Aquarium of the Pacific
Marine Conservation Research Institute

Aquaculture Siting Workshop Summary

July 16, 2007

Jerry R. Schubel
Zhong Shang
Corinne Monroe

ATTENDENCE

Participants and Staff

Mark Drawbridge, Phyllis Grifman, Mark Helvey, Don Kent, Dale Kiefer, Sam King, Corinne Monroe, Frank O'Brien, Paul Olin, Patti Parisi, Jack Rensel, Jerry R. Schubel, YaYa Shang, Neil Anthony Sims, Keith Stolzenbach, Eric Terrill, Dallas Weaver, Steve Weisberg

Agenda and Contact List

Appendix A contains the agenda. Contact information for participants and staff is listed in Appendix B.

SUMMARY OF DISCUSSIONS

Goals of the Workshop

- Determine the offshore zones within which the physics of water motion and mixing create conditions favorable to siting offshore farms
- Describe a process of defining zones and for identifying sites within these zones
- Outline a monitoring program
- Determine types of farms most appropriate for California.
- Identify leading candidate species.

Initial Discussion on Goals

JACK RENSEL

Ecological benefits are rarely discussed with aquaculture. The industry has to develop and educate the public about the benefits because right now, most of the information is focused on the problems and negative issues. In addition, most of these negative issues are untrue.

DALLAS WEAVER

The energy involved in doing aquaculture should be compared with wild fisheries. For example, the energy of farmed salmon, including that of going out to catch fish for the fish meal, was better than trawled and netted salmon. The carbon footprint for farmed fisheries is less than for capture fisheries.

DALE KIEFER

The PEIR is a critical document. Can we say the goal of this workshop is to have an influence on this document? If this is the case, then the timing of the Conference would be critical.

SAM KING

I believe the primary goal of this group is to have California allow somebody to have a demonstration or pilot site. This demonstration site can be set up before the PEIR is finalized. A small number of demonstration projects can address issues on economic and environmental viabilities.

DON KENT

A lack of permitting infrastructure in California would impede a demonstration startup. Hubbs had a site off Catalina and we found out that we could have ten-folded the operation and still not have a significant impact. We submitted an application to have a 300 metric ton year operation and our biggest obstacle came from the idea that aquaculture is bad and we should not do it. There are no real reasons not to do it except that it is an untested area. Our studies are in the public record because the Coastal Commission wanted consistency review of our application even though the proposed site was seven miles outside the three mile coastal zone defined by the Coastal Act. A lack of clearly defined process allows for bureaucratic mis-direction that can seriously delay or stop a project.

JERRY SCHUBEL

On the issue of terminology, key legislatures have clearly stated not to say "offshore aquaculture will be allowed in the following areas" but rather "offshore aquaculture will be prohibited except in the following areas".

NEIL SIMS

To add to that, the terms "demonstration" and "pilot" program should be used less, the focus needs to be on commercial success. We therefore also need to consider the size of the operation that would ultimately turn a profit. To my understand, SB201 allows people to begin the process of obtaining a lease in state waters prior to the PEIR passage, as long as environmental assessments are made, and the potential significance of any impact is adequately assessed.

We should be placed under greater scrutiny. People often compare offshore aquaculture's regulatory burden with the minimal requirements for other protein production systems (chicken, beef, etc.). However, terrestrial farms are on private land, and aquaculture is in the public domain. We should therefore expect and accept more scrutiny. The real underlying reason for many of the objections to aquaculture is that it is competing with commercial fishing, even if that's not the issue that is immediately apparent in California.

DON KENT

Zeke Grader, or other lobbyists for commercial fishermen, will fight against aquaculture even if it is in California. We need to have the technology transfer written in the beginning of this so the commercial fishermen will realize that they can do both.

One of the main arguments is that aquaculture takes away fishing jobs, but that's because we don't offer aquaculture jobs in the United States. Fishermen can also transfer over to farming during off seasons. We need to stress the importance of jobs aquaculture will bring and vest commercial fishermen into the process as they are the people most likely to undertake farming operations in open water.

Identifying Zones

For permitting, California Fish and Game and the California State Water Resources Control Board would be the lead agency for state waters (those within three miles of shore). Outside the three mile limit, a permit would need to come from various federal agencies such as Corps of Engineers, EPA, NOAA, etc.

Southern California Coastal Ocean Observing System, (SCCOOS) program has models of coastal water movement. The motions of this model indicate that the southern California bight is back water. It has irregular water depth but the water motion does have some long term patterns that can be counted on. The movement is overall from the northwest to the southeast but is variable with eddy circulation at times and locations. These eddies are influenced by the islands and bathymetry. Rates of water movement are energetic, but not in one direction. There are no fixed eddy cores and we know the harbors are areas of minimal movement and flushing. . It is easier to indicate areas with poor flushing.

Fish farms should be in areas where the water is moving, but it would be difficult to work on the cages when the water is too strong. Minimal average velocity would be around 10 cm/s (~0.2 mph), but average rates are not the sole means to describe water motion. Rather, a frequency diagram of flow rates is more informative and variability of direction can mitigate for less than ideal flow rates. Due to present anchoring limitations, farms should not be in waters deeper than 150 meters or shallower than 25 meters depending on the type of cages (e.g., surface cages need less depth than submerged cages). Depth is not too important if currents are strong and the downstream directions of flow do not affect habitats of special significance. In general farms should not be too close to the coast for visual aesthetic reasons or to avoid special habitats and existing uses.

By process of elimination, using the above considerations there is a narrow ribbon of possible sites. The farms cannot be in Santa Monica due to political reasons, nor should it be near plume storm waters. This leaves only south Orange County and Santa Barbara County. Lastly, it should also not be near sewage treatment plants. The best choices are northern Ventura County, Santa Barbara County, and Camp Pendleton.

Deep cages will not be affected by plume water and toxic plumes dissipate generally within the first mile. However, a “demonstration” farm is all about perception and we need to stay away from plumes.

The state is already involved in regard to ocean zoning and it is too late to stop it. It would help entrepreneurs when broad initial zones are established by the state but because of final regulation hurdles there are no guarantees.

Areas selected for siting should be in clean water which would lead to healthy fish. Other important considerations include:

- Habitats of special significance (wildlife, marine mammals, fish breeding, etc.)
- Bottom type (avoid hard bottom and other reef structure)
- Water depth (deeper than 150 ft and shallower than 300 ft)
- Currents (at least 0.2 knots/hr but no greater than 1.0 knots/hr)
- Avoid other user conflicts (commercial fishing, recreational fishing, shipping lanes, military operations)
- River plumes (plumes to be avoided: San Gabriel River, LA River, Tijuana River, Santa Ana River, and Ventura/Santa Clara River)
- Marine Protected Areas
- Outfalls
- Areas prone to red tides
- Sight lines
- Aesthetics

Possible zones mentioned at the end of discussion: Camp Pendleton, top of sea mounts, in lee of islands.

Cage Types

Depths for cages should be within ~150 to 300 feet and no shallower than 150 feet. There are two fundamentally different types of cages: submerged and floating.

Submersible Cage	Surface Cage
Advantages: • Public will not see them most of the time • May be good for high current environment, but they are difficult to operate and maintain in high currents • May be used in river plume areas Disadvantages: • Harder to maintain – need divers • Higher costs: $30-40 per cubic meter	Advantages: • Less expensive by up to a factor of ~ 4x • Easier maintenance and operation Disadvantages: • Visibility for aesthetic reasons • Not as durable in high currents • Not as stable in high waves • Polyethylene cage can be a problem with marine predators if not operated correctly

To have fish production all year long, permits for both types of cages should be applied for even if plumes occur only after rainfall during the winter. This way, we avoid caging ourselves to specific technologies and species

Fish Species

Best fish species for California: California halibut, white seabass, California yellowtail, and perhaps stripped bass although it is not native. Other possible species: sablefish (if done in deep water), mahi mahi (may not be due to water temperature), California sheephead (maybe not be due to slow growth rate), and sturgeon.

