University of Minnesota. Once again, the movement of transgenic fish from the "inside" to the "outside" provoked controversy. In contrast to Auburn's applied aquaculture research context, the policy initiative in Minnesota arose from an internal debate between molecular biologists and fisheries ecologists over the scope, movement and consequences of building transgenic sportsfish.

In the mid-1980s, the "Minnesota Transgenic Fish Group" (MTFG) was put together by one scientist who linked four collaborative laboratories to conduct research on developing transgenic sportsfish (Hew and Fletcher 1992). Initially different scientific disciplinary foci were brought together including molecular biology and genetics, fisheries ecology, aquaculture and animal science. Early gene transfer efforts by the MTFG attracted a great deal of public attention. Partly due to the Group's promotional efforts, both media and political attention became focused on some of the early developments involving the creation of transgenic stocks of northern pike and walleye (Thornton 1988). As a former member of the MTFG recalled these developments:

> This is a real interesting story. When I was at Minnesota as a post-doc we were producing transgenic walleye and northern pike with money from the state and the eventual application was to use these as sportsfish, to get trophy fish. I had no problems with the goal, I figured we'd do it in very step-wise fashion -- we'd show efficacy leading to investigation of aspects of gene regulation and expression and such.

However, media portraits, political interests and the claims made by some members of the Group greatly exaggerated some very preliminary experimental results. These claims centered around the rapid growth of a few experimental fish. These unrealistic expectations and resultant political and media attention disturbed the post-doc:

> My immediate boss was interviewed by Sports Illustrated. And they were basically saying this was going to be the brave new world of sportsfishing and it had a snowball effect. Several of the PI's were interviewed on television, that was followed by a clip of someone catching a fish saying "someday soon in a Minnesota lake near you," and politicians of course who had given us the money were coming through saying "when can we get these fish out?" And here I am a post-doc telling them we haven't shown efficacy and we haven't shown environmental safety. Politicians stated "It doesn't even matter if they are really transgenic, just tell the public that they are in the lakes" and then the tourist dollars come in. Red flags went up all over the place. I figured no problem -- there certainly is a policy saying you can't do it and I was also interested in making sure we were obeying the laws, the NIH guidelines and stuff. I went and spent an afternoon in the library and soon found out that there were no rules and I was very disturbed by this.

A debate over the environmental risks associated with transgenic fish developed within the MTFG. Some members of the group were oriented around narrower questions concerning molecular biology and the applied feasibility of the research. The molecular biologists tended to downplay environmental risks. Other members of the group, oriented around fisheries ecology, raised the question: Would transgenic fish have an adverse environmental impact? In the words of one MTFG member:

> I was starting to have questions and concerns about how will these fish really be used and what are the possible environmental risks. I kept on trying to bring these questions up in our lab meetings, where all four PI's would come, the graduate students and then the two post-docs. The other PI's would always sort of discount me and say "Well, that's not important, we have so much work to do to figure out how to do this" or "Let's not worry about that right now" or "It's probably not a problem, let's talk about that some other time."

The molecular biology - fisheries ecology debate within the MTFG led to the instigation of public policy research by two of the fisheries ecology scientists. Tensions existed between the molecular biologists and fisheries ecologists over questions that could be legitimately asked and further investigated. As a consequence, an environmentally oriented focus emerged as the debate within the MTFG reached an impasse. As one of the members of the MTFG recalled:

> We decided, look, we're going to go search the literature for the ecological principles and also past cases that would be relevant to this question of "would transgenic fish have an adverse environmental impact?" And we were going to lay it out on paper in a journal article (at first we thought it was going to be one) and then we were going to get out of this field because we were upset at the behavior of our colleagues and their kind of attitude that our training in ecology and fisheries was not science. It was kind of a level below their rarefied, wonderful, high prestige molecular biology.

At this time, attention emerging around the release of genetically engineered microbes, plants and animals was becoming widespread (Tiedje et al. 1989). These controversies transcended narrower technoscientific issues and involved a growing array of scientific and public interests. As a result of these growing concerns, two members from the MTFG were asked to author a position paper on genetically engineered fish by the American Fisheries Society (AFS).

The initial drafting of the AFS position paper by two members of the MTFG turned into three peer reviewed papers which appeared in the official AFS Fisheries Bulletin in early 1990 (Kapuscinski and Hallerman 1990a; Hallerman and Kapuscinski 1990a; Hallerman and Kapuscinski 1990b). The three papers outlined the scope of transgenic fish and public policy over potential environmental impacts, regulation, and patenting of transgenic animals with an emphasis on fish. After these papers were published the AFS adopted a summary of them as their official position on genetically engineered fish (Kapuscinski and Hallerman 1990b). The effect of these publications brought a high level of visibility concerning the very recent developments in the transgenic fish field to the attention of fisheries managers, policymakers and the public. As one of the co-authors of the papers recalled:

> It really dovetailed well because what we ended up doing was using the three articles as the basis for the position statement which came out in the same year. That position statement was important because it was adopted by the full parent society and it represents the position of the society.

In interviews, both authors stated that these initial efforts unexpectedly led them into an uncharted policy trajectory:

> The irony of all this is that we thought "Okay we get those papers published and then we wash our hands of this field." Neither of us ever dreamed that we were going to start being called and asked to come testify before Congressional Committees or serve on the ABRAC. Stuff started to snowball and before we knew it we kind of created -- we were filling a niche that nobody else was filling and we both became kind of recognized leaders in this whole area. I would have never predicted any of that.

The direction of this unexpected effort led to a major policy oriented action -- the creation of performance standards. As one of the author-scientists recalled:

> A key point came in `92 when rather suddenly the Office of Agricultural Biotechnology summoned us to Washington. They basically said "It's time we had an oversight policy." This business of -- you're well aware of the fuss about the experiments down at Auburn -- we had to have a more well crafted oversight policy -- it didn't work. So we talked to them and came up with the notion that we should have performance standards not regulatory guidelines where you do A, then B, and then C. But NO -- you have to meet a certain level of confinement and that gave rise to the process.

This direction meshed with USDA-OAB's outlook at the time. In the words of a former OAB official:

> In the late 1980s, the ABRAC developed some very general guidelines for agricultural research that covers all kinds of organisms and I think those have proven to be either difficult or unwieldy to implement because they are so broad and general. We've had actually better experience by focusing on groups of organisms that have similar traits. One of the reasons why these performance standards were necessary is that transgenic fish is one variety of organism that sort of falls through the cracks in the regulatory system. It is sort of hard to portray these fish as plant pests or as pesticidal substances, animal drugs or whatever. And that is sort of the orientation of some of the existing legislation. And so I think that we did have some sort of tacit agreement with some of the regulatory agencies in developing these performance standards which sort of fill which is almost a regulatory vacuum and so that was a welcome source of support. So, I think this will enable researchers in the aquatic area to anticipate and address some of the issues of concern before they really, you know, get hauled in by a regulatory agency or a department.

The process which led to the creation of the <u>Performance Standards for Safely Conducting Research With Genetically Modified Fish and Shellfish</u> (USDA-ABRAC 1995) was subsequently authored by the ABRAC Working Group on Aquatic Biotechnology and Environmental Safety. The performance standards took over three years (1992-1995) to complete and involved input from over two hundred individuals from the aquatic research community, environmental groups, the aquaculture industry and State and Federal Fisheries management agencies (USDA-ABRAC 1995). The performance standards received widespread attention and were closely followed by researchers and policymakers in several foreign countries. As such, the performance standards represents a substantive effort at sociotechnical ordering.

ACT II: CREATION OF PERFORMANCE STANDARDS

The creation of Performance Standards for Safely Conducting Research With Genetically Modified Fish and Shellfish (USDA-ABRAC 1995) falls under a broader political economic rationale which anticipates that the biotechnology driven future of the U.S. aquaculture industry will provide the nation and the world with considerable nutritional and economic benefits. According to some policymakers and scientists, aquaculture biotechnology is expected to greatly contribute to meeting growing consumer demand for aquatic products, reduce the U.S. seafood trade deficit and competitively advance U.S. technology and the industry in the global marketplace (Parker et al. n.d.).

Biotechnology, and aquatic GMOs feature in this industrial growth strategy. Policymakers favorably envision that biotechnological applications in aquaculture will result in improved organisms, benign environmental compatibility, improved products and processes, and enhanced conservation of important aquatic genetic resources. Outcomes and impacts from aquaculture biotechnology applications are expected to bring forth new markets in the applied biomedical, pharmacological, human nutrition, agricultural and industrial fields. Moreover, conserving genetic biodiversity, reducing waste from aquaculture systems, and producing safe, affordable aquatic products are anticipated through research investments in aquaculture biotechnology development (Parker et al. n.d.).

As Chapter 2 demonstrated, the global industrialization of aquaculture has resulted in numerous environmental and social conflicts. Policymakers have struggled to balance economic, social and environmental concerns under the rubric of "sustainable" aquaculture development. Within this industrial development context, aquatic GMOs have also been subjected to widespread scrutiny and criticism as to their proper economic, social and environmental balance. In this respect, performance standards attempt to address the environmental concerns of doing safe research while advancing towards commercial applications.

The rapid research advances, complexity and scope underlying the creation and movement of aquatic GMOs into wider sociotechnical ordering has given rise for a focused and comprehensive national oversight policy which at present extends into the international environmental policy arena (OTA 1995). In point, there is no single federal or state agency which provides explicit oversight regarding the multifarious developments which cover a broad range of aquatic GMOs, products and processes. Generally, federal jurisdiction weakens at the state level, with a few states enacting legislation pertaining to environmental oversight which:

> go beyond federal regulations to address key loopholes or procedural ambiguities. However, most of these do not effectively address concerns unique to aquatic GMOs (Kapuscinski and Hallerman 1994:43).

At the national level for example, federally funded research involving aquatic GMOs requires compliance with NEPA and NIH guidelines which may fall under the jurisdiction of any number of federal agencies. However, compliance with NEPA "does not preclude approval of actions even when they may have a significant impact" (Kapuscinski and

Hallerman 1994:40). At the same time, the Food and Drug Administration (FDA) regulates new animal drugs under the Federal Food, Drug and Cosmetic Act. While undergoing formulation, FDA may ultimately define a transgene in terms that could "affect the structure or function of the body of an animal" and thus constitute a new animal drug falling under FDA jurisdiction (OTA 1995: 6). Likewise other federal and state fisheries agencies (e.g., National Marine Fisheries Service, U.S. Fish and Wildlife Service, Sea Grant, State Departments of Fish and Game) may be responsible for overseeing aquatic GMO research within their particular jurisdictions. As Kapuscinski and Hallerman (1994:31) summarized:

> Federal policy relevant to research, development, and application of biotechnology in aquaculture has some important gaps and ambiguities, and is in great flux. Comprehensive and stable federal policies, coordinated across the relevant federal agencies are needed in order to realize economic benefits while minimizing environmental risks and addressing other societal concerns.

In contrast to federal directives, research institutions and the private sector not receiving federal funding are merely expected to voluntarily comply with federal guidelines.

Nonetheless, an extensive review of available documents and interviews conducted with key federal policymakers and policy advisory scientists reveals that the primary focus in the current field of transgenic fish research and development pertains to international and national environmental risk assessment and management frameworks centered around aquatic GMO field trials (OTA 1995). This is not to discount commercialization, food safety, and the intellectual property scope of aquatic GMOs. Policymakers and scientists have recognized them as forthcoming political issues of significant national and international importance. However, the environmental arena features given the concerted social ordering effort that went into establishing performance standards. In the view of key policymakers and scientists, the effort to create performance standards regarding the safe conduct of aquatic GMO *research* represents a first sequential step in addressing these future policy matters.

The creation of aquatic GMO performance standards was undertaken within a complex political and social arena which overlaps with research and development of microbe, plant and animal biotechnology for a number of reasons. First, the development of aquatic GMOs has advanced to the field testing stage. As the Auburn case illustrated, the movement to outdoor facilities sparked a protracted and costly environmental-regulatory controversy. Second, in assessing the environmental risks associated with aquatic GMOs, the growing range of diverse organisms and experimental requirements, genotypic-phenotypic effects and unknown environmental interactions were found to be difficult to manage and clarify under existing guidelines and legislation, let alone effectively regulate. As a result, aquatic GMOs have eluded established protocols covering other genetically modified organisms. With the anticipation of future aquatic GMO releases, USDA envisioned the need "to develop scientifically-based performance standards that one could readily apply to determine that a particular research study could be conducted safely" (USDA-ABRAC 1992:3).

Table 6.1 below lists the major federal policies and regulations relevant to the release of aquatic GMOs since 1984.

Table 6.1 - Federal Policies and Regulations Related to the Environmental Release of Aquatic Genetically-Modified Organisms Since 1984.

Year	**Office of Science and Technology Policy**
1992	Exercise of Federal Oversight Within Scope of Statutory Authority: Planned Introductions of Biotechnology Products into the Environment, 57 Federal Register (FR) 6753 (Policy Statement)
1990	Principles for Federal Oversight of Biotechnology: Planned Introduction into the Environment of Organisms with Modified Hereditary Traits, 55 FR 31118 (Proposed Policy)
1986	Coordinated Framework for the Regulation of Biotechnology, 51 FR 23302 (Policy Statement and Request for Public Comment)
1985	Coordinated Framework for the Regulation of Biotechnology: Establishment of the Biotechnology Science Coordinating Committee, 50 FR 47174
1984	Proposal for a Coordinated Framework for the Regulation of Biotechnology, 49 FR 50856 (Proposed Policy)
	The President's Council on Competitiveness
1991	Report on National Biotechnology Policy (Policy Statement)
	U.S. Department of Agriculture, Animal and Plant Health Inspection Service
1993	Genetically Engineered Organisms and Products: Notification Procedures for the Introduction of Certain Required Articles; and Petition for Nonregulated Status, 58 FR 17044 (Final Rule)
1992	Genetically Engineered Organisms and Products: Notification Procedures for the Introduction of Certain Required Articles; and Petition for Nonregulated Status, 57 FR 53036 (Proposed Rule)
1987	Introduction of Organisms and Products Altered or Produced Through Genetic Engineering Which Are Plant Pests or Which There is Reason to Believe Are Plant Pests, 7 CFR 340 (Final Rule)
1986	Final Policy Statement for Research and Regulation of Biotechnology Processes and Products, 51 FR 23336 (Final Policy Statement)
1986	Plant Pests: Introduction of Organisms and Products Altered or Produced Through Genetic Engineering Which Are Plant Pests or Which There is Reason to Believe Are Plant Pests, 51 FR 23352 (Proposed Rule and Notice of Public Hearings)
	U.S. Department of Agriculture, Office of Agricultural Biotechnology
1995	Performance Standards for Safely Conducting Research With Genetically Modified Fish and Shellfish (Voluntary Performance Standards)
1990	Proposed USDA Guidelines for Research Involving the Planned Introduction into the Environment of Organisms with Deliberately Modified Hereditary Traits, 56 FR 4134 (Proposed Voluntary Guidelines)
1986	Advanced Notice of Proposed USDA Guidelines for Biotechnology Research, 51 FR 13367 (Notice for Public Comment)
	U.S. Environmental Protection Agency
1994	Microbial Products of Biotechnology Proposed Regulations Under TSCA, 59 FR 45528 (Proposed Rule)
1993	Microbial Pesticides; Experimental Use Permits and Notifications, 58 FR 5878 (Proposed Rule)

1989	Biotechnology: Request for Comment on Regulatory Approach, 54 FR 7027 (Notice)
1989	Microbial Pesticides; Request for Comment on Regulatory Approach, 54 FR 7026 (Notice)
1986	Statement of Policy; Microbial Products Subject to the Federal Insecticide, Fungicide, and Rodenticide Act and the Toxic Substances Control Act (TCSA), 51 FR 23313 (Policy Statement)

Source: OTA (1995: 24).

Table 6.1 shows that outside of the 1995 Performance Standards, the majority of policies and regulations may only indirectly apply to aquatic GMO cases. However, this does not preclude federal and state oversight as specific aquatic GMO cases may require further interpretation and multiple review. Moreover, some aquatic GMOs may not fall under federal guidelines and legislative statutes (OTA 1995). Within the fluctuating arenas of agency discretion and jurisdiction, USDA has taken the national lead in developing federal oversight of aquaculture biotechnology. Performance standards were created to streamline and reduce ambiguities inherent in the organization of federal oversight in diverse national research settings involving a range of aquatic organisms. The aquatic GMO performance standards are held up as a model to emulate in other fields of biotechnology as well as across various political boundaries.

More generally, federal biotechnology policy directives were grouped around the Coordinated Framework for the Regulation of Biotechnology (Office of Science and Biotechnology 1985:1986). As Kapuscinski and Hallerman (1995: 37) explain, The Coordinated Framework:

> is based on the premise that no special legislation is needed to regulate biotechnology, i.e., existing statutes can be used to effectively cover concerns raised by the development and commercialization of GMOs. Several agencies have updated their policies and issued new regulations or guidelines as appropriate.

However, this view is contested. According to some scientists, policymakers and Congressional members, the premise of "no special legislation" may not be adequate thus requiring further Congressional action given the need to "limit potential impacts on the environment and human health and safety" (OTA 1995:2-3). Questions have also been raised regarding the priority emphasis in balancing research areas such as genetic engineering and traditional breeding programs (OTA 1995). The USDA's emerging leadership in biotechnological applications in the growing U.S. aquaculture industry subsumes the need for direct Congressional action (USDA-ABRAC 1992; OTA 1995). However, concerns have been raised by a number of scientists that the voluntary performance standards may eventually become regulations if appropriated by "overzealous" environmental groups, federal and state agencies (USDA-CSREES 1995).

In this fluctuating policy context, one important influence in the creation of performance standards was the Office of Science and Technology Policy's (OSTP) supplement to the Coordinate Framework, the "Scope" document (OSTP 1992). The "scope" supplement was designed "to provide guidance to agencies in proposing new regulations or implementing statues within the scope of discretion afforded by existing law" (Kapuscinski and Hallerman 1994: 38).

Two contentious points were raised in this policy statement. First federal oversight applied to the phenotypic characteristics of the organism itself, not to the process used to produce it. Problematic in this regard was that phenotype is highly influenced by the environment. As a result, phenotypic variability make large numbers of aquatic GMOs difficult to evaluate (OTA 1995). Hence, oversight concerning release of aquatic GMOs would have to proceed on a case by case basis and require extensive phenotype-ecology studies. Second, the regulation of a genetically modified organism would focus on the risks that organism posed to human health and the environment. Risk assessment and management of aquatic GMOs are greatly constrained by a lack of information.

Performance standards represent a concerted attempt to address these noticeable gaps, shortcomings and ambiguities. First and foremost, performance standards were created to "aid researchers and institutions in assessing the ecological and evolutionary safety of research activity involving genetically modified fish, crustaceans, or molluscs" (USDA-ABRAC 1995:1). Contrary to the views of some dissenting scientists, performance standards are not regulatory statutes or design standards. They "define endpoints or goals to be achieved, and they provide guidance and criteria for achieving those goals. They differ from design standards in that they are not rigid or prescriptive" (USDA-ABRAC 1995:2). Importantly, performance standards are voluntary "science-based" standards for *research* only. There is no legal authority to sanction non-compliance with the performance standards. The distinct social organizational trajectory that the creation of the performance standards took also underscores a collective consensus by scientists rather than top-down federal regulatory intervention. Clearly, scientists are the primary political actors. The process was organized around a series of workshops and meetings centered around drafting a rationale, flow charts and worksheets. In the words of one of the key actors involved:

> Everyone saw the benefits for a faster growing fish that was disease resistant, for example. We started saying look it's more nuanced than that. As the first group calling attention to the potential for unwanted impacts a lot of people vilified us because we were bursting a bubble. We were saying look it could be dangerous. It was hard for us to have a nuanced theme saying balanced risks and benefits. After our point of view got out there the question turned

> to: What are we going to do about it? So we started talking about having a risk management framework and this is where our work with OAB got really interesting. This is where I think the intelligent thing was done. Early on we decided rather than design an oversight policy that was prescriptive and mandated from above we would basically call in a wide range of scientists and try to build something more or less by consensus.

ABRAC's only previous experience with aquatic GMOs involved the outdoor experiments at Auburn. This case, along with other developments in the field, relied on an "expert" focus due to the relative uniqueness posed by aquatic systems and organisms. There was a need for concerted input and review by aquatic scientists who were better informed about aquatic ecosystems, fisheries, and aquaculture than those in the ABRAC-constituted microbial, plant and animal fields. Hence, the USDA-ABRAC created a working group on aquatic biotechnology and environmental safety in March of 1992 (USDA-ABRAC 1992). The working group was put in charge of drafting performance standards and organizing an experts' workshop to review the draft. The performance standards were strictly targeted as "a science based activity intended to be useful to the research community" (USDA-ABRAC 1992:3). Commercialization, food safety and regulatory issues were ruled out as beyond the scope of the standards.

In the creation of the performance standards three sociologically oriented themes standout. First, there was a political requirement to legitimate standards as an "expert system" in order to balance the perceived economic promises and the environmental impacts of anticipated aquatic GMO releases. Voluntary adherence to "scientifically based" performance standards fill this requirement by establishing "objective" guidelines that allow established researchers to flexibly address environmental risk minimization through research practices. In the words of the Working Group (USDA-ABRAC: 1995:1):

> Technical guidance that has broad support throughout the scientific community would help stimulate the research needed for aquaculture to meet growing consumer demands by reducing the uncertainty regarding acceptable standards for conducting that research. Such standards would also assure the public that appropriate guidance is available to the research community to address ecological and evolutionary safety concerns.

These voluntary standards allow aquatic GMO proponents to anticipate the next move towards commercialization, unencumbered by excessive regulation mandated from federal or state authorities.

Second, the concrete manifestation of performance standards has significantly altered the directions of the research. Given the gaps and lack of data on aquatic GMO-environment interaction, the direction leads to studies of this type. Although, researchers were forced to detour from direct field testing, they now surmise that environmental assessments in confined but "natural" outdoor rearing facilities constitute the key link to advancing commercialization and a major extension of the network. As such, the performance standards act as a powerful rationale and justification in solidifying the movement from laboratory to the field, and to the eventual commercialization of aquatic GMO products. The effect becomes one where an expert system guides policy and research to ensure greater environmental safety when undertaking research. Although there remain some who dissent, the majority of researchers have achieved a voluntary consensus which acts to enhance the movement of aquatic GMOs into eventual commercial aquaculture applications.

Third, performance standards represent a proactive response by established aquaculture biotechnology advocates which strengthens the research and development network. The performance standards preclude any broader ethical questions and concerns. Moreover, they fill an apparent political void by acting as a consensual social covenant which circumvents challenges by oppositional groups. Performance standards act to politically fortify the research on the outside by creating "objective" standards which promote "environmentally safe and responsible" protocols and procedures on the inside. Performance standards "assure" the public that the research is safe thereby legitimating the choice *for* genetic engineering. In this way, established scientists with an immediate stake in the research can appeal to a much stronger and socially constituted framework by voluntary compliance with the standards. They can restrict access by new entrants and fend off challenges by those opposed.

Importantly, participating scientists achieved a collective sense of "scientific" translated as "social" objectivity through persuading or excluding dissenters by establishing an actor world constructed around the standards -- a framework which aligns aquatic GMOs with human desires and interests. USDA first enabled scientists to reach a social consensus that performance standards were needed. Second, scientists relied on negotiation and persuasion for including or excluding certain phenomena. Third, scientists constructed performance standards by establishing inclusive definitions, rigorous criteria, classification schemes and organizational frameworks for proceeding with research-environmental risk minimization through research management practices. The questions become: How inclusive are these *voluntary* standards, and to what and to whom do they apply?

Bringing a large number of scientists together from divergent disciplinary outlooks required preliminary debate over the need for performance standards. In particular, molecular geneticists argued that there was no need for performance standards. While opposed in principle, molecular geneticists were eventually persuaded by stronger arguments made by ecologists. As discussed by a key policy advisory scientist central to the process:

> Early on we were taking a lot of criticisms especially from the molecular geneticists. I think when they heard that we were really listening, when heavy duty ecologists would... make stronger statements [in favor of performance standards] -- the molecular geneticists started to be a little more quieter in listening to people instead of arguing past each other.
>
> MS: What were some of the objections raised by molecular biologists?
>
> Biotechnology has been safe all along. We've had all these field tests and no one has had any problems to report. And we would add -- the people who were more concerned -- would answer back that fish are only one or two generations removed from the wild, the notion that they would retain a fitness in order to survive is different from a soybean. It's very different from a pig or chicken. The arguments were all debated and eventually people started listening and they started attacking pieces of the performance standards as opposed to the content of them.

An examination of the draft standards documents, minutes from ABRAC Working Group meetings and key informant interviews illustrates that once the majority of scientists consented they debated the defining of applicability criteria for including or excluding certain phenomena. For example, the performance standards specifically address aquaculture systems but do not encompass genetically modified aquatic plants because of financial and logistical limitations (USDA-ABRAC 1994). At the various meetings and workshops, internal negotiations and debates centered around establishing inclusive definitions, applicability criteria, classification schemes and organizational frameworks for the content and application of the standards. In the first draft, performance standard content was organized around the characteristics of modified organisms, the characteristics of the receiving ecosystem, culture methods, physical confinement and inspection. This content was subsequently refined throughout the process.

For example, at the first Working Group meeting in 1992, much debate took place over defining the inclusion or exclusion of indigenous aquatic organisms and gamefish, what constitutes a novel trait, the naturalness or artificiality of the receiving ecosystem in terms of determining risk, and what constitutes effective containment. Moreover, worksheet questions (see Appendix C) feature applicability criteria such as receiving ecosystems, experimental scale, location of research, and ranking levels of high, medium or low risk. Ecological input was requested in order to classify aquatic GMO's phenotype change with corresponding ecological effects. Participants also envisioned organizational frameworks for confinement. Questions arose as to whether or not IBC's had adequate expertise and the organizational capacity to inspect aquatic research facilities. Issues also arose concerning the importance of managing such facilities (USDA-ABRAC 1992). This sample of concerns and issues captures only a small part of the debates that went into drafting the standards.

What Constitutes an Applicable Organism?

In the creation of the performance standards, a key exemplar consists of the protracted debate centered around what constitutes an "applicable" organism. More nuanced and revealing as to what underscores applicability is the scientists' efforts to define a "novel trait" against a backdrop of a receiving ecosystem and managing confinement. As expressed here, the concern is not one of merely seeking consensus on language conventions but a heightened awareness of the political-scientific effects of applicability. This critical turn was brought out at the first meeting (USDA-ABRAC 1992:11) where one scientist:

> expressed his concern about the far-reaching implications of these standards, because of the possibility that they will be used to guide regulations. He

> agrees that while there are extreme ramifications if no standards are in place for recombinant DNA research, he is greatly concerned that when the standards are applied to breeding programs they will seriously disrupt aquaculture and genetic research in the country.

In response, a leading scientist addressed these concerns by focusing on the "importance of the definition of a novel trait." In the minutes summary:

> the definition [of a novel trait] might not include the case, for example, where average growth rate has changed but it is in the range of past average growth ranges. Selective breeding exploits the variation already there, and the conundrum is that biotechnology allows the creation of something truly novel. Deciding where to draw the boundary between novel and not novel will be very important.