Mahi mahi are usually too temperamental to farm and the local water is probably too cold for them. Stripped bass may not be a favorable species because it is not an indigenous species; however, it is currently the only species for which there are hatcheries that would allow an entrepreneur to start farming in 2008 or 2009. Other species would require extra money and time for development of hatcheries.

AquaModel

Model created by Dale Kiefer, Frank O'Brien, & Jack Rensel

Currently, this is the only three dimensional GIS with modeling capability for marine applications that simulates both benthic and water column effects simultaneously. There are four interlinked modules: flow, fish physiology, pelagic, and benthic.

A primary concern of farms is waste materials, mainly feed, that hits the bottom. There is a flux of several elements across sediment interface to consider whether the farm is doing well or not. Hydrogen sulfide is a major criterion whether or not the farm is harming the benthic community. The "halo" enhancement zone is described when a farm is sited in sufficient currents to allow organic waste assimilation over a broad area while maintaining the aerobic surficial sediment conditions. Under such circumstances, the organic wastes may enhance the biomass and diversity of benthic organisms around the perimeter of a farm and may also provide for higher trophic levels such as marine birds.

The key to process of when the system becomes unstable or anaerobic is largely determined by diffusion of oxygen into the sediment in the benthic boundary. The biggest uncertainty is determining the respiration and growth rate of benthic organisms.

Sinking rate and rates of dispersion of feed can be determined easily but it is difficult to simulate feed resuspension after hitting the bottom. A diffusion equation cannot be simply used because it is not unilateral diffusion. It is also assumed that uneaten feed will hit the bottom. The calculations do not include wild fish that may eat the feed, which is common in tropical areas. For these reasons AquaModel's calculations are conservatively based.

The AquaModel can be used to help define specific areas within zones and also the numbers and sensitivity calculations. This allows bounds to be put on the sizes and carrying capacities of farms. Because of its graphic user interphase, it allows the user and decision makers to view processes in action which helps build understanding of the processes.

The complete PowerPoint Presentation of AquaModel can be found in Appendix C

Monitoring Program

On the environmental side, the monitoring program would need to start by identifying the clients and the types of decisions they will be making. For example, with water quality, the Water Resources Board would be the client. For escapees, the client would be California Fish and Game.

Both the water column and the benthic community would need to be monitored, at least initially. It is difficult to measure impacts of either more than a few tens of meters downstream even from very large farms. In particular water column effects (reduced DO, elevated ammonia nitrogen or urea levels) are sometimes undetectable and many jurisdictions have opted to discard any monitoring as the volume of nitrogen discharged can be easily calculated based on known physiological rates. The water column is easily monitored through measurement of changes in dissolved oxygen, water clarity, nutrients, temperature, etc. and the requirements are relatively easily met. The principle issue is the organic enrichment (contamination is a word best used for persistent pollutants) of the sediments and resulting changes in the benthos. This is measured either by looking at physicochemical measures such as total organic carbon or sulfides or by assessing the benthic infauna species composition and determining whether or not the population would be the same in an unaffected area. Typically fish farms are allotted a sediment impact zone that ranges from a few tens of meters or more depending on local conditions. Governmental jurisdictions typically do not require that benthic conditions within that zone be the same as background or reference conditions. Pollution tolerance of individual species would be assessed as is currently done in other projects.

There are four or five classes of impact on the loss of benthic species. The least damaging is the exchange of similar animals (for example, one species of amphipods replacing another species of amphipods that occupy the same ecological niche). Next would be the loss of functional groups. The highest class of impact would be in the disappearance of a phylum (ex., echinoderms). These class identifications have been developed against contamination, not hypoxia.

The core of the monitoring program would be mapping the bottom for organic carbon and benthos. Their monitoring programs typically go about three kilometers (even gigantic fish farms have no detectable impacts on the bottom more than 150 meters, see Weston 1991). Experience and modeling allows you to identify the spatial scales of monitoring that would be needed.

Benthic performance standards could incorporate use of a surrogate for infauna or carbon such as sulfides; however, it should not be started with a surrogate because of skeptical audiences. Carbon is the property of the wastes that causes sediment oxygen demand so it has a direct relationship to impact on the bottom. It is, of course, not refractile and is rapidly respired by benthic organisms and various studies show return of bottom conditions to normal after periods ranging from a few months (fast current areas) to a few years (very slow current areas).

Kona Blue Water Farms (Hawaii): Monitoring of outfalls is expensive: large sewage plants spend around $2 million a year and small plants spend about $100 thousand a year on monitoring. Kona Blue Water Farms in Hawaii, by comparison, spends about $100 thousand a year. The monitoring data is collected and analyzed by an objective third party company, and reported to the State Clean Water Branch, who operates under the oversight of EPA. NPDES permits are designed to monitor sewage plumes. Fish farms adhere to the same basic plan. Turbidity and ammonia are measured monthly and nitrates and other nutrients are measured quarterly at Kona Blue. Both effluent and mixed water are monitored and the zone of mixing is at 4000 ft. All of the data is submitted to Hawaii's State Department of Health Clean Water Branch; we also make our data available at a local repository at the harbor, and on our web site.

Because of concerns about proliferation of pests and parasites on net pen farms, Kona Blue also monitors wild fish around their farms. Wild fish show frequent infections from parasitic copepods, but these have not been found in the farm population. The public perception is that farms are incubators of parasite problems which can then spread to the wild population, but in reality it is often the opposite. If an escape should occur from a California offshore farm, it would need to be reported. To address public concerns, some initial statement should be made early in the application process that this farm will not do Genetic Modification (GM) to the fish stock.

The issue of antibiotics, vaccines, and disease: Whenever medication of any kind is used in Hawaii, it must be reported, under the NPDES permit, and tests must be done on effluent toxicity. This includes all antibiotics. Use of vaccines has largely replaced the use of antibiotics in large scale commercial net pen aquaculture worldwide due to their efficacy, relatively low cost and negative aspects of antibiotic use.

The issue of tagging: Tagging may not be an important issue unless there is an introduction of new species. All of the white seabass at Hubbs SeaWorld are tagged because it is a stock enhancement program and the fish are intentionally released into the wild. Hubbs uses non-intrusive tags that are a labor intensive and a costly method of tagging. Visual tags would be cheaper but they affect the fish, and in turn, affect the product.

The issue of quality feed monitoring: Typically the feed is bought from large, multinational feed production companies. There are no specific requirements for farmers to test the quality of their feed. The responsibility for quality control of fish feed is on feed manufacturer. Reduction in fish meal and fish oil usage is mandated by SB 201, but no-one really understands how this will be applied.

Environmental Monitoring

Protocols need to be set up so sites can be compared. Maine previously relied primarily on diver-operated video that provided immediate and excellent feedback to the growers but did not involve use of numerical performance standards. Washington State developed the first system of physicochemical performance standards that were based on comparison to benthic infauna and that can be used for comparison among sites. Transparency is very important. One of the main distinctions of mariculture and agriculture (cattle) is the lobby. The lobbying effort could be just having transparent data, but it would need to reach the public so they can understand the effects of farms.

A high level oversight committee would promote change in public perception even though it is unnecessary for regulation purposes. The oversight committee from an accredited and trusted source will generate positive images on aquaculture farming and could be used as a marketing tool.