Deciding where to draw the boundary between "novel" and "not novel" serves as a crucial exemplar because the subsequent elaboration of defining applicability criteria excludes or includes specific aquatic organisms. From there, the researcher is led along specific pathways which determine the level of risk assessed against the receiving ecosystem and efforts to manage confinement. Because the information is non-existent, undertaking ecological assessments becomes a hypothetical exercise leaving risk management practices as the modus operandi. Future research will attempt to assess ecological impacts by combining computer simulations with actual field test data. As a result, research under the performance standards falls back on a risk management framework.

The working group addressed the applicability question in two ways: by delineating organisms in terms of *type* of genetic modification and by *classifying* phenotypic changes against anticipated ecological effects. With the exception of two qualifications, three different kinds of genetic modifications defined as "deliberately induced changes in the genomic structure" (USDA-ABRAC 1995: 5-6) fell under the performance standards definition of applicable organism:

> *Deliberate Gene Changes* - including changes in genes, transposable elements, non-coding DNA (including regulatory sequences), synthetic DNA sequences, and mitochondrial DNA;
>
> *Deliberate Chromosomal Changes* - including manipulations of chromosome numbers and chromosome fragments; and
>
> *Deliberate Interspecific Hybridization* - referring to human-induced hybridization between taxonomically distinct species.

The type of genetic modification determines what constitutes a truly novel trait as:

> one that does not occur in the natural populations of the parental species of the genetically modified organism. A novel trait may be (1) expression of a compound not normally found in the species, e.g., antifreeze polypeptide in Atlantic salmon . . . or (2) a clearly novel value in a quantitative trait, such as changes in metabolic rate; reproductive fertility; tolerance to a physical environmental factor; a behavior; resource or substrate use; or resistance to disease, parasitism, or predation (USDA-ABRAC 1995:8).

The two qualifications refer to non-applicable exotic or nuisance species which may pose environmental risks and applicable organisms with a non-dioecious mode of reproduction. Research involving non-applicable exotic or non-indigenous aquatic species falls under the purview and protocol of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. Here the researcher exits the performance standards. Applicable, non-dioecious organisms are defined by hermaphroditic and parthenogenetic reproduction. In particular, hermaphroditic organisms, possessing both male and female reproductive organs, and parthenogenetic organisms which reproduce by selfing, applies to a wide range of commercially important molluscs. Organisms of this type pose the highest level of risk because one single accidental escape could result in the establishment of a population. The performance standards provide some guidance by "identifying issues to consider in developing risk management" (USDA-ABRAC 1995:B3). However, much is left up to the researcher to provide a defensible rationale within a risk management framework.

In further defining applicable organisms, Table 6.2 below classifies possible phenotypic changes against anticipated ecological effects.

Table 6.2- Classes and Examples of Possible Phenotype Changes in Genetically Modified Fish, Crustaceans, and Molluscs.

Class	Examples of Phenotypic Change	Ecological Effect
Metabolism	-Growth Rate -Energy Metabolism -Food Utilization	-Shift to different prey size -Alter nutrient and energy flows
Tolerance of Physical Factors	-Temperature -Salinity -pH -Pressure	-Shift preferred habitats -Alter geographic range
Behavior	-Reproduction -Territoriality -Migration -Chemosensory -Swimming/Navigation	-Alter life history patterns -Alter population dynamics -Alter species interactions
Resource/ Substrate Use	-Food Utilization	-Release from ecological limits -Alter food webs
Population Regulating Factors	-Novel Disease Resistance -Reduced Predation/parasitism	-Alter population and community dynamics -Release from ecological limits
Reproduction	-Mode -Age at maturation and duration -Fecundity -Sterility	-Alter population and community dynamics -Interfere with reproduction of related organisms
Morphology	-Shape and size -Color -Fin/appendage form	-Alter species interaction
Life History	-Embryonic and larval development -Metamorphosis -Life span	-Alter life history patterns -Alter population and community dynamics

Source: USDA-ABRAC (1995: 15).

Table 6.2 requires that the researcher provide detailed information about the effects of the deliberate gene modification. If the required information is available, "the assessment path can be bypassed if the only change is expression of a marker gene that has no impact on traits identified" in Table 6.2 (USDA-ABRAC 1995:14). However, given the non-existent information required, researchers could not rule out trait changes and "further assessment is needed in order to reach a defensible decision about safety or risk" (USDA-ABRAC 1995:16). At this point, insufficient information encourages hypothetical scenarios but prevents a thorough ecological assessment thereby introducing risk management practices embodied by safe project siting, barriers, security, alarms, and operational plans. Further oversight is provided by the institution's IBC, expert review, as well as compliance with federal, state and local jurisdictional procedures, permits and protocols.

Given the establishment of applicability criteria, decision pathways involve assessment of (1) survival, (2) reproduction and (3) ecosystem effects. If an aquatic GMO does not exit any of the pathways, the researcher is led into risk management procedures such as "project siting, design of barriers, security, alarms, operational requirements (includes written operational plan, emergency response plan, training, and traffic control), and review before and after start-up of project" (USDA-ABRAC 1995:36). These are *minimal* requirements. Due to great variation in conducting aquatic GMO research, a case approach is recommended complemented by intensive peer review. For the researcher, the performance standards are completed by filling out a standardized worksheet (Appendix C) which accompanies project documentation.

Objections to the Performance Standards

Prior to the final authorization of the performance standards by the Secretary of Agriculture, the draft documents underwent one final review. A number of policymakers, scientists, commercial aquaculturists and environmentalists subsequently responded. For the most part, the comments were highly favorable with the majority of recommendations referring to minor editorial clarification (USDA-CSREES 1995). However, in some very important respects, some comments greatly diverged from the orientation of the standards by raising further problematic issues not covered in the draft document. In particular, the Environmental Defense Fund (USDA-CSREES 1995: 1):

> strongly urges USDA to make compliance with the Standards mandatory for USDA-funded researchers... compliance with the Standards should not be onerous. As performance rather than design standards, the draft Standards offer researchers considerable flexibility to determine appropriate containment measures for their experiments. It is thus entirely reasonable to require that researchers comply with the Standards as a condition of receiving taxpayer funds.

Opposed to this mandatory application of Standards were two research scientists and one commercial aquaculturist. One research scientist (USDA-CSREES 1995: 1-2) argued that:

> In earlier stages I voiced my deep concern that zealous environmentalists with good intentions, coupled with the lack of knowledge on the performance of GMOs, will create regulations that will overkill the entire present research in this area... Strict confinement is a prohibitory, expensive barrier for field experiments. Without field experiments of GMOs, fitness and performance parameters cannot be calculated... Based on thorough consideration and past records on other organisms, I strongly believe that there is no danger to the environment from any accidental release of fish GMOs during field experiments. I therefore recommend that the voluntary "performance standards" be "laid to rest" before groups of "concerned citizens" and politicians use them as a basis for compulsory federal and regulatory initiatives. I suggest that energies should be used to raise financial support for research on the possible biological/ecological risk of GMOs. Only when

> these data will be available should the "performance standards" be reconsidered.

Another research scientist (USDA-CSREES 1995: 1) went further by raising the issue of "exportation" of research in the following letter:

> I have been involved with transgenic fish production since 1988 . . . I certainly agree with the ideas regarding the potential destruction that released transgenic organism might have on natural ecosystems. However, over regulation of recombinant DNA research, such as we see in the State of Minnesota, will only lead to exportation of research projects. Indeed, I am currently conducting transgenic fish research projects in China where regulations are much less stringent, and thus less costly. This same work in the United States would have involved much bureaucratic red tape, such as that encountered by Auburn University, than we could have handled on our restricted budgets. Therefore, my main concern is whether the relationship between restrictions and regulations and the exportation of scientific research has been given adequate attention in your analysis of performance standards.

Finally, a commercial aquaculturist (USDA-CSREES 1995: 1) echoes these regulatory issues within the applied commercial sphere:

> Because of our interest in the commercial possibilities of transgenic aquatic organisms, salmon in particular, I note that the Performance Standards have limits . . . Completely accurate predictions are not possible and the limits of knowledge, time and money require that some assumptions regarding potential safety of individual GMOs be used. The alternative will be a never ending process of studies and paperwork which will effectively prevent any advance arising from genetic engineering from being used commercially. Particularly in the hands of individuals or agencies with an ideological bias against genetic engineering, the Performance Standards will be manipulated to imply that there can never be enough knowledge or assurances of safety to allow for a commercial application of transgenic research . . . given the latitude with which the Standards are written at present, an agency could easily and arbitrarily determine that there is and probably always [will] be "Insufficient Information" and short of a multi-year, multi-million dollar study, that a "no/negligible escape" standard is appropriate. I therefore urge you and the entire ABRAC to consider how best to limit the possibility of administrative requirements based on the Performance Standards becoming so onerous that commercialization of transgenic research becomes practically impossible, regardless of potential benefits and limited risk.

The above comments capture the paradoxical effects behind the performance standards process. Moreover, they provide a sociological lens by which to critically examine the claim to objectivity made by the working group and some of the effects created by this move to extend the network. In short, the standards create an actor world centered around (1) the defining characteristics and applicability of aquatic GMOs, (2) receiving ecosystems and (3) risk management procedures in order to minimize adverse environmental impacts. In this respect, the working group attempted to arrive at "clear objective criteria . . . that can readily be applied a priori to conducting a comprehensive risk assessment" of aquatic GMO research (USDA-ABRAC 1995).

However, asymmetry remains evident. The performance standards are *socially* constructed around exclusive *biological* criteria pertaining to the organisms' applicability and the research management necessary to contain it in accord with human desires and interests. Similar to the asymmetrical problematic discussed in Chapter 3, the standards maintain a divide between technoscience and society. First, partiality is introduced because the social settings (e.g., receiving ecosystem and risk management procedures) of aquatic GMO research vary widely across the research and development sites. Second, dissent arises from the particular social, political, ethical and technoscientific situatedness of a standards application. Not only from within the transgenic community alone does dissent arise, but also from a host of new actors situated in these diverse social contexts. It is doubtful that an expert based sense of objectivity, which is socially constituted through and through, can mitigate against these broader forms of dissent and controversy.

Seen as a social text, the performance standards reduce objectivity to an expert system. Although the working group attempted to arrive at a priori objective criteria for conducting risk assessment, the decisions for determining applicability rested solely on particular biological phenomena and parameters which are only applicable in local contexts (e.g., transgenic carp in Alabama, oysters in Maryland) as determined by scientist-experts. Indeed, the performance standards seek to encompass a broad range of organisms, ecosystems, facilities and management schemes. However, the standards do not encompass the broader social dimensions of regulation, political boundaries and jurisdiction, and ethical orientations associated with diverse and multiple human use of aquatic organisms, ecosystems and ultimately food production and consumption.

As a result, views over the perceived benefits and risks of aquatic GMOs have clashed and while consensus prevails over what constitutes an "applicable organism" the above letters indicate that the social setting of where, what and for whom that organism will be used for generates ongoing controversy in sociotechnical ordering. Moreover, these controversies are replete with unexamined ethical, legal, social and policy concerns. The EDF recommends *mandatory* compliance and brings the interests of taxpayers into the fray; a research scientist objects to the potential imposition of excessive regulation by politicians spurred on by well-intentioned but unknowledgeable citizens and environmentalists; another research scientist asserts that over-regulation will lead to the export of the research and; a commercial aquaculturist cautions against an "ideological bias against genetic engineering" which would allow bureaucratic manipulation of the standards to prevent commercialization of transgenic fish.

It is from implicit ethical, social, legal and policy contexts that "outside" actors, scattered along diverse points throughout the network, provoke objections and dissent. As a result, the effects of the move to extend the network generates social controversies. On the surface, the performance standards clearly favors established research interests, programs and institutions while ignoring relevant others who remain unconvinced by the transgenic spokesperson. The performance standards act to make established research networks stronger by the inside-outside move which at least temporarily allows researchers to voluntarily address localized biosafety issues associated with their immediate research activities. At the same time, different social circumstances exclude those researchers and many relevant others on the outside of a growing network. As a result, some researchers voice their dissent regarding onerous regulatory interventions, call for no oversight or threaten to move their research to locations where the performance standards do not apply. Moreover, the direct assessment of receiving ecosystems has emerged as an important area of new aquatic GMO research which was brought on by the Auburn controversy and subsequent performance standards process. Again, those actors with the facilities, organizational capacity and skilled personnel seem highly positioned to benefit from this research trajectory move towards a transgenic sociotechnical ordering through the performance standards. At the same time, these actors are opposed by other actors from a variety of environmental, food safety, and political regulatory standpoints which are international in scope.

While heralded as a major contribution to U.S. national environmental safety and oversight and closely watched by other nations, the standards create paradoxical effects. The standards preclude ethical, social and political dimensions of aquatic GMO research by restricting objectivity to biological phenomena and parameters. In short, the standards bypass *society in the making* while favoring established research interests, programs and institutions in a move towards a transgenic sociotechnical ordering. While the standards clearly improve over the patchwork Coordinated Framework and Scope initiatives, they open up extensive new arenas for further contestation. In this respect, the commercialization, food safety, intellectual property and the state, national and the international scope of aquatic GMOs currently are in great flux. Future resolve of these policy and decision making matters will require a much greater collective and consensus building effort than that which went into the U.S. based performance standards. At the same time, the rapid advances in the field lead to the anticipation of international controversies which would dwarf the previous U.S. cases discussed in this chapter.

CONCLUSION

This chapter has illustrated a move to the outside by aquatic GMO actors. From an initial localized controversy, the building of a stronger network was embodied through the creation of performance standards to overcome ambiguities in oversight of the research. While the performance standards represent an improvement over previous policy frameworks by directly addressing the unique parameters of aquatic systems and GMOs, the effort has resulted in a series of new problematics with contested social applicability. As a consequence, it is anticipated that many more controversies will develop over the continuing efforts to extend the aquatic GMO network.

In this respect, objectivity criteria for the standards were shown to have been deduced from exclusive biological factors which ignore the social situatedness of technoscience in the making. The voluntary nature of these socially constructed standards, have opened up further avenues for dissent and the emergence of new network actors. As a result, the effects of performance standards are anticipated to open up many more ethical, political, legal and public policy debates and controversies than they resolve. The majority scientist-policymaker view is that the performance standards represent the first sequential step in crafting a comprehensive oversight policy which will lead to commercialization. However, this view becomes increasingly fraught by divergence at the international political level because a different socially constructed sense of objectivity informs the further positioning of aquatic GMOs into social contexts which are dissimilar to that of the United States.

Indeed, technoscience in the making has an outside which is traceable to the inside craft work transformation into inscriptions which carry a vision of sociotechnical ordering. To an extent, the performance standards embody this vision of a world which is predicated on its' becoming more laboratory-like (Latour 1983). At the same time, many more actors remain unconvinced and hence unenrolled by the claims of the spokesperson. The effects of research and development are uneven as some actors resist and controversies ensue. However, in going beyond the laboratory, actor networks allow a glimpse of how a technoscientific society in the making emerges which thus elucidates the forthcoming shape and form of our social world.

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Chapter 7

AQUACULTURE AS TECHNOSCIENCE IN SOCIETY

Throughout this work, a series of stories have depicted the social content and context of a nascent technoscience in the making: aquaculture. Two questions have guided this inquiry: How do aquacultural scientists go about doing research and development? What are the effects of aquaculture research and development? In addressing these questions, conventional accounts of aquaculture research and development by social and aquacultural scientists were found problematic. Overwhelmingly, social and aquacultural scientists characterize aquaculture technoscience as ready made, removed from social inquiry, and never socially constituted and in the making. In this respect, a peculiar asymmetry prevails: social scientists avoid problematizing technoscience and, aquaculture scientists avoid problematizing society. These problematics were traced to a priori assumptions based on the ontological separation of technoscience and society. As a result, accounts of aquaculture research and development are reduced to social or technical determinism.

In Chapter 4, I argued that actor network theory provided the theoretical and methodological resources for avoiding social or technical determinism and addressing my central research questions. Unlike diffusion theory, the dominant theoretical framework in aquaculture, actor network theory assumes no a priori divide between technoscience and society. Actor network theorists study technoscience and society by recasting these socially constituted phenomena into the same terms. Methodologically, analysis is extended to things by following human *and* non-human actors. In concluding this work, I find that in applying actor network theory the social production of technoscience *in the making* becomes inseparable with the social production of nature and society *in the making*.

In addressing how scientists go about doing research and development, actor network theorists often begin at the initial site of its knowledge production – the laboratory bench. The results from these studies have been pathbreaking in demonstrating how technoscience is socially constructed, composed and partially constituted in sociotechnical ordering (e.g., Knorr-Cetina 1995; Latour 1983; Latour 1987; Latour and Woolgar 1979; Law 1994). However, these studies are all too often confined to the immediate laboratory setting. Moreover, as we trace the extension of lab-created products and assertions into non-laboratory arenas the laboratory itself dissipates into inscriptions and texts. As a result, the effects of laboratory positioning in sociotechnical ordering remain elusive.

In a case study of transgenic fish research and development, I observed that laboratory positioning in sociotechnical ordering *begins* at the lab bench. In its entirety, laboratory is a point along a network consisting of a set of human and non-human associations which have been displaced *from nature* and developed to fit social time, place and ordering. In this manner, laboratories act in ordering the world. Through cumulative modes of organizing and ordering, the network position of a laboratory becomes manifest as a center of calculation capable of action at a distance (Latour 1987). As Chapter 5 demonstrated, the laboratory was situated in a transgenic research community, collaborations were a distinguishing feature of this community, and the efforts to extend these products, processes and assertions along the length of the network generated social controversy. From an initial laboratory site, I found that the actor network embodies an "outside" world which was inseparable from the "inside" craft work of daily laboratory organizing, trials of strength and tribulations.

The extension of the network into non-laboratory environs elicited widespread controversies which raised the question about the effects of aquaculture research and development. The movement of transgenic fish from concepts, proposals and daily laboratory work into wider sociotechnical ordering was initially traced through the centrality of instruments. *Scientists work with and from instruments.* Some of these configurations produce inscriptions which transform the daily processes into the ideas, concepts and theories which circulate beyond the laboratory as texts. These texts also convey a lab-like ordering of the world by which to insert the lab-created products.

The movement into broader sociotechnical ordering also simultaneously involved the effort to enroll nature and actors from within the laboratory and society. First, as the fish moved from the realm of concepts to laboratory production, they encountered obstacles or passage points posed by nature. These passage points posed by nature were overcome when scientists incorporated rDNA into fish tissue. Inscriptions composed from PCR and Southern blot allowed for a representation of transgenic fish to be inserted into texts which attempted to persuade relevant others of the importance of the work, ideas, concepts, theories and the social ordering of a lab-like world.

Second, as genetically engineered fish became tangible entities in the laboratory, a proposal was put forth to move them outdoors. In moving outside the laboratory a critical passage point was posed by the environmental safety of outdoor pond research. Some actors resisted this move and an ensuing controversy erupted which outlined the network's lengthening trajectory as one extending into the jostling of sociotechnical ordering. An effort to resolve this controversy concerning transgenic fish and a whole range of aquatic GMOs in nature and society led to the collective impetus for creating national voluntary performance standards by researchers and governmental agencies.

Third, in establishing performance standards, a sense of closure was not reached. New controversies were generated because the movement of aquatic GMOs into sociotechnical ordering encountered additional passage points which eclipsed the limited scope of the U.S. based actions. The paradoxical effects of the performance standards were traced to a truncated sense of objectivity socially constructed around a priori biological criteria which did not apply to particular social, political, ethical and technoscientific situatedness of standards application. As a consequence, new forms of dissent and questions concerning aquatic GMOs in nature and society have been raised which are not readily answerable. Thus, the international ramifications of aquatic GMO research and development strongly suggest divergent responses which may not follow the U.S. address of a limited set of environmental and social points of contestation.

This work concludes that aquaculture is a social activity where sociotechnical ordering: nature, technoscience and society are starting points and outcomes of particular material associations constructed by human and non-human network actors in laboratory and non-laboratory settings. Actor networks elicit how nature, technoscience and the social world unfold, take shape and produce effects as sociotechnical ordering. In this respect, I find that actor networks hold three advantages for addressing the effects of aquaculture research and development and renewing its study:

(1) the principle of symmetry provides the means to recast nature, technoscience, and society as socially constituted phenomena in the same terms.

(2) the recasting of nature, technoscience and society provides the basis for conceptualizing power-knowledge, and structure-agency, as network effects.

(3) the consequences of these actions illustrate the shaping of actor worlds and attendant power, knowledge, structure and agency effects. In this respect, the sociology of objectivity provides a socially constituted frame of reference by which to assess the decisions which comprise an ordering of the social world.

First, the effects of aquaculture research and development and a renewed approach to its study can be productively analyzed by applying the principle of symmetry. By not assuming a priori what one intends to demonstrate at the onset, an observer follows the actors in a manner which is not predicated by place, time, or disciplinary boundaries. Moreover, actor network theory allows for symmetrical comparison of lab and non-lab associations as part of the same network thus overcoming the problematic divides between nature, technoscience, and society. Indeed, as we move along the lengthening network, the fate of aquatic GMOs undergoes transformations in the hands of others. When the controversies are settled, these transformations shape nature, technoscience and society whereby power-knowledge, and structure-agency emerge as the seamless network effects of sociotechnical ordering.

Second, because actor networks include non-humans, the social construction, composition and constitution of power, knowledge, structure and agency must account for these non-human actors. We can no longer exclusively attribute power and knowledge, structure and agency to human actors alone. Power-knowledge, and structure-agency are co-extensive, materially heterogeneous and generated by the jostling of networks. These productive effects are part of the recursive processes of sociotechnical ordering. Through the simultaneous exertion of power-knowledge we collectively structure a world, act in it and anticipate a contingency laden future.

In concluding this work, an outline for a sociology of objectivity provides a framework by which to situate actor worlds and attendant power, knowledge, structural and agency effects. How we go about making technoscientific decisions acts as a critical nexus in configuring the kind of nature, technoscience and society we desire, construct and act in. Clearly, technoscience is one of the most powerful means by which we attempt to understand and transform our world (Rouse 1987). However, the crucial decisional contexts of technoscientific choice for understanding and shaping the world have become fixated on an "objectivism" and reduced to appeals to technological progress. As a consequence, unintended and inevitable consequences in the form of social conflict, restricted access to technoscience, and uneven benefits are borne by different actors. Herein lies the value and contribution of applying actor network theory to these decisional arenas. By framing technoscientific choice within its social situatedness, a turn towards a broader social objectivity can better inform decisions, anticipate consequences and reenforce societal values of all the actors in the shaping of the social world.

In the following sections I first apply the principle of symmetry to aquaculture technoscience and society. Contributions to a mutual conversation between the sociology of aquaculture and sociology of scientific knowledge highlight actor networks with respect to the value of following technoscience in the making, research, policy, and sociotechnical ordering. In particular, sociohistorical studies of aquaculture networks would elicit valuable accounts of the recent industrial ordering of aquaculture. These contributions lead to an overall actor network assessment of sustainable aquaculture development. I find that the contemporary discourse over sustainable aquaculture development reflects contrasting and conflicting values centered around the social use and deployment of its technoscience in society.

Second, an actor network approach offers a basis for rethinking some conventional sociological categories. In particular, the relations between knowledge and power, and structure and agency need to be analytically reconstituted as simply being heterogeneously generated and reproduced by networks. This reconceptualization points to the outlining of the sociology of objectivity as a context by which to account for network effects in nature, technoscience and society. A guiding assumption of this approach is that power, knowledge, structure, agency and objectivity are not reified categories but are grounded in the recursive processes of sociotechnical ordering.

In brief, this work elicits a series of novel contributions to both the sociology of aquaculture and the sociology of scientific knowledge. On one hand, the sociology of aquaculture lacks theoretical development and overwhelmingly rests its accounts on problematic divides between technoscience and society. My intention has been to demonstrate the value of following aquaculture technoscience in the making which would complement accounts by sociologists of aquaculture. On the other hand, there are few studies available on aquaculture evident in the sociology of scientific knowledge. In this respect, aquaculture can provide interesting opportunities and applied points of departure due to its burgeoning status as a nascent technoscience. At the same time, this work has demonstrated that network studies of technoscience must follow the actors out of the laboratory and into the social situatedness of technoscience in society.

TOWARDS A SYMMETRICAL READING OF AQUACULTURE

Received accounts of aquaculture research and development are problematic concerning joint address of nature, technoscience and society. In renewing the study of aquaculture, it makes sound sense to follow aquacultural scientists as they go about doing research and extending product development because scientists act as social engineers (Callon 1987). In laboratories, scientists take bits and pieces from nature and transform it by working with and from instruments through re-presenting objects in texts as social products which are fit ro social time and place. These inscriptions signify an ordering of the social world. The goal behind these ensembles is to reconstruct nature in a manner which is consistent with scientists' interests which they translate as society's interests. By attempting to speak on behalf of nature, technoscience and society, scientists seek to persuade and enroll relevant others and become indispensable for a program of action in the laboratory *and* society.

Second, the separation between research and public policy as depicted in the aquaculture development literature needs to be reconstituted as part of the recursive processes of sociotechnical ordering. Decision making permeates technoscientific research, development and policy. Decisions over technoscientific choice embody the interests of certain actors who seek to control other actors in both laboratory and non-laboratory settings. If persuasive, a spokesperson emerges who speaks on behalf of nature, science and society. In contrast to received accounts, I conclude that lab activities are simultaneously linked with broad public policy formulations. Policy formation is not a detached exercise but is tied to decisions and exertions at the laboratory level to intentionally create sociotechnical ordering. Thus, laboratory activities carry into, and are relevant for examining wider policy and social developments.

Third, by following scientists *in action*, one can more symmetrically address technoscience *in the making* as opposed to technoscience *made*. Two important points follow: (1) technoscience *made* is when all controversies have been resolved by nature and society. Hence, nature and society emerge as effects and; (2) aquacultural technoscience is *in the making*. However, nature and society are not passive. They act. Scientists seek to overcome the resistance posed by nature and society. In doing so, controversies develop and are sustained among the various actants until a spokesperson emerges who speaks on behalf of all the actors. Clearly, the maturing field of aquaculture research and development exhibits widespread controversy where a spokesperson has yet to emerge to speak on behalf of numerous networks. As a consequence, the extension of industrial aquaculture networks faces growing resistance from a variety of actors situated in diverse international contexts.

Given the growing controversies surrounding aquaculture development, it is clear that we are witnessing a transformation of nature, the formation of a nascent technoscience and a growing global industry *in the making*. The study of aquaculture laboratories and technoscience can anticipate social developments. It makes questionable sociological sense to merely address the visible effects of industrial aquaculture "out there" which characterizes much of the aquaculture development literature. Moreover, appeals to policymakers for political will remain ineffective without taking technoscience into full account. In point, the case study of transgenic fish clearly demonstrates that it was through an effort to extend the network, the move to outdoor pond research, which instigated a policy process. In particular, the decisional contexts, arguments and texts which seek to extend the network from the laboratory require full examination by sociologists of aquaculture. In sum, present social configurations, controversies and policy matters concerning aquaculture in society can be productively and symmetrically traced to laboratory origins and the efforts to extend the network.