For more on Fish and Game Commission (FGC) standards, please see Appendix E

Next Steps and Advice

Involve the local fishing community. Kona Blue has a 20 year lease and the lease was issued with the permit. Kona Blue succeeded because the people who started the project were local residents and they were able to get their community to commit to the project. You need to get someone who lives near the area willing to do it in your own backyard. But more importantly, the project needs to start now and address the issues as they come.

Identify someone interested and willing to invest in a demonstration project. A permit would need to be obtained before setting up a site and although the cost might be reasonable; the actual cost of actually setting up the site would be great and would require solicitation of investors. This would be very difficult because the regulations are so stringent. A great deal of money would be required in the beginning (~$10 million) and nothing could come out of it. If no one is willing to step up to the plate, then we need to encourage Chrisman and his people to become a proponents of this and they have to know what's good about farming.

Indicate profitability. At the present time, domestic seafood harvests are only worth about $3 billion and domestic aquaculture is only about $1 billion. We import $12 billion of seafood, and export about $3 billion leaving about and $8-9 billion trade deficit, which is second only to the oil trade deficit. If aquaculture can produce $100 million to $200 million within the state, this could be a way to get Chrisman excited about the project. Seafood is becoming more expensive, and even though California is expensive to buy from, by cutting out traveling costs from imports it may cost the same or less to buy from California.

Demonstrate demand. A white paper showing the demand written by an economist who has a MBA, not just a scientist, would be the best way to tell the story of aquaculture. In terms of NOAA, it would be beneficial to get VADM Lautenbacher to take part in this along with Mike Chrisman. Another thing would be approaching the federal council and getting them into the loop. Recreational and commercial fishing should also be engaged. On the side of NGOs, NOAA has had some success with WWF, whereas many other NGOS are totally against aquaculture.

SSF's next steps

- Summarize this workshop,
- Look into the PEIR process and the window of time for input
- After we get the PEIR comment schedule, decide on the next steps in planning for the conference
- Get to the California Ocean Protection Council

POST WORKSHOP UPDATES

PEIR Draft Expected Completion Date as of 8/16/07
The public draft of the PEIR for the Coastal Marine Aquaculture Projects is expected to be available mid-February 2008. There will be 45 day period for the public comment.

Regulatory Framework - from the report Open Ocean Aquaculture in the Santa Barbara Channel: *An emerging challenge for the Channel Islands National Marine Sanctuary* (The full report can be found at: http://www.channelislands.noaa.gov/sac/pdf/5-23-07.pdf)

This was discussed at the Channel Islands National Marine Sanctuary: Sanctuary Advisory Council Meeting held on July 20, 2007.

A. The Federal regulatory framework has not been coherently developed for Open Ocean Aquaculture (OOA). Currently, there is no specific federal framework, nor a designated lead agency to regulate OOA; however, pending legislation provides NOAA to be the leading agency for offshore aquaculture. Presently, the Department of Agriculture is considered the lead coordinating agency under the National Aquaculture Act of 1980. The U.S. Army Corp of Engineers (USACE) and U.S. Environmental Protection Agency

(EPA) are considered lead permitting agencies. Various other agencies may have implicit authority over OOA operations, such as:

- USDA: Animal and Plant Health Inspection Service
- US Coast Guard
- US Fish and Wildlife Service
- NOAA Fisheries Service
- Minerals Management Service
- Food and Drug Administration
- Office of Ocean and Coastal Resource Management

B. California state regulatory framework has clearly stated a lead agency for aquaculture, the California Department of Fish and Game (DFG). DGF will enforce current laws and regulations and coordinate with other regulatory agencies including the State Lands Commission, the State Water Resources Control Board, and the California Coastal Commission. The Sustainable Oceans Act (SB201) has specific environmental standards for aquaculture leases and regulations in state waters.

For a summary of recommendations, please see Appendix F of the report.

NOAA's FishWatch Program

Michael Kelly of NOAA came to the Aquarium of the Pacific on July 23, 2007 to describe NOAA's new FishWatch program. It is an online seafood resource that will be launched on August 4, 2007. It is designed to give wholesalers, retailers, and consumers the kind of information they need to make better choices about seafood.

The website has facts about individual fish species on environmental sustainability, fisheries management, health, and trade. The site also has special tabs on fishing gear, aquaculture, and various people in the fishing industry.

The Aquarium of the Pacific is exploring several cooperative programs and projects with NOAA staff responsible for FishWatch.

FishWatch website: www.fishwatch.noaa.gov (online August 4, 2007)

List of Appendices

Appendix A

SUSTAINABLE SEAFOOD FORUM

AQUARIUM OF THE PACIFIC
Aquaculture Siting Workshop

We know our desired destination and will use "point-to-point navigation" to get there.

Administration Offices
320 Golden Shore, Suite 100
Long Beach, CA 90802

16 July 2007

0830 Continental Breakfast

0900 Welcome & Introductions

0915 Overview of Goals and Objectives for the Day

0945 Discussion of the Motion & Mixing of Waters of the Southern California Bight in the Context of Siting Aquaculture Farms

- Preliminary Identification of Zones of Good Exchange & Mixing
- Refining the Zones to Avoid Conflicts with Protected Areas, Shipping Channels, etc.

1030 Break

1045 Application of AquaModel to Further Refine the Zones.

1200 Working Lunch - Continued Discussion. Lessons Learned From Other Areas & How We Can Apply Them to the S. California Bight

1300 Continued Refinement of the Zones for Siting Offshore Farms in the S. California Bight

- Gain Consensus on “Acceptable” Zones (acceptable from the perspective of physics and avoidance of obvious user conflicts) for Siting Offshore Aquaculture Farms
- What kinds of offshore farms are most appropriate for the S. California Bight?
- What Can We Say About Carrying Capacity? How Do we Relate It to Number of Farms, Stocking Densities, etc?

1500 Identification of Elements of a Diagnostic Monitoring Program

- Station Locations Relative to Zones & Farms
- Properties to Measure
- Frequency of Measurement
- Ideas on Methods of Measurement
- Transforming of Data into Information and Presentation & Distribution of Information
- Lessons From Well-Respected Coastal Monitoring Programs

1600 Thoughts on a Research Program to Eliminate or Reduce Critical Uncertainties

- Topical Areas/Issues
- Who Should Pay? What Level of Support is Required?