Fourth, by symmetrically following scientists in research and development we can account for success and failure in the same terms. Aquatic GMO research and development has been partially successful because researchers have enrolled the relevant others necessary for extending the network. In contrast, scallop aquaculture in St. Bireuc Bay, France, failed to overcome the resistance posed by scallops, starfish (nature) and fishers (society) who dissented from the researcher's program to transform them into actants in a proposed aquaculture network (Callon 1986). By not examining success and failure in the same terms we are led back to outcomes restricted by social or technical determinism. At present, many accounts of aquaculture research and development announce the "success stories" of an emerging industry -- widely hailed as the "Blue Revolution." While past failures in the field are numerous and widespread, they have disappeared without a trace. In some cases, a network collapse can be attributed to when nature acts.

For example, in a coastal Thai village where I worked from 1983-85, monsoon storms destroyed a sea bass cage culture complex which was linked to an international development network. Within a few hours, the cage culture complex was reduced to twisted metal, torn netting and thousands of sea bass swimming in the Gulf of Thailand. Prior to the storms, the project staff asserted that the Gulf of Thailand could be transformed into a netpen operation. It becomes clear that in this case nature spoke otherwise. In another case, society resisted when vacation home owners effectively opposed the siting of fish culture cages along scenic waterfronts in Nova Scotia (Dwire 1996). In India, the Supreme Court recently ruled that coastal shrimp ponds must be removed due to intractable environmental and social problems (Goldberg and Triplett 1997). These examples illustrate that nature and society act and can resist efforts to enroll the heterogeneous actors within aquaculture networks.

Symmetrical readings of aquacultural technoscience successes and failures would contribute to a much better understanding of aquaculture development. For example, the previously discussed success of cage culture of carp in Lake Toba, Indonesia (Pollnac and Sihombing 1996) can be symmetrically read as the building of a strong network which overcame the earlier resistance posed by nature, technoscience and society. To attribute the success of this network to exclusive social or technical factors introduces asymmetry into what is better accounted by a heterogeneous network effect which overcame the resistance of nature and society.

Actor networks broaden the scope of sociological analyses by examining how human *and* non-human actors produce, or fail to produce intended and desired effects: (1) Successful if actors enroll other actors into a juxtaposed pattern which overcomes their resistance, or (2) Failure if resistance is not overcome by those who attempt to speak on behalf of them. At the same time, these networks are fragile and can just as quickly collapse into bits and pieces (Law 1992). For example, if Lake Toba and the carp (nature) are not enrolled into the smaller cage size as suggested by the technical expert (technoscience) then the collaboration between the NGOs and the farmers (society) collapses. Alternatively, if farmers resist the efforts of the NGOs (society) to promote cage culture of carp (technoscience) in Lake Toba (nature), once again the network collapses. In short, actor networks allows us to examine an effect from multiple perspectives encompassing nature, technoscience and society.

The above examples illustrate the differences between networks and systems. Networks analysis provides a focus on technoscience *in the making*. In contrast, a systems approach focuses on technoscience *made*. A major distinction between the two rests with the the seemingly autonomous nature of technology in a system as opposed to the fragility of technology evident in a network. Thus "technological momentum" distinguishes a system from a network (Bijker 1995). In the above example, it would make sense to depict the netpen culture of carp in Lake Toba as a system *once* all the trials and tribulations have been settled by nature and/or society. However, as the case study stands a network analysis better underscores the relatively recent and fragile status of netpen culture of carp in Lake Toba because all the trials and tribulations have not been settled by nature and/or society.

Likewise, the outcomes of transgenic fish research and development are open to further speculation because the contingencies underlying the negotiations, debates and controversies have not been settled by nature and/or society. A spokesperson has not emerged to speak on behalf of *all* the relevant actors. On one hand the network may continue to extend along the lines of situating faster growing fish into industrial aquaculture operations. However, an ongoing question is: How will nature and/or society act? In the laboratory, researchers have demonstrated faster growth rates in some experimental trials but the network behind "faster growth" is poorly understood. On the other hand, some human and non-human actors resist and a series of questions remain. Will escaped transgenic fish threaten biological diversity? Who will emerge to speak on behalf of the fish, farmers, corporations, and consumers? Will farmers, corporations and consumers accept the faster growing genetically altered fish? In ocean netpen salmon farming, Canadian farmer groups have resisted by calling for a ban on transgenic salmon research which is some of the most impressive in the field (Devlin et al. 1994). Farmers argue that "genetically engineered" salmon taint the consumers' image of pure "ocean raised" salmon (Goldberg and Triplett 1997).

Key informant interviews with technoscientists indicated that another possible outcome of transgenic fish research and development may be the creation of genetically engineered vaccines which would then be applied to traditional selectively bred fish stocks. The need for a faster growing genetically altered fish (advanced by the researchers and USDA) may not be as desirable as the more pressing need (expressed by the farmers) for vaccines. Key network actors such as farmers may not be convinced of the need for genetically engineered fish. In this manner, the network involving those who speak on behalf of faster growing fish for industrial aquaculture may be displaced by another network comprised by those who speak on behalf of vaccines which allows farmers to overcome *their* passage points. To attribute success or failure to either case is an oversimplification. An actor network analysis suggests that one network comprised of spokespersons for the vaccines) displaced another one comprised of spokespersons for genetically altered fish.

Sociotechnical Ordering as an Effect of Aquacultural Research and Development

Sociotechnical ordering is a starting point and effect which arises from the network building of technoscientific research and development. As new networks replace traditional ones, the heterogeneous engineering of non-humans and humans have successively defined "aquaculture" as one particular mode of sociotechnical ordering. Aquaculture networks originate and are extended around specific actors such as wild fish, hatcheries, technoscientists, rearing facilities, laboratories, rDNA, processors and consumers. In aquaculture, network associations between actors establish material relations which result in a desired set of sociotechnical ordering effects. Some aquaculture research and development networks are relatively embryonic, short and extensive (e.g. yellow perch culture in the Midwest) while others are more mature, much longer, more intensive, and include a strong array of non-human and human actors (e.g., tropical shrimp farming). These networks can not be exclusively attributed to either social or technoscientific categories and diffusion processes which reside outside of the material relations between human and non-human actors. As actor networks demonstrate, nature, science and society are inextricably linked to the recursive processes of sociotechnical ordering. In this respect, sociohistorical studies of aquaculture can potentially illuminate these particular modes of sociotechnical ordering.

Comparative Sociohistorical Studies of Aquaculture

The principle of symmetry applied to aquaculture research and development provides fertile grounds for undertaking sociohistorical comparisons between and across aquaculture systems and their development. First, the origins and effects of research and development are traced to *contingent* configurations, patterns and outcomes. Rather than distinguishing between species, systems and their macro/micro scale of development within individual countries or regions and so on, or classifying systems based on biological categories and levels of inputs and control, we can compare different aquaculture systems in terms of relatively short or longer networks. Hence, we can bring into account society to situate technoscientific practices and technoscience to situate societal practices.

The aquaculture development literature often makes macro/micro distinctions between regions or between industrialized and non-industrialized nations. These distinctions are further divided into particular species, culture systems and their development. Hence, one speaks of tilapia culture in Thailand or Asia with little comparative focus applied to numerous networks which have incorporated tilapia into other social contexts. In contrast, by following tilapia as actants within networks we can expand the scope of analysis to include linkages which cut across place, time or biological classification schemes. Moreover, we can further follow tilapia as a commodity form in terms of post-harvest processing and consumption thereby addressing the social constitution of tilapia within broader a sociotechnical ordering.

Second, these broader symmetrical comparisons suggest that sociohistorical studies of aquaculture systems can be effectively probed to identify the early associations which established the creation and extension of an aquaculture network. Aquaculture networks originate and exert effects within nature and the social milieu. However, sociotechnical ordering does not just spontaneously occur but emerges, takes shape and form through the ordering of actants which have been successfully enrolled into a program of desired interests and intentions. Conversely, actants may resist enrollment in a network and the network may change its constitution or collapse. Thus, the effects of research and development are traceable to early network building efforts in the laboratory as well as society. Often these early network efforts are hidden from current sociological analyses of aquaculture "out there" in society.

The interests animating transgenic fish research and development are intentionally designed to fit specific societal contexts and interests. Since a spokesperson for the transgenic network has not emerged, the outcomes of transgenic fish in society are marked by contingency laden controversy, divergent trajectories and competing interpretations surrounding the perceived risks and benefits to nature and society. Perhaps nature will speak by resisting the scientists' efforts to enroll the fish. At the same time, technoscientists and some policymakers have argued that transgenic fish will extend into industrial modes of sociotechnical ordering. By identifying early technoscientific developments within an emerging field of research and development, the sociologist can simultaneously trace and envision contingent outcomes in terms of nature and society. While there are a range of contingent outcomes imaginable, global aquaculture development and transgenic fish in particular, exhibit a strong impetus along the lines of an emerging science tied to industrial modes of sociotechnical ordering.

A Nascent Technoscience Based Industry

Actor networks, including aquaculture networks, are never static or monolithic entities. New networks can displace traditional ones as society's needs change (de Sousa and Busch 1998). In the case of aquaculture, industrialized networks are displacing traditional ones. Consistent with other forms of sociotechnical ordering, aqua*culture* embodies both human and non-human interests which has shaped the materials, practices and uses associated with it. The transformation of aquaculture into a global technoscience-based activity has involved simultaneous translations into distinct sociotechnical modes of organizing and ordering. Beginning as an ancient and localized farming practice, the controlled cultivation of some economically important aquatic organisms has emerged as an organizing focus for a modern technoscience and a growing global industrial ordering. This focus is primarily organized around increasing profitable production. Only recently has consideration of the environmental or social consequences of industrial aquaculture become a point of social contestation. As a consequence, nature, technoscience and society progressively take shape and are contested around this mode of sociotechnical ordering.

Aquaculturists have always evoked production mythologies by which to animate their craft work, stories and interests. As this work has demonstrated, the ethos of an aquaculture where "small is beautiful" (Schumacher 1974) has been displaced with an ethos of economic development through industrial modes of aquaculture. Increasingly, the industrialization of aquaculture and its vision of nature and society have resulted in environmental and social problems which are contested throughout the world. Advocates of industrial aquaculture argue that stagnation of wild fisheries harvests and increasing demand for aquatic food products require the development of more production from fish culture. However, this mythology oversimplifies a much more complex story. In contrast to earlier developments which focused on the alleviation of hunger in developing countries, industrialized aquaculture commodities are often relatively expensive and out of reach for the poorer segments of society (Goldberg and Triplett 1997). Growing aquaculture production has not lessened environmental pressure on wild fish stocks (Martinez 1997). Moreover, industrial aquaculture has been identified as a polluting industry, a threat to genetic diversity, and a source of social conflict throughout the world (Goldberg and Triplett 1997).

In sum, aquaculture provides a growing source of high quality protein for relatively well-fed and affluent consumers in the world. Currently, aquaculture production accounts for 27% of global fish production for human consumption (Goldberg and Triplett 1997). However, in the drive to increase production and become economically viable on a mass production and consumption basis, aquaculture has neglected environmental and social impacts which have in turn, threatened its sustainablility. For example, in many Latin American and Asian locales nature and society have been *ordered* to fit the extension of technoscientific networks. As a consequence, traditional networks of the coastal ecosystem thus displacing primary production which is linked to traditional ***human and non-human*** use of this environment have been displaced and transformed into a resemblance of a giant hatchery (see Sagoff 1989). In another case, critics who attempt to speak on behalf of nature warn against the loss of genetic diversity through the escape of cultured fish species such as salmon in Norway and North America. In Florida, escaped tilapia from aquaculture operations have established themselves as an aquatic "nuisance" in the Everglades (Goldberg and Triplett 1997). Clearly implicated in these scenarios are products and processes derived from aquacultural technoscience and its extension into sociotechnical ordering.

The myth of "farming the seas and feeding the world" as espoused by proponents of the "Blue Revolution" holds little resonance and credibility to those that question its sustainability. Along these lines, the Environmental Defense Fund (Goldberg and Triplett 1997) has recently released a report concerning the environmental effects of aquaculture in the United States. This report, which also refers to other aspects of global aquaculture, is an exemplar in that it clearly sets out a more nuanced portrait of aquaculture development and the environment. In brief, Goldberg and Triplett (1997) recommend that aquaculturists should:

(1) adopt sustainable management practices: move away from netpen culture, limit wasteful use of fishmeal in feed and become organically certified, and,

(2) the federal government should develop clear oversight policies pertaining to effluent, biological pollutants, regulation of open ocean aquaculture facilities, and ensure environmental protection by enhancing long-term social and economic benefits in impoverished communities.

In the EDF report, transgenic fish are identified as potential biological pollutants. Opposed to the genetic engineering of fish, Goldberg and Triplett (1997) advocate for traditional selective breeding of fish to the point where domesticated stocks would not be capable of surviving in the wild. Martinez (1997) extends this argument by stating that transgenic fish and intensive aquaculture mask more fundamental problems in managing capture fisheries in the world's oceans. In short, these critics argue that the genetic engineering of fish and shellfish, although still in its infancy when compared to terrestrial plants, is nothing more than a short term measure which will result in corporate industrialization of the aquatic environment. While these accounts are critical of industrial forms of aquaculture and genetic engineering, numerous donors such as the World Bank continue to advocate for increasing aquaculture production through biotechnology. This strategy features the genetic engineering of fish for food and export. Thus the myth of the Blue Revolution is perpetuated in numerous loans to developing countries by these international donors (Martinez 1997).

At the Crossroads of Sustainability

Implicated in these social controversies are products and processes originating at the lab bench and from the efforts to extend aquaculture networks at a distance. These technoscientific products and processes have been harnessed to industrial forms of production in order to create profitable mass production and consumption. Thus, the interests driving industrial aquaculture research and development are predicated on production oriented *values* which are embedded in the decisions regarding *what* technoscience to develop, *how* to deploy it and *who* will benefit from it. Absent from these decisional contexts until only recently, is consideration of the wider social situatedness of aquaculture technoscience, nature and society. As a result, aquaculture has become an arena of growing controversy and contestation. On one hand, the industrial networks of global aquaculture proliferate and thus transform nature, technoscience and society. On the other hand, critics attempt to speak on behalf of those actors negatively effected by these transformations.

Controversies surrounding specific aquaculture networks such as tropical shrimp culture, transgenic fish, netpen culture of salmon and so on, mask a primary set of differences. As aquaculture approaches the crossroads of sustainability, a more fundamental conflict between economic and environmental *values* becomes evident and structures contemporary discourse on aquaculture research and development. Environmentalists argue that aquaculture can be made more environmentally sound through sustainable technoscience, better management practices and more government oversight and regulation. In contrast, proponents of industrial aquaculture argue that the environmental agenda would simply put them out of business in a competitive global economy. Moreover, environmentalists propose technoscientific developments such as recirculating systems but they are not economically viable at present. What is not detected in these policy matters is the fundamental stake in different value orientations towards nature, science and society which are espoused by those who seek to speak on behalf of each network.

The contemporary discourse over aquacultural research and development reflects contrasting and conflicting values embedded in the use and deployment of its technoscience in society. With increased production as the dominant value system of aquacultural technoscience, the decisions and interests which guide development of products and processes produce controversies over the effects and outcomes in nature and society. The singular focus on production values is vigorously contested by those who alternatively propose the *integration* of economic *and* environmental values into aquaculture research and development. As a result, the discourse concerning sustainable aquaculture development is characterized by divergent outlooks and stratagems.

Both industrial aquaculture proponents and their critics currently contest the meaning and application of "sustainable aquaculture development." In this discourse, asymmetries once again appear with both sets of actors speaking on behalf of "sustainable" networks, variously defined. However, industrial aquaculturists skew their position towards the economic with environmental values subordinate to industrial ordering. Critics skew their position towards the environmental with economic values subordinated thus ignoring *real world scenarios and practices*. Often the rhetoric over sustainable aquaculture development assumes an ideal world where these value systems can be harmonized. However, there is a lack of concrete examples to support these claims.

What is lacking in the asymmetrical arguments over sustainable aquaculture development is an examination of technoscience in terms of values and contingencies, and the choices which shape aquaculture networks. Aquacultural technoscience embodies values, contingencies and shapes networks that produce effects in nature and society. If the values of production are tied to fostering economic efficiency, then the contingent set of production practices will embody network effects which have been criticized as "unsustainable." Given this characterization, negative effects produced by aquaculture in nature and society can be somewhat mitigated by incorporating technoscientific developments into the network which lessen pollution, for example, by building sewage treatment facilities on corporate farms. However, these sustainable measures remain secondary to the primary production values which anchor the industrial network.

In contrast, environmental critics propose a much more radical reorientation of values, contingencies and the transformation of aquaculture networks to environmentally sound ones shaped by a set of values and contingencies which outline an alternative ordering of nature and society. If environmental values are tied to fostering sustainable aquaculture production then the contingent set of practices will lead to less adverse network effects in nature and society. At present, the aquaculture practices required to address this sustainable transformation are not clearly evident. For example, Goldberg and Triplett (1997) argue that more research attention be paid to traditional selective breeding and recirculating systems to promote sustainable and environmentally sound aquaculture. However, in order for these research and development networks to thrive, they would have to displace more embedded networks focused on genetic engineering and a myriad of established culture systems which are sources of pollution. Hence, proposals which seek to advance environmental values face fierce resistance from representative spokespersons of the aquaculture industry.

It is apparent that the debate over sustainable aquaculture development will be with us for some time. While some predict that aquaculture will contribute upwards of 50% of food consumption by the year 2015, others see limits to growth and a series of intractable problems associated with this form of food production (Goldberg and Triplett 1997; Martinez 1997). Given growing world population alone, it is clear that increased pressure will be brought on *all* forms of aquatic food production. Whether aquaculture can meet these demands is highly doubtful because currently cultured fish are often carnivores and require large amounts of fish meal and oil which greatly reduce one source of protein to produce another. Thus industrial aquaculture of shrimp, salmon and catfish to an extent, are luxury commodities and affordable for higher end consumers in affluent nations of the world. As presently constituted, aquaculture is clearly no panacea which will lessen our reliance on wild fish stocks and more affordable sources of protein.

ACTOR NETWORKS AND SOCIOLOGY

In this work, an actor network approach was used to follow the actors in a specific field -- aquaculture, and in particular a specific case study -- transgenic fish research and development. Actor network theory allowed me to symmetrically analyze aquaculture research and development by not predicating it on place, time or specifics of a particular culture system or disciplinary boundaries. In concluding this work, actor networks contribute to a more nuanced grasp on the dynamics of how nature, technoscience and society in the making originate, take shape and produce effects. As such, actor networks provide a further means to conceptualize power-knowledge, and structure-agency, as network effects. An outline for a sociology of objectivity highlights the social situatedness of technoscientific choice.

Knowledge and Power

Actor network theorists advance that power and knowledge are materially heterogeneous and are exerted to achieve effects through collective action (Latour 1987; Law 1994) . These exertions give rise to controversies which are ultimately settled through representations attributed to a spokesperson who speaks on behalf of *all* the actors in a network. As Murdoch (1994:9) has stated:

> Power is a 'composition' made by many people but **attributed** (via representations) to one of them. Thus the amount of power exercised is not related to how much someone 'has' but to the number of actors involved in its composition.

Through the simultaneous exertion of power and knowledge we interpret, organize and order the world. Research-generated knowledge is intertwined with productive power. The exertion of knowledge *and* power transforms nature, science and society. Knowledge and power are starting points and effects arising from material relations among actors in a network. In contrast to received views of power and knowledge which stress the repressive or abstract character of each, power and knowledge are starting points which lead to *productive* effects which arise through the simultaneous exertion of both in animating the social (Rouse 1987). Through collective action, exerting power can create knowledge, and exerting knowledge can create power. If spokespersons are able to speak on behalf of *all* the entities in a network, then technoscience is *made* and results in the everyday ordering of the social.

The exertion of knowledge and power in the laboratory and in society animates transgenic fish research and development. Scientists simultaneously construct knowledge and exert power in the laboratory when they build aquatic GMOs. In order for laboratory products to extend into society many more actors must be enrolled by technoscientific spokespersons into the power-knowledge collectivity which animates and structures the network. For example, transgenic technoscientists have enrolled certain policymakers who support their research and journal editors who publish their texts. These actors are not passive but also enroll others actors, including the technoscientists, thereby strengthening and extending the network in society.

If the technoscientist's enrollment efforts are ultimately successful and controversies are settled, then a spokesperson for transgenic fish will restructure aquaculture. However, the transgenic network continue to face resistance from other actors and networks. These actors are not convinced by the claims of the technoscientists. They resist. Clearly, evidence exists where the claims made by transgenic fish spokespersons are currently contested by other networks anchored by environmentalists, other technoscientists, policymakers, scientifically literate publics, farmers and consumers. These political points of contestation further shape the direction and contingent outcomes concerning the structure of the transgenic fish network.

While research and development of transgenic fish has advanced in the laboratory, the social composition of power and knowledge broadens the dimensions resulting in controversies regarding the potential effects. On the one hand, technoscientists argue that the global problem of aquatic food shortages can be addressed by producing high performance fish. On the other hand, opponents seek to mitigate these transformative claims by arguing that transgenic fish may give rise to adverse effects in other networks. They attempt to mitigate the potential effects brought on by the exertion of knowledge and power on the part of the technoscientists. Thus knowledge and power are contested social products which emerge out of patterned networks comprised of human and non-human actors. In making technoscience, power and knowledge are always contested, contingency-laden and variable in the composition of the social. Transgenic fish are no exception.

Structure and Agency

Actor network theorists state that analytically, humans are patterned networks of heterogeneous materials (Law 1992). Humans are bodies but more than mere bodies. A human agent not only inhabits a body, but exists in *a web of material relations* with other heterogeneous entities which extends into the social as a patterned network or a network effect. Likewise non-humans extend into the social as patterned networks or network effects. Hence network entities, including humans, are co-extensive (Callon and Law 1996). Networks act through humans and non-humans. Agency emerges as an effect of these fundamentally co-extensive material relations.

Agents struggle to overcome resistance posed by other actors. The site of this struggle is social structure. The origin and effects of social structure are created by the recursive processes of sociotechnical ordering which heterogeneously regenerates and reproduces itself. That is, social structure is nothing more than the jostling of bits and pieces of the heterogeneous material relations of a network which is juxtaposed into patterned sociotechnical ordering. As a consequence, social structure does not lie outside the social, like a frame of a house, but *consists of and constitutes* the social.

In the case of transgenic fish research and development, an actor network approach offers great latitude in addressing the *analytical* effects of agents and structure. Rather than attributing the decisions and contingent outcomes to a specific technoscientist, a policy formulation, performance standards, transgenic fish or industrial aquaculture, we can look at the composition of each network, their effects and envision a set of contingency-laden patterns which are punctuated by the transgenic network.

Agency and structural effects are never final, autonomous or rigid. The bits and pieces of a network are all heterogeneously engineered in sociotechnical ordering, including agents and structure, which constitute the network and its effects. As a result, the social takes shape and changes through the sociotechnical ordering effects of networks. Agents and structures are starting points and effects of this recursive process.

The structure of the transgenic fish research and development network is a highly contested site. While the research structure exhibits some relative stability in terms of ongoing work and the emergence of transgenic fish as tangible entities, this network further seeks to extend itself through society. As a result, resistance is evident in the discourses underlying the transgenic network. In part, the resistance posed by environmental networks has restructured the transgenic network. No longer is it a matter (as transgenic technoscientists previously argued) of creating transgenic fish and then simply inserting them into commercial aquaculture systems. Transgenic technoscientists must address the perceived environmental effects and the specific passage points posed by the environmental network. As a result, recent transgenic fish work has reoriented its direction to address passage points concerning the environmental effects of transgenic and non-transgenic fish in controlled research environments.

Power and knowledge, structure and agency are effects of networks. In this regard, the preliminary movements and outcomes which have shaped the field of transgenic fish research and development currently exhibit more pronounced social ordering effects and implications. The decisional arenas underlying these translations are dominated by technoscientists who support their justifications by appeals to scientific objectivity. However, biological criteria can not pass as objective social criteria. In societal terms, the application of scientists' sense of objectivity produces a reductionist effect and generates controversy. Indeed, the fate of transgenic fish-aquatic GMOs lies in the hands of others – nature and society. However, as the major actors, scientists undertake the research and envision a society where food shortages are addressed by their laboratory products. Moreover, it was through the efforts of scientists that the socially constructed performance standards were created. Overall, other members of society have played only secondary roles, if any in these processes and decisions. The transgenic network is a socially constructed, composed and constituted network and must be looked at in this manner. Hence consideration of sociological objectivity outlines a potential framework by which to assess technoscientific choice from the standpoint of society.

The Sociology of Objectivity

This work has raised some critical questions concerning how technoscientific decisions and outcomes are reached in society. Paradoxically, the discourse over situating transgenic fish in society has largely been provided by technoscientists who advocate the situating of transgenic fish in industrial aquaculture. Assuming negligible environmental impacts, transgenic fish advocates further envision highly positive social effects through address of world food problems. This discourse is justified by appeals to scientific objectivity with decisions and anticipated outcomes based on exclusively biological criteria. From this perspective biological criteria are simply translated into social desirability. However, these arguments while often repeated in the literature, are too simplistic and ignore society's definition of objectivity. Hence, a broad sociological examination of objectivity is central in elucidating the effects of transgenic fish in society.

The question of objectivity in technoscience requires concerted sociological readdressing. In contrast to scientific objectivity or what Harding (1991) has criticized as "objectivism," the sociology of objectivity envisions social organization, social values and the kinds of societies which would best enhance democratic decisions regarding technological choice. Hence the sociology of objectivity is concerned with the social conditions underlying the pursuit of knowledge and how these conditions affect society (Restivo 1994). Moreover, as Restivo (1994:189) states "the very notion of objectivity depends on inquiry that is guided by broad and diffuse values rather than by the values of specific organizations, institutions or social classes."

In the transgenic fish research and development network, specific individuals and organizations dominate inquiry and make absentee decisions on the part of society. It is clear that the basis of this inquiry is guided by narrow criteria and grounded in expert systems of decision making which are reduced to biology. These decisions and potential effects are highly speculative, narrow and above all rest on socially derived contingencies which clearly require more thorough and socially responsible address and deliberation by wider segments of society. For example, I found in the course of this study negligible non-scientist public input into any of the decisions regarding transgenic fish. However, various "publics" stand to be the ultimate winners or losers associated with this technoscience. More specifically, the major transgenic work being undertaken takes place with fish species which are destined for industrial aquaculture systems. As such, it becomes apparent that small-scale farmers will be bypassed by transgenic fish research and development despite the unsubstantiated claims made by transgenic fish advocates about the social benefits for small-scale farmers. These social parameters are simply ignored in the current discourse over transgenic fish in society.

A sociology of objectivity could greatly contribute to broadening the dimensions of social inquiry regarding technoscientific choice underlying transgenic fish and other areas of genetic engineering and biotechnology. A sociology of objectivity elicits multiple perspectives as social realities. These components provide the context for decisions and anticipating outcomes in a socially accountable manner which enhances the social constitution of a free democratic society. At present, the transgenic fish research and development network provides little evidence that democratic outcomes are likely or even desirable due to the heady mixture of short-term technological fixes. Thus, contingent speculation and widespread social controversy and conflict regarding nature, technoscience and society runs rampant. The social situatedness of technoscientific choice must be incorporated into decision making contexts by consciously using social values. Only then would a sociologically defined sense of objectivity emerge in a fuller democratic sense and help guide the choices as to what kind of technologies *and* societies are desired.