1700 Wrap-up & Next Steps

1730 Adjourn

Appendix B

Aquaculture Siting Workshop

July 16, 2007

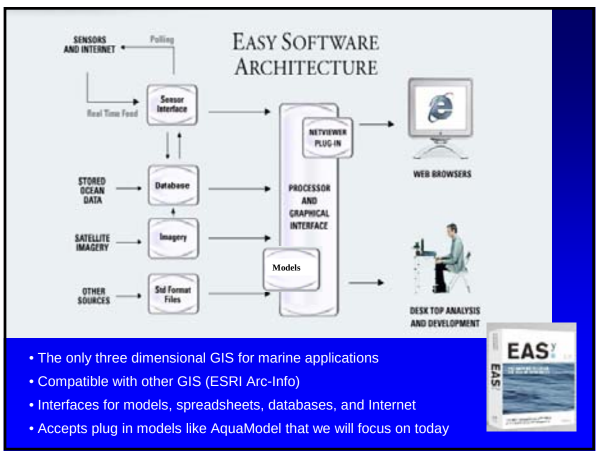
Invited Participants & Staff

Name	Organization	Email
Mark Drawbridge	Hubbs SeaWorld Research Institute	mdrawbr@hswri.org
Phyllis Grifman	University of Southern California	grifman@usc.edu
Mark Helvey	NOAA, National Marine Fisheries Service	mark.helvey@noaa.gov
Don Kent	Hubbs SeaWorld Research Institute	dkent@hswri.org
Dale Kiefer	University of Southern California	kiefer@usc.edu
Sam King	King’s Seafood Company	sking@kingsseafood.com
Corinne Monroe	Aquarium of the Pacific	cmonroe@lbaop.org
Frank O’Brien	System Science Applications	fjobrien@cox.net
Paul Olin	University of California, Davis	pgolin@ucdavis.edu
Patti Parisi	King’s Seafood Company	pparisi@kingsseafood.com
Jack Rensel	Rensel Associates Aquatic Sciences	jackrensel@att.net
Michael Rubino	NOAA	Michael.Rubino@noaa.gov
Jerry R. Schubel	Aquarium of the Pacific	jschubel@lbaop.org
YaYa Shang	Aquarium of the Pacific	yshang@lbaop.org
Neil Sims	Kona Blue Water Farms, LLC	neil@kona-blue.com
Keith Stolzenbach	University of California, Los Angeles	stolzenb@ucla.edu
Eric Terrill	University of California, San Diego	eterrill@ucsd.edu
Dallas Weaver	Scientific Hatcheries	deweaver@scientifichatcheries.com
Steve Weisberg	Southern California Coastal Water Research Project	stevew@sccwrp.org

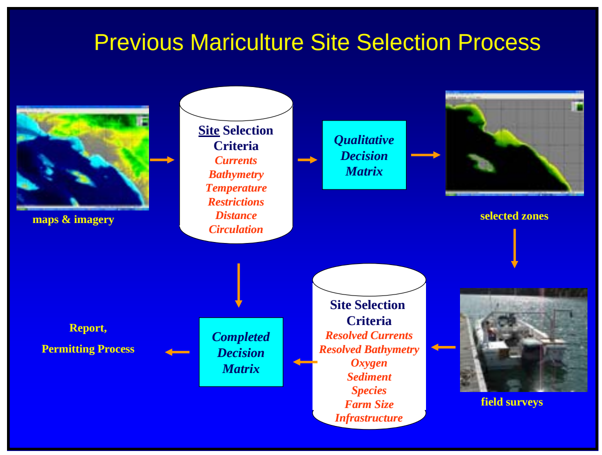
Appendix C

Modeling for Aquaculture Site Selection in Southern California
Long Beach California, July 16, 2007
Jack Rensel, Rensel Associates Aquatic Sciences
Dale A. Kiefer, University of Southern California
Frank J. O'Brien, System Science Applications

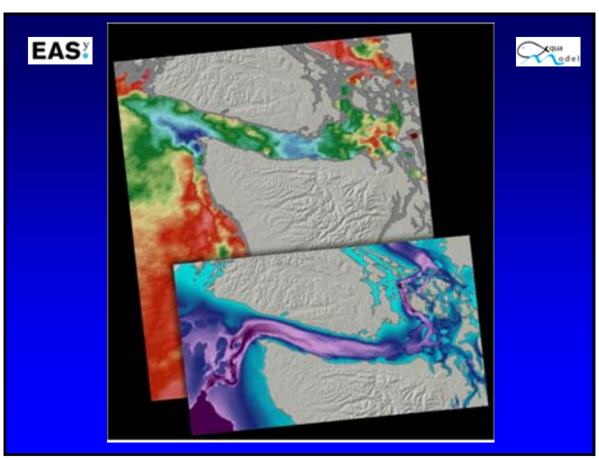
EASy
Presentation Topics
Site Selection: Pacific NW & Offshore: Rensel
AquaModel and EASy GIS Overview: Rensel & Kiefer
Demonstration of S. California Prototype: O'Brien & Kiefer
Conclusions & Discussion



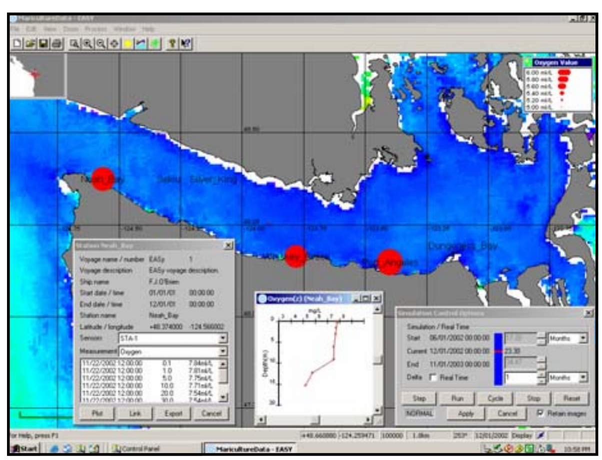
EASY SOFTWARE ARCHITECTURE
SENSORS AND INTERNET
Polling
Real Time Feed
Sensor Interface
STORED OCEAN DATA
Database
SATELLITE IMAGERY
Imagery
OTHER SOURCES
Std Format Files
NETVIEWER PLUG-IN
PROCESSOR AND GRAPHICAL INTERFACE
Models
WEB BROWSERS
DESK TOP ANALYSIS AND DEVELOPMENT
• The only three dimensional GIS for marine applications
• Compatible with other GIS (ESRI Arc-Info)
• Interfaces for models, spreadsheets, databases, and Internet
• Accepts plug in models like AquaModel that we will focus on today
EASy



Previous Mariculture Site Selection Process
maps & imagery
Site Selection Criteria
Currents
Bathymetry
Temperature
Restrictions
Distance
Circulation
Qualitative Decision Matrix
selected zones
field surveys
Site Selection Criteria
Resolved Currents
Resolved Bathymetry
Oxygen
Sediment
Species
Farm Size
Infrastructure
Completed Decision Matrix
Report,
Permitting Process



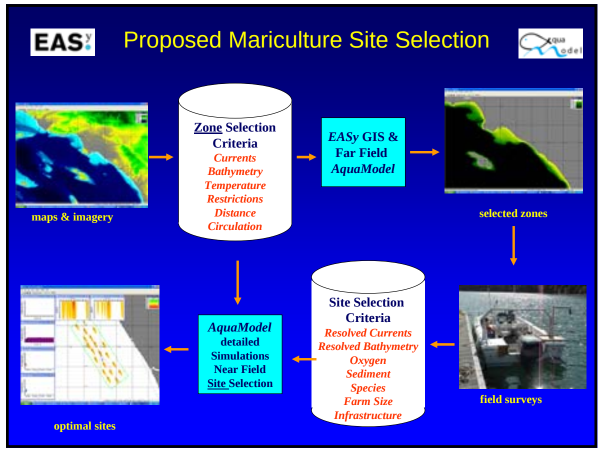
EASy



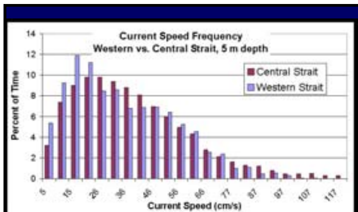
Site Comparison Matrix

Characteristic	West	Central	East Central
Tidal currents	Moderate	Moderate	Moderate
Winter-Spring wave height	Tolerable	Less	Least
Mesoscale gyres	None	Transient	None observed
Dissolved oxygen	Midway	Possibly lower	Possibly higher
Area with preferred depth	Modest width	Modest width	Wide area
Nutrients	Naturally high	Naturally high	Naturally high
Harmful algal blooms	Low Frequency	Low Frequency	Low Frequency
Infrastructure support	Very Good	Very Limited	Excellent
Birds & marine mammals	Whales, others	Birds, dolphins	Birds, dolphins
Shoreline residences	None	Few	Many
Commercial fishing	Common seasonally	Limited, seasonal	Very Limited
Recreational fishing	Common seasonally	Limited, seasonal	Very Limited
Marine debris	Fall kelp moderate	Fall kelp abundant	Less than others

Proposed Mariculture Site Selection



Physics

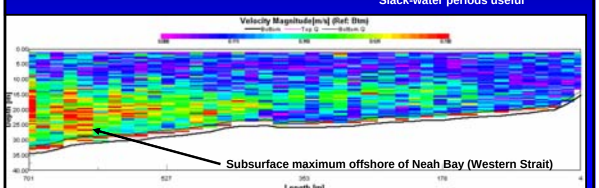


Range varies with species & pen type but 8 to 50 cm/s best, mean of about 20 cm/s

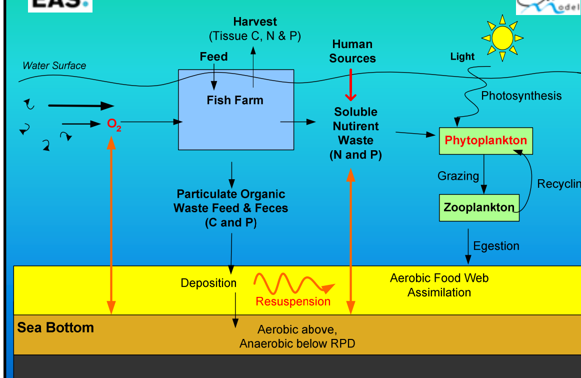
Solid waste resuspension occurs at ~ 5 to 10 cm/s (fecal) & 15 to 30 cm/s (feed)

Higher velocity requires larger fish: optimum growth for Salmo salar at 1 to 1.5 BL/s

Slack-water periods useful



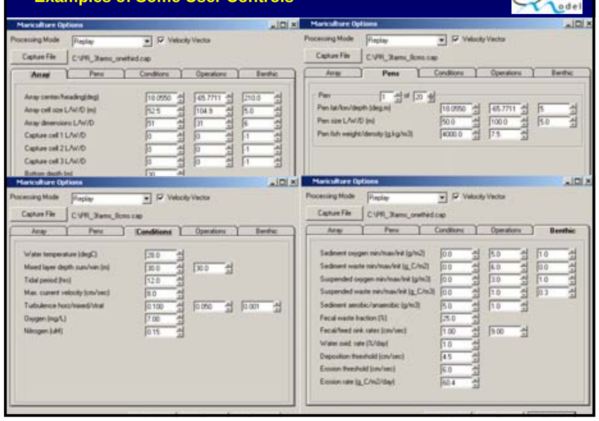
Model Overview

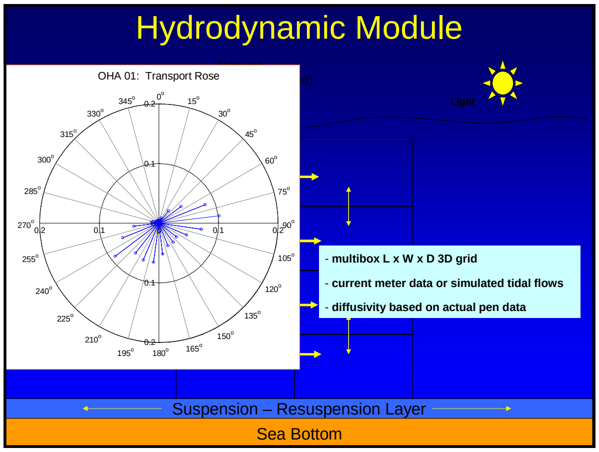


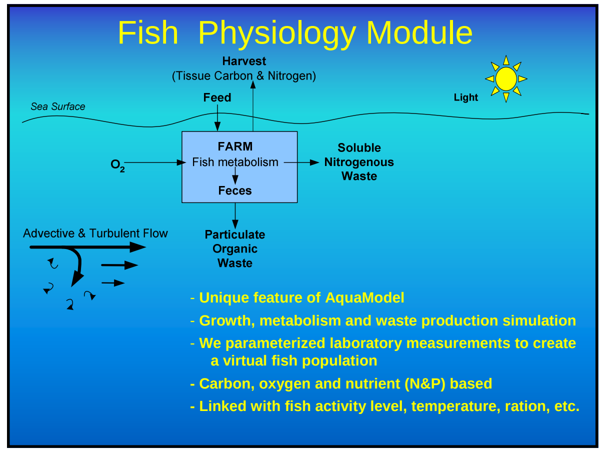
Features of the model

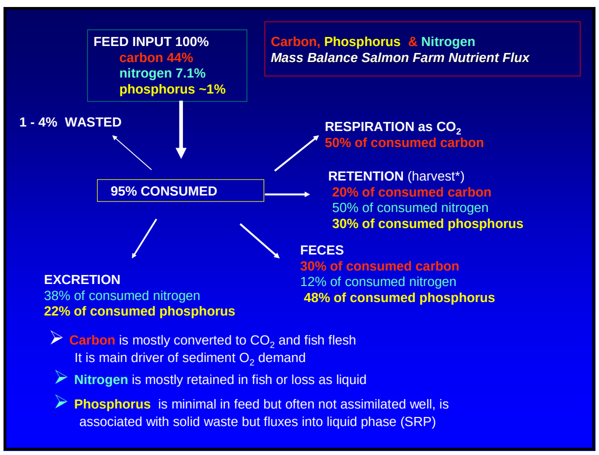
1) The only combined water column – benthic simulation model for aquaculture. Others are benthic only, inflexible
2) Fish physiology submodel that will accept constants and functions from different fish species
3) Only real time visualization model with useful GUI
4) First windows-based package that couples to a parent GIS system (EASy)
5) Relatively easy for coastal managers to use
6) "Raises the bar" for those seeking permits to compare sites, improve and defend their choices, graphically demonstrate to the public or decision makers
7) Four interlinked modules: flow, fish, pelagic, benthic

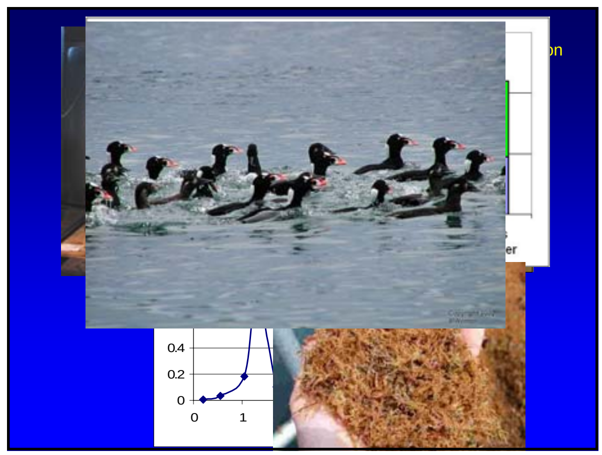
Examples of Some User Controls

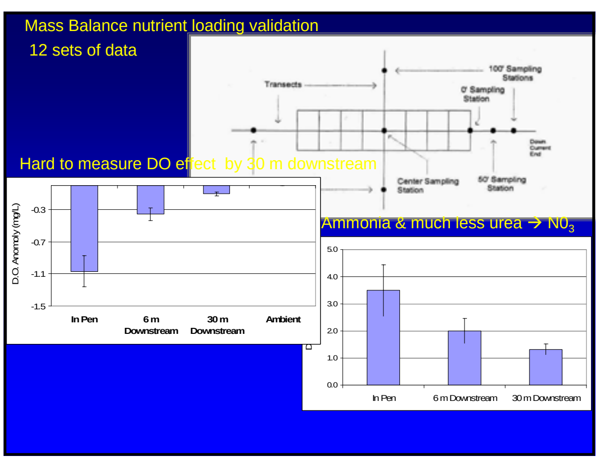


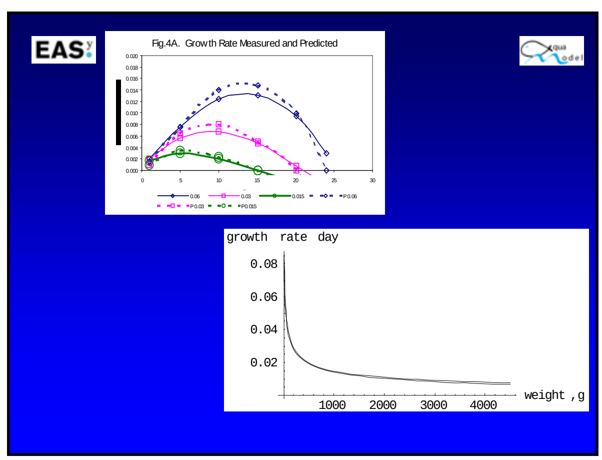

Hydrodynamic Module
OHA 01: Transport Rose
Light
- multibox L x W x D 3D grid
- current meter data or simulated tidal flows
- diffusivity based on actual pen data
Suspension – Resuspension Layer
Sea Bottom

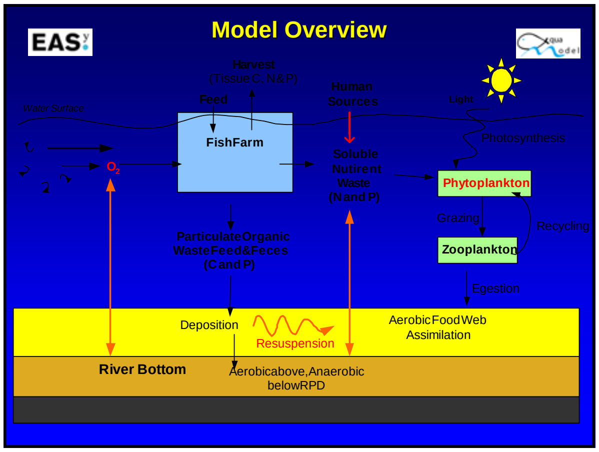

Fish Physiology Module
Harvest
(Tissue Carbon & Nitrogen)
Feed
Light
Sea Surface
FARM
Fish metabolism
Feces
O_2
Soluble Nitrogenous Waste
Advective & Turbulent Flow
Particulate Organic Waste
- Unique feature of AquaModel
- Growth, metabolism and waste production simulation
- We parameterized laboratory measurements to create a virtual fish population
- Carbon, oxygen and nutrient (N&P) based
- Linked with fish activity level, temperature, ration, etc.

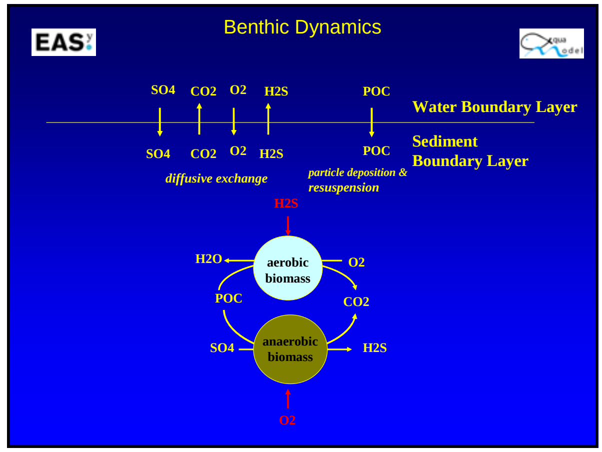

FEED INPUT 100%
carbon 44%
nitrogen 7.1%
phosphorus ~1%
Carbon, Phosphorus & Nitrogen
Mass Balance Salmon Farm Nutrient Flux
1 - 4% WASTED
RESPIRATION as CO_2
50% of consumed carbon
95% CONSUMED
RETENTION (harvest*)
20% of consumed carbon
50% of consumed nitrogen
30% of consumed phosphorus
FECES
30% of consumed carbon
12% of consumed nitrogen
48% of consumed phosphorus
EXCRETION
38% of consumed nitrogen
22% of consumed phosphorus
Carbon is mostly converted to CO_2 and fish flesh
It is main driver of sediment O_2 demand
Nitrogen is mostly retained in fish or loss as liquid
Phosphorus is minimal in feed but often not assimilated well, is associated with solid waste but fluxes into liquid phase (SRP)

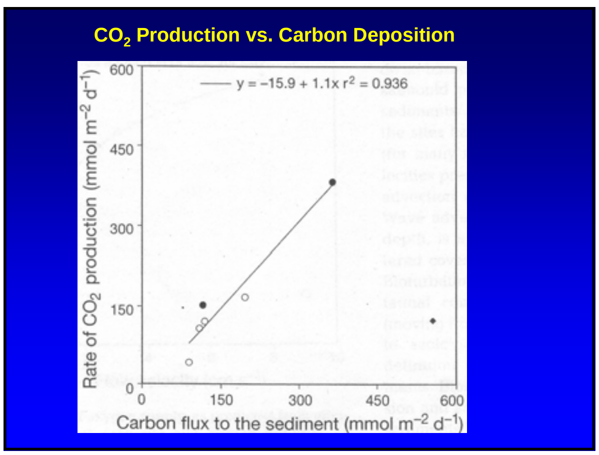

0.4
0.2
0
0
1

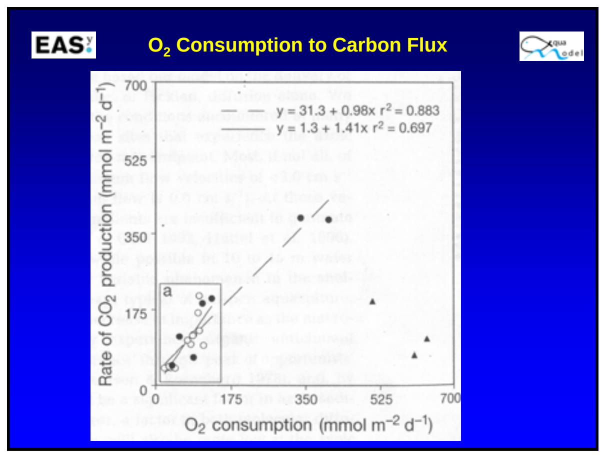

Mass Balance nutrient loading validation
12 sets of data
Transects
100' Sampling Stations
0' Sampling Station
Center Sampling Station
50' Sampling Station
Hard to measure DO effect by 30 m downstream
D.O. Anomaly (mg/L)
-0.3
-0.7
-1.1
-1.5
In Pen
6 m Downstream
30 m Downstream
Ambient
Ammonia & much less urea → NO_3
5.0
4.0
3.0
2.0
1.0
0.0
In Pen
6 m Downstream
30 m Downstream

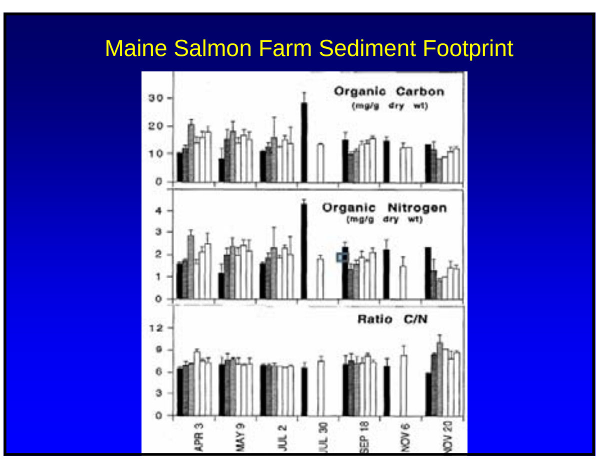

EAS
Fig.4A. Growth Rate Measured and Predicted
growth rate day
0.08
0.06
0.04
0.02
1000
2000
3000
4000
weight ,g











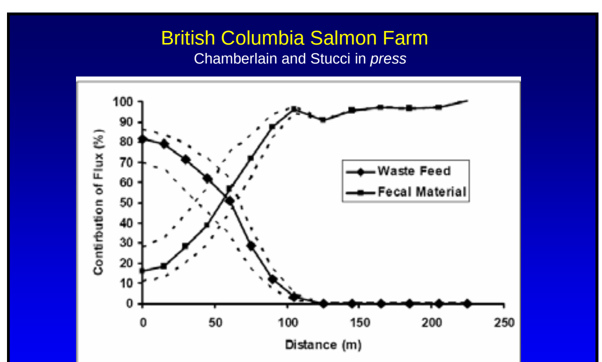
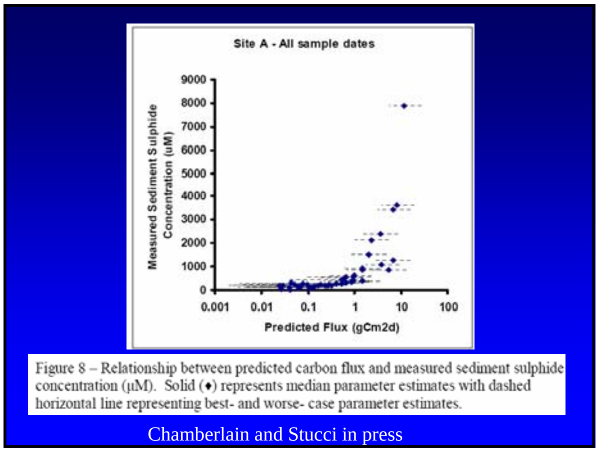
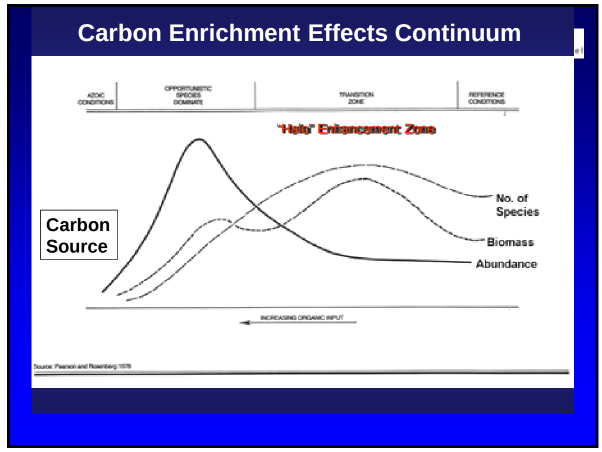
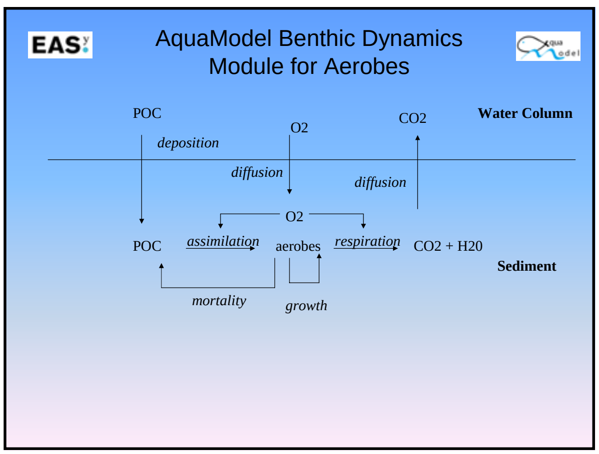
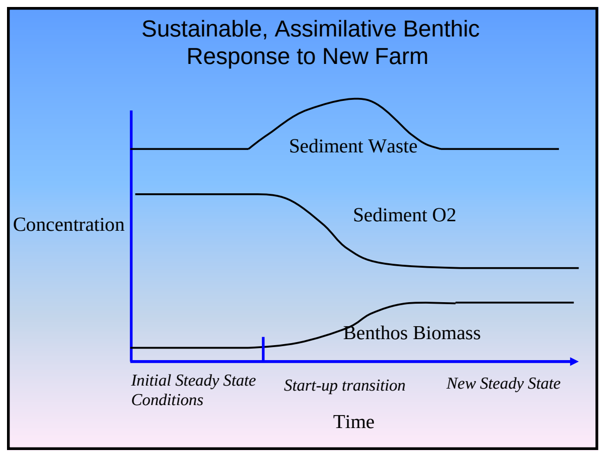


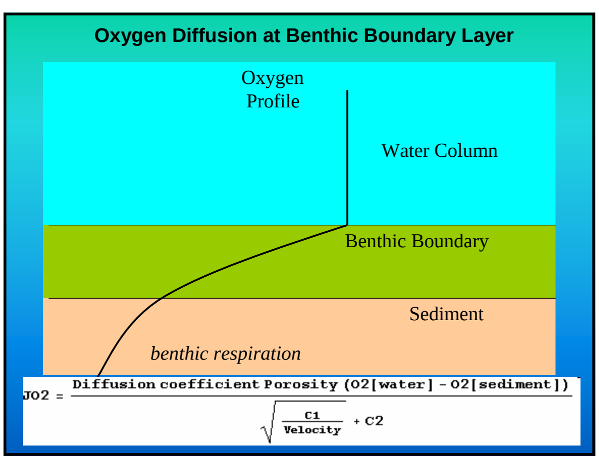
Figure 6 Percentage contribution of waste feed and fecal material to predicted flux at sample station locations for all time periods surveyed. (Solid line indicates median parameter estimates; Upper and lower dashed lines indicate best- and worse-case estimates respectively)

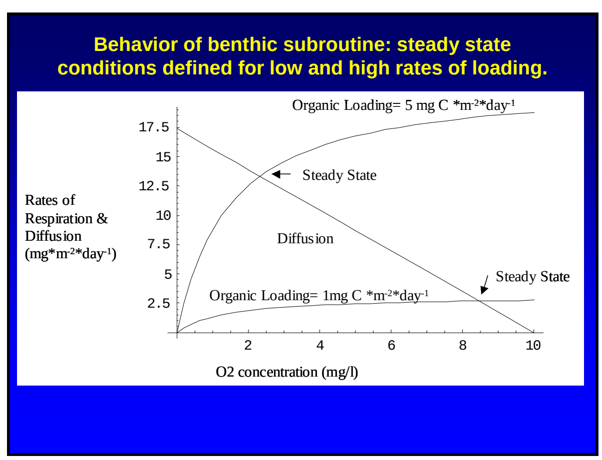

Site A - All sample dates
Measured Sediment Sulphide Concentration (uM)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0.001
0.01
0.1
1
10
100
Predicted Flux (gCm2d)
Figure 8 – Relationship between predicted carbon flux and measured sediment sulphide concentration (µM). Solid (♦) represents median parameter estimates with dashed horizontal line representing best- and worse- case parameter estimates.
Chamberlain and Stucci in press


Carbon Enrichment Effects Continuum
"Halo" Enhancement Zone
Carbon Source
No. of Species
Biomass
Abundance

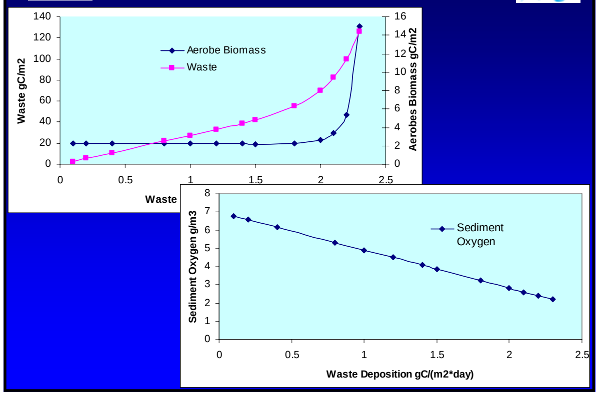

EAS
AquaModel Benthic Dynamics Module for Aerobes
POC
O2
CO2
Water Column
deposition
diffusion
diffusion
O2
POC
assimilation
aerobes
respiration
CO2 + H20
Sediment
mortality
growth


Sustainable, Assimilative Benthic Response to New Farm
Sediment Waste
Concentration
Sediment O2
Benthos Biomass
Initial Steady State Conditions
Start-up transition
New Steady State
Time


Oxygen Diffusion at Benthic Boundary Layer
Oxygen Profile
Water Column
Benthic Boundary
Sediment
benthic respiration
JO2 = Diffusion coefficient Porosity (O2[water] - O2[sediment]) / (sqrt(C1 / Velocity) + C2)


Behavior of benthic subroutine: steady state conditions defined for low and high rates of loading.
Organic Loading= 5 mg C *m-2*day-1
17.5
15
12.5
10
7.5
5
2.5
Steady State
Rates of Respiration & Diffusion (mg*m-2*day-1)
Diffusion
Steady State
Organic Loading= 1mg C *m-2*day-1
2
4
6
8
10
O2 concentration (mg/l)

Benthic Model Output



Simulations:

Southern California Bight AquaModel

Southern California Bight Depths & Currents

Google Earth Summary of Model Run

Summary

We have made an investment of our time to further the goal of offshore mariculture in California.

We believe we can use AquaModel to assess suitability of regions & perform preliminary site assessments

We invite discussion of how to do this, who would be collaborators and partners and how to best move forward

---

Funding

NOAA Office of Oceanic & Atmospheric Research

NOAA SBIR Program

USDA SBIR Program

Collaborators

Dr. Katsyuki Abo, National Research Institute of Aquaculture, Japan

Dr. Paul Olin, California Sea Grant

Mike Rust, NOAA Marine Fish Research Leader

Hubbs Seaworld Research Institute, San Diego

Troutlodge Inc. Western Washington

AGS Fish Farms, Inc. Puget Sound

Kona Blue Farms, Hawai'i

Cates International, O'ahu

Hawaii Dept. of Agriculture

Using GIS for Offshore Aquaculture Site Selection in the Gulf of Mexico

Jeff Rester
Gulf States Marine Fisheries Commission

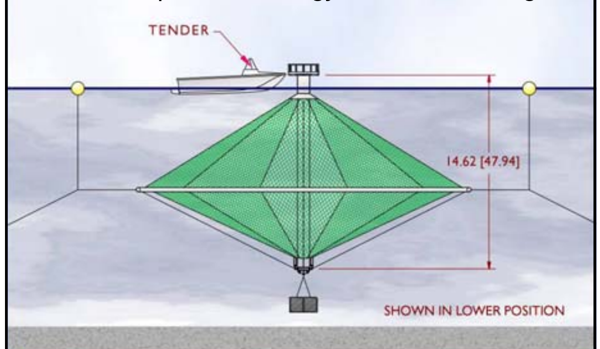
GIS

Geographical Information Systems (GIS) are integrated computer based systems which allow for the input of digital geo-referenced data to produce maps plus other textual, graphical and tabular output. The essential usefulness of GIS lies in its ability to manipulate data in a large number of ways and to perform various analytical functions so as to produce output which makes for more efficient decision making.

Why GIS for Site Selection?

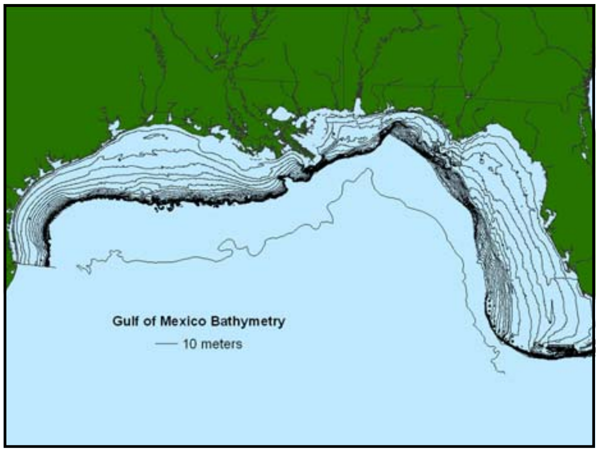
GIS can be used to explore relationships by querying data in different ways combining relevant data layers and exploring the possible relationships between them, using overlaying functions and more complex modeling structures. This allows exploration of model sensitivities and investigation of different scenarios, leading to optimization of site location, exploration of visual and environmental impacts and estimation of sustainable production benefits (Perez et al. 2005).

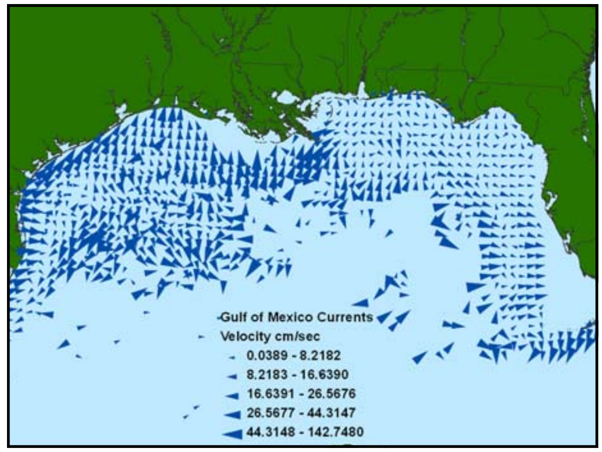
Ocean Spar Technology Sea Station Cage

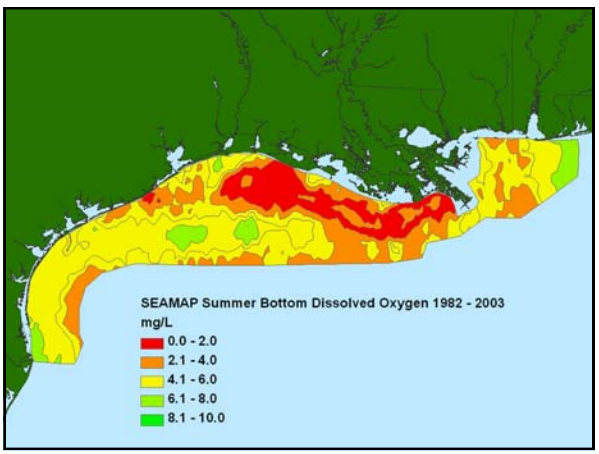