THE SOCIOLOGY OF AQUACULTURE AND SCIENTIFIC KNOWLEDGE

In conclusion, this work has presented a novel approach to the study of aquacultural technoscience and society. By examining both technoscience and society in the same terms, findings are generated which extend earlier contributions in the sociology of aquaculture and scientific knowledge. My intention has been to contribute to and to stimulate further study of the multiple dimensions of aquaculture, and encourage fuller consideration for the societal basis of technological choice. In particular, by bringing technoscience back into a sociological frame of analysis, sociologists could overcome deterministic accounts and greatly strengthen their analyses concerning the social impact of a relatively new way to produce food.

Actor network theory offers a viable means by which to readdress technoscientific research and developments due to its symmetrical focus on humans and objects within a relational materialism. Given that the world we live in is increasingly populated by the objects of technoscience, it makes sense to include objects as constituent and meaningful parts of the hybridized social world. These new political sites, such as the laboratory, bring into focus an array of increasingly complex arenas constituted by political contestations, and the proliferation of contingent outcomes. However, the pursuit and mapping of the extension of technoscience from the laboratory into non-laboratory publics requires more attention by sociologists of scientific knowledge. Going into the laboratory *and* especially coming out of it, rethreads the sociological context of technoscience's effects in the world.

Actor networks contribute not only to the sociology of aquaculture but also an extension of conventional sociological categories such as power and knowledge, structure and agency. By avoiding a priori assumptions at the onset, actor network theory provides an ontological basis and methodological means for arriving at these dynamic human and non-human composites as effects. Ignoring objects and objectivity in sociology leads us back to a priori assumptions found to be problematic in the earlier chapter of this work. In this way actor network theory opens up broad new horizons in the field of sociology -- a move away from the "purely social" or "purely natural" to a hybrid form of both -- a socionature. In the final analysis the sociology of objectivity clearly stands as a promising framework for the kind of comprehensive analyses needed for adequately addressing these complex technoscientific issues.

At the same time, actor network theory poses challenges to conventional sociological thinking. Unlike the a priorism of "grand theory" actor networks theorists make no assumptions about the social world prior to a methodological approach to it. Actor network theory is based on well grounded methodological assumptions arising from the identification of a series of problematics. Pursuit of these assumptions and problematics offers convincing avenues by which to pursue the hybrid study of social life in a manner which is highly resonant with the dramatically increasing technological composition of contemporary societies. In this manner actor network theory need not dismiss other orientations but identify and mark its point of departure and translations of the social, technoscientific and natural world.

APPENDICES

APPENDIX A

APPENDIX A

RESEARCH IN AQUACULTURE SCIENCE AT AUBURN UNIVERSITY

I. In order to analyze research directions in aquaculture science at Auburn University, your answers are appreciated for the following questions. All responses are guaranteed the <u>strictest</u> confidentiality. Thank you for your cooperation.

1. What is your educational background?

<u>Degree</u>	<u>Institution</u>	<u>Year Completed</u>	<u>Field</u>
Baccalaureate			
Masters			
Doctorate			
Postdoctorate			
Other (specify)			

2. Please indicate the title, years on the job and type of setting (academic department, government, lab, etc.) for your present, previous and first professional position(s).

	<u>Title</u>	<u>Years Employed</u>	<u>Institution & Dept.</u>
Present			
Previous			
First			

3. What is your current field of aquaculture science?

____

____

____

4. During the last 12 months what have been the **actual** (not formal) conditions of your appointment?

__________% Research __________% Administration

__________% Teaching __________% Extension

__________% Other (specify) __________

II. In this next section your choice of research topics and your opinions about your discipline are requested. Some of the questions are complex and others call for opinions about the aquaculture discipline. Please try to answer all the questions. When the answers do not reflect your situation or attitudes, please check the open ended response and elaborate.

The National Science Foundation defines **basic** science, **applied** science, and **development** in the following ways:

Basic research: stresses that it is directed toward increases of knowledge in science with "... the primary aim of the investigator... a fuller knowledge or understanding of the subject under study, rather than a practical application thereof."

Applied research: is directed toward practical application of knowledge. It covers "... research projects which represent investigations directed to discovery of new scientific knowledge and which have specific commercial objectives with either products or processes."

Development: development may be summarized as "... the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes."

5. Using these definitions, how would you characterize your research during the last five years (1989-1994)? (Indicate percentage of research effort). What do you think it should be?

Actual % Ideal %

_____ Basic Research _____

_____ Applied Research _____

_____ Development _____

6. Using these definitions, how would you characterize <u>your research</u> during the last ten years (1984-1994)? (Indicate percentage of research effort). What do you think it should be?

Actual %		Ideal %
______	Basic Research	______
______	Applied Research	______
______	Development	______

7. What is your perception of the distribution of research in the <u>department</u> during the last five years? <u>Ideally</u> what should it be?

Actual %		Ideal %
______	Basic Research	______
______	Applied Research	______
______	Development	______

8. During the last five years, how important were the following considerations in your choice of research problems? Please rate **each** criterion by circling one number from **"Not Important" (1)**, to **"Very Important" (7).**

CRITERIA FOR PROBLEM CHOICE	**Not Important**					**Very Important**
Potential contribution to scientific theory......................1	2	3	4	5	6	7
Likelihood of clear empirical results..............................1	2	3	4	5	6	7
Potential creation of new methods,useful materials and devices...1	2	3	4	5	6	7
Potential marketability of the final product...................1	2	3	4	5	6	7
Funding..1	2	3	4	5	6	7
Length of time required to complete the research.......1	2	3	4	5	6	7
Publication probability in a professional journal.........1	2	3	4	5	6	7
Publication probability in farm and/or industry journal...1	2	3	4	5	6	7
Publication in experiment station or research service bulletins and report..1	2	3	4	5	6	7
Availability of research facilities..................................1	2	3	4	5	6	7
Currently a "hot" topic..1.	2	3	4	5	6	7

Evaluation of research by scientists in aquaculture.........	1	2	3	4	5	6	7
Colleagues' approval..	1	2	3	4	5	6	7
Credibility of other investigators doing similar research...	1	2	3	4	5	6	7
Enjoy doing this kind of research..................................	1	2	3	4	5	6	7
Importance to society..	1	2	3	4	5	6	7
Scientific curiosity..	1	2	3	4	5	6	7
Demands raised by clientele...	1	2	3	4	5	6	7
Feedback by extension personnel...................................	1	2	3	4	5	6	7
Client needs assessed by you..	1	2	3	4	5	6	7
Priorities of research organization..................................	1	2	3	4	5	6	7
Other (specify)________________________________	1	2	3	4	5	6	7

9. In choosing your research during the last five years, in what way did the following people influence you?

For each person circle the appropriate letter(s). Then indicate the **degree** of influence by putting a **number from 1 to 7** on the line next to each circled letter indicating whether the person was **slightly important =1 to most important =7.**

A_____B_____C_____D______............Your immediate supervisor
A_____B_____C_____D______............A colleague in your department
A_____B_____C_____D______............A colleague in another agricultural science department at Auburn
A_____B_____C_____D______............A colleague in a basic science department at Auburn
A_____B_____C_____D______............A colleague at another institution
A_____B_____C_____D______............Staff at funding agency
A_____B_____C_____D______............A research assistant/technician
A_____B_____C_____D______............A graduate or postdoctoral student
A_____B_____C_____D______............A former professor
A_____B_____C_____D______............Director of your research facility
A_____B_____C_____D______............Client or potential user
A_____B_____C_____D______............Research review committee
A_____B_____C_____D______............Other (specify)__________

10. How frequently do you communicate with the following people regarding your research? (Please circle one number for each group).

	Rarely	Monthly	Bi-weekly	Weekly	Daily
Scientists in your department............	1	2	3	4	5
Aquacultural scientists outside your department............	1	2	3	4	5
Other (non-aquacultural) scientists...............	1	2	3	4	5
Administrators........	1	2	3	4	5
Clients...................	1	2	3	4	5
Funding agencies...	1	2	3	4	5
Extension staff.......	1	2	3	4	5
Graduate students.....	1	2	3	4	5

11. How many of the following persons are currently working under your direction?

Graduate students ____________
Post-doctoral fellows ____________
Technicians ____________
Other (specify)__________________________

12. What has been your average annual research expenditure (including all salaries) over the past five years, to the nearest $1,000 excluding overhead?

$____________, 000

13. Are there topics that are consistently avoided in your field?

Yes__________
No __________

If so, which ones?
____

Why?____
____

14. Over the past five years, <u>how many</u> of each of the following types of publications have you authored or co-authored?

Sole or lead author		Co-authored
____________	Journal articles....	____________
____________	Books.................	____________
____________	Book chapters.....	____________
____________	Abstracts............	____________
____________	Bulletins.............	____________
____________	Reports..............	____________
____________	Other..................	____________

15. To what journals do you subscribe?

a______________________ e______________________
b______________________ f______________________
c______________________ g______________________
d______________________ h______________________

16. Over the past five years, in what journals have you published (authored or co-authored) articles?

a.______________________ e______________________
b______________________ f______________________
c______________________ g______________________
d______________________ h______________________

17. Apart from your discipline, d o you believe that your research and publishing over the past five years has already or will directly or indirectly benefit any of the following? In your opinion who should the research benefit?

Will or Does <u>Benefit</u> (Not at All ... A Great Deal)		Should <u>Benefit</u> (Not at All ... A Great Deal)
	Other scientific disciplines	
1 2 3 4 5	....(specify)______________	1 2 3 4 5
1 2 3 4 5	....Small farmers......................	1 2 3 4 5
1 2 3 4 5	....Large farmers.....................	1 2 3 4 5
1 2 3 4 5	....Aqua-business....................	1 2 3 4 5
1 2 3 4 5	....Rural residents....................	1 2 3 4 5
1 2 3 4 5	....General public.....................	1 2 3 4 5

1 2 3 4 5....Local or state governmental
agencies.................. 1 2 3 4 5
1 2 3 4 5....Federal agencies.................. 1 2 3 4 5
1 2 3 4 5....Foreign farmers, institutions
or governments........1 2 3 4 5
1 2 3 4 5....Other__________________ 1 2 3 4 5

18. Recently, a number of social issues relating to aquaculture have been raised by various groups and individuals. Would you please indicate the degree to which your research reflects these concerns? (Please circle one number for **each** concern).

Rarely Frequently

Appropriate technology available to a
wide range of producers........... 1 2 3 4 5 6 7
Consumer issues (e.g., nutrition).......... 1 2 3 4 5 6 7
Economic issues (e.g., seafood deficit,
farmer productivity)................. 1 2 3 4 5 6 7
Environmental issues (e.g., pollution,
spread of diseases to humans).. 1 2 3 4 5 6 7
Diversification approaches to agriculture
(e.g., integrated farming).......... 1 2 3 4 5 6 7
World food "crisis" (e.g., problem of food
sufficiency and distribution)..... 1 2 3 4 5 6 7
Other (specify)_______________........ 1 2 3 4 5 6 7

19. How would you characterize your research philosophy, "school" or paradigm within your discipline (e.g., advancing scientific and technological progress, "oil spot phenomenon" etc.,)?

____
____
____

20. About what percent of the members of the discipline share your orientation?
____________ %

21. What significant advances are currently taking place within aquaculture science?

____
____

22. Why are they significant?

____
____

23. Outside of your own research, who or what research group at Auburn University can be considered as significantly advancing aquacultural science and research (rank up to three in terms of importance)?
1_________________
2_________________
3_________________

24. Why did you list a particular scientist or group in question 23 above?
____
____

25. Are there any research interests you would like to pursue which you have not been able up to now?
___________Yes
___________No

26. If so, what would make it possible for you to do these things?
____
____

27. What is your sex?
Male_________ Female_________

28. What is your year of birth? 19_____

No questionnaire of this type can adequately cover points considered by individuals with diverse interests. In light of this, your comments are appreciated on the next page. Again, your answers are STRICTLY CONFIDENTIAL. THANK YOU FOR YOUR COOPERATION.

Source: Busch and Lacey 1983

APPENDIX B

APPENDIX B

INTERVIEWS

Approximately 28 one to three hour face-to-face and phone interviews were conducted in the United States and abroad with the following:

Title	Number
Principal Investigator Scientist	8
Policymaker (foreign and domestic)	10
Laboratory Technicians (non-PhD)	4
Laboratory Scientists (PhD)	1
Graduate Students (pre-PhD)	3
University Administrator/Staff	2

All interviews were tape recorded and transcribed producing over six hundred pages of single-spaced transcripts. When requested, each interviewee was sent a copy of the interview. All interview questions were the same except for question 5 which was modified in order to address the specifics of each occupational category.

Biotechnology Interview Questions

ORAL SCRIPT

I am conducting this interview as part of my dissertation research in Sociology at Michigan State University. My dissertation pertains to a sociological study of science. Towards this end I am currently observing activities at a field station/laboratory as well as interviewing scientists and others who conduct research and formulate policy concerning aquatic GMOs.

Your participation in this interview is voluntary. Under no circumstances will you be identified by name in any subsequent document. You do not have to answer any particular question is so desired.

Because of the technical nature of this interview, I request your permission to tape record it. Under no circumstances will you be identified by name in any subsequent document. You may request that I turn off the tape recorder is so desired. You may also request me to provide you with a written transcript of this interview. I want to assure you that the strictest confidentiality will be maintained.

WANTS TRANSCRIPT? __________YES __________NO

NOTES:

BIOTECHNOLOGY INTERVIEW QUESTIONS

Name:

Date:

Time:

Code:

Comment:

I. BACKGROUND INFORMATION

1. EDUCATION____________HIGHEST DEGREE COMPLETED_________FIELD
NOTE: (ask PI for C.V.)

2. In general, How would you describe your work? How long have you worked in this field?

3. How would you describe your work as it related to transgenic fish research and development?

4. Who did you collaborate with? Who did you report to?

II. TRANSGENIC FISH RESEARCH AND DEVELOPMENT

5. I'm very interested in your work in transgenic fish R&D. How did this come about?

{For Principal Investigators}

(5A). How do you view the overall progress in this area of research?

{For Policymakers}

(5A): How do you view the overall progress in this area of research? How would you assess USDA's stance (policy) and support (funding) for this type of R&D in the short-run? Long-run? How would you assess the scientific community's view on this type of R&D in the short-run? Long-run? How would you assess the public's view for this type of R&D in the short-run? Long run?

{For Lab Technicians}

(5A): I'm very interested in your work in developing lab techniques and procedures for transgenic fish. How did this come about? What was it like in the early stages of the research?

{For Graduate Students}

(5A): I'm very interested in your research/dissertation work. Could you describe it to me? Who do you see benefitting from it?

6. In your opinion, what are the benefits associated with transgenic fish research and development?

7. In your opinion, what are the constraints associated with transgenic fish research and development?

8. How would you assess the regulatory climate concerning transgenic fish R&D?

9. In your opinion, how safe is transgenic fish R&D work in terms of research, development and commercial options?

10. Do you expect that transgenic fish will be patented anytime in the near future?

11. Do you expect that commercialization of transgenic fish will influence the relationships between universities and private firms (e.g., farms, processors, biotech firms)?

12. How would you define objectivity in your work? What social factors did you take into account when conceptualizing or proposing various actions? Who/what influenced you?

III. CONCLUSION

13. Is there any issue, topic or consideration which you feel is important that I have left out in this interview?

14. Could you recommend anyone else I should talk to?
NAME:

NAME:

NAME:

THANK YOU FOR YOUR COOPERATION AND YOUR TIME

APPENDIX C

APPENDIX C

Performance Standards Worksheet

Introduction

The Performance Standards for Safely Conducting Research with Genetically Modified Finfish and Shellfish are voluntary guidelines intended to aid researchers and institutions in assessing the genetic and ecological effects of research activities involving genetically modified fish, crustaceans, and molluscs, and in determining appropriate procedures and safeguards so that the research can be conducted without causing adverse impacts on the environment. The Flowcharts of the Performance Standards guide researchers in identifying, assessing and managing specific risks. This Worksheet accompanies the Flowcharts. Once completed by the researcher, the Worksheet will document both the decision path taken through the flowcharts of the Performance Standards, and any risk management measures. It is designed to assist researchers and reviewers in evaluating the project. Until the Performance Standards are incorporated into a computerized expert system with the capability of producing a hard-copy trace of the decision path, this worksheet should be used.

Principal
Investigator: ____________________
Proposed project: ____________________

____

____

Please mark your response to a question by checking "Yes," "No," "Don't Know," "EXIT," or by indicating your routing to a subsequent flowchart. Marking of more than one blank may be appropriate in particular situations. **Attach written explanatory materials as directed below.**

<u>Flowchart Documentation</u>

Please list the numbers of all flowcharts that you used:

____

____

Flowchart
No.

I. Do the performance standards apply to the proposed experiment?
_____ Yes or don't know. Where were you routed?

_____ Continue to flowchart II.A.
_____ Consult Appendix B.
_____ No. EXIT the standards.

II.A. Does the GMO result from deliberate gene changes?
_____ Yes. Where does flowchart II.A. route you?
_____ II.A.1. Assess impacts of deliberate gene changes
_____ EXIT the standards. **Attach your rationale.**
_____ No. Continue to flowchart II.B.

Flowchart
No.

II.A. 1. Where are you directed following completion of the flowchart regarding possible impact of deliberate gene changes? **Attach a written description of any identified risks.**
_____ II. Assess potential interference with natural reproduction.
_____ IV.A. in Ecosystem effects assessment.
Accidentally escaped GMOs may establish population posing potential for introgression.
_____ IV.B. in Ecosystem effects assessment.
Accidentally escaped GMOs may establish population posing adverse effects on ecosystem structure or processes.
_____ VI.A. Risk management - identified risks: manage risks to protected population.
_____ VI.A. Risk management - insufficient information.
_____ EXIT the standards. **Attach your rationale.**
_____ EXIT but consult relevant federal and state agencies regarding the use of non-indigenous species. **Attach your rationale.**

II.B. Does the GMO result from deliberate chromosomal manipulations?
_____ Yes. Where does flowchart II.B. route you?
_____ II.B.1. Assess potential impacts of chromosomal manipulations.
_____ II.C. Assess impact of additional modifications.
_____ EXIT the standards. **Attach your rationale.**

_____ No. Continue to flowchart II.C.

II.B.1. Where are you directed following the completion of the flowchart regarding possible impacts of deliberate chromosomal changes? **Attach a written description of any identified risks.**

_____ III. Evaluate potential interference with natural reproduction.

_____ EXIT the standards. **Attach your rationale**.

_____ EXIT but consult relevant federal and state agencies regarding the use of non-indigenous species. **Attach your rationale.**

II.C. Does the GMO result from interspecific hybridization?

_____ Yes. Where does flowchart II.C. route you?

_____ II.C.1. Assess potential impact of interspecific hybridization.

_____ EXIT the standards. **Attach your rationale.**

_____ No. Exit the standards. **Attach your rationale.**

II.C.1. Where are you directed following completion of the flowchart regarding potential impact of interspecific hybridization? **Attach a written description of identified risks.**

_____ III. Evaluate potential interference with natural reproduction.

_____ VI.A. Risk management - specific risks: Manage risks to protected population.

_____ VI.A. Risk management - specific risks: Manage risks of losing population of pure species.

_____ EXIT the standards. **Attach your rationale.**

_____ EXIT but consult relevant federal and state agencies regarding use of non-indigenous species. **Attach your rationale.**

III. If you were directed to use the flowchart regarding potential interference of a sterile GMO with natural reproduction, where were you routed? **Attach a written description of identified risks.**

_____ IV.C. Ecosystem effects - impacts of reproductive interference.

_____ VI.A. Risk management - specific risks. Manage risks to protected populations.

_____ EXIT the standards. **Attach your rationale.**

Flowchart No.

IV.A. If you were directed to use the flowchart regarding potential ecosystem effects of GMOs expressing deliberate gene changes, where were you routed? **Attach materials describing risks identified.**

_____ IV.A.I. Ecosystem effects - impacts of introgression of modified gene(s).

_____ VI.B. Risk management - insufficient information

_____ EXIT the standards. **Attach your rationale.**

IV.A.1. If you were directed to use the flowchart regarding potential ecosystem effects of GMOs expressing deliberate gene changes, where were you routed? **Attach material describing risks identified.**

_____ V. Assess effects on ecosystem structure and processes.

_____ VI.A. Risk management - specific risks. Manage decline in population abundance.

_____ VI.B. Risk management- insufficient information.

IV.B. If you were directed to the flowchart regarding potential barriers to reproduction of the GMO associated with the accessible ecosystem, where were you routed? **Attach a written description of identified risks.**

_____ IV.B.1. Ecosystem effects - potential for non-reproductive interaction.

_____ EXIT the standards. **Attach your rationale.**

IV.B.1. If you were directed to use the flowchart regarding the potential for non-reproductive interaction of the GMO with conspecifics or closely related species, where were you routed? **Attach written description of identified risks.**

_____ V. Effect on ecosystem structure and process.

_____ VI.B. Risk management - insufficient information.

_____ EXIT the standards. **Attach your rationale.**

IV.C. If you were directed to use the flowchart regarding potential ecosystem impacts of reproductive interference by sterile GMOs, where were you routed? **Attach written description of identified risks.**

_____ VI.A. Risk management - specific risks. Manage risks to protected populations.

_____ VI.B. Risk management - insufficient information.

_____ EXIT the standards. **Attach your rationale.**

V. If you were directed to use the flowcharts regarding potential effects of the GMO on ecosystem structure and process, where were you routed?

_____ VI.A. Risk management - specific risks. Manage risks to protected populations.

_____ VI.A. Risk management - specific risks. Manage risks of alteration of ecosystem processes.

_____ VI.B. Risk management - insufficient information.

_____ EXIT the standards. **Attach your rationale.**

VI.A. If you were directed to use the flowchart regarding risk management when there are identified risks, what measures do you plan to adopt to manage these potential risk(s). **Attach a written description of the risk management measures you plan to implement. Be certain to address the topics listed in the Risk Management Documentation section below.**

Flowchart
No.

VI. B. If you were directed to use the flowchart regarding risk management when there is insufficient information to assess risks, what measures do you plan to adopt to effectively confine the proposed experiment? **Attach a written description of the risk management measures you plan to implement. Be certain to address the topics listed in the Risk Management Documentation section below.**

Additional Questions

1. Are you working with a non-indigenous species?
_____Yes.
_____No.

2. If yes, have you consulted the state and federal agencies which oversee uses of non-indigenous fish, crustaceans, and molluscs and complied with the procedures?
_____Yes.
_____No.

List names, addresses, telephone numbers, and areas of expertise of the experts you contacted for substantial advice in assessing effects of a proposed experiment and in designing adequate safety measures.

____
____
____
____

______________________ ______________
Signature of researcher Date

Address and Phone No.

____
____
____
____
____

Risk Management Documentation

As part of compliance with the voluntary Performance Standards, the researcher must describe and provide the rationale for the risk management measures. Major points explained in the text on Risk Management Recommendations are listed below. Researchers and reviewers should read the text on Risk Management recommendations before using this portion of the Worksheet. The risk management documentation must fully respond to these major points. For items which request a narrative response, attach your written responses and identify the numbered item being addressed.

Project siting

1. Explain how the siting and structures of the project prevent accidental releases during flooding or other natural disasters.

a. If project involves placement of GMOs in uncovered tanks or ponds, is there potential for sudden high winds to wash organisms in a natural body water (accessible ecosystem) via water spray or waves?
_____Yes. Proceed to item 1.b.
_____No. Proceed to item 2.

b. If there is potential for GMOs held in outside units to be washed via sudden high winds in a natural water body, what measures will be taken to adequately cover these outside units or otherwise protect against movement of GMOs by water spray or waves into nearby natural water bodies? (Explanatory diagrams may be useful).

Design of Barriers

The Standards identify four types of barriers: (1) physical or chemical; (2) mechanical; (3) biological; and (4) scale of experiment as a barrier.

2. Was the project site chosen because the surrounding accessible ecosystems are lethal to all life stages of the GMO?
_____ Yes. Address items 2.a and 2.b.
_____ No. Proceed to item 3.

(a) Describe evidence that the accessible ecosystems are indeed lethal to the GMO.

(b) Explain how the siting reduces the need for barriers on-site.

3. Could the project's GMOs potentially escape through any of the paths (aquatic and non-aquatic) listed below? Answer "Yes" if there is potential for escape or uncertainty about potential escape of GMOs via the listed path. Answer "No" only if escape is clearly precluded.

___ a. Influent/makeup water?
___ b. Effluent and drawdown water?
(Note: if discharge to sanitary sewer is used as one barrier against accidental escape of GMOs in effluent, at least one additional barrier is necessary).
___ c. Waste slurries?
___ d. Disposal of experimental animals?
___ e. Aerosols (applies only to shellfish with small larvae)?
___ f. Equipment cleaning and storage?

4. Have you identified additional, potential escape paths? If yes, briefly describe each path.

5. For each escape path identified in items 3 and 4 above, describe the arrangement and types of barriers to escape: a diagram of layout of barriers at the site or facility may be useful. Describe: treatment and disposal of waste slurries; disposal of experimental animals; and cleaning and storage of equipment.

6. Describe how the types and numbers of barriers in series are sufficient to achieve the "acceptable number of accidental escapees" specified in Flowcharts VI.A. or VI.B.

Special Concerns

7. _______ If biological barriers are used for a given escape path, does the path have at least one other type of barrier? (Because of their variable efficacy, biological barriers cannot comprise the entire set of barriers).

8. _______ If scale is used as a barrier, are you certain the GMO is not a self-fertilizing hermaphrodite or true parthenogen? Attach supporting evidence.

Security

9. Describe the security measures implemented to:
   a. control normal movement of authorized personnel,
   b. prevent unauthorized access to the site, and
   c. eliminate access for predators who could potentially carry animals off-site (applies only to outdoor projects).

Alarms

10. Describe and justify the adequacy of the entire set of installed alarms. Be sure to address the following:
   a. Have you installed a water level alarm (required for all projects)?
   b. Do all installed alarms have backup power?
   c. Describe the plan for notifying designated personnel.

Operational Plan

11. Attach written operational plan. Required components are:
   a. Training.
   b. Traffic Control.
   c. Record Keeping.
   d. Emergency Response Plan.

Review and Inspection

12. Has your institutional biosafety committee, biosafety officer, or other appropriate expert reviewed and approved the proposed project and its risk management measures? If no, explain the status of review of your project.

_____ Yes.
_____ No.

Have you notified federal, state, and local agencies having jurisdiction over any aspects of your proposed project? If no, please explain.

_____ Yes.
_____ No.

Please list all required permits and authorizations and check appropriate line regarding status of your application.

	approved	pending	not yet submitted
______________________	______	_____	_____
______________________	______	_____	_____
______________________	______	_____	_____
______________________	______	_____	_____
______________________	______	_____	_____

Source: USDA-ABRAC (1995)

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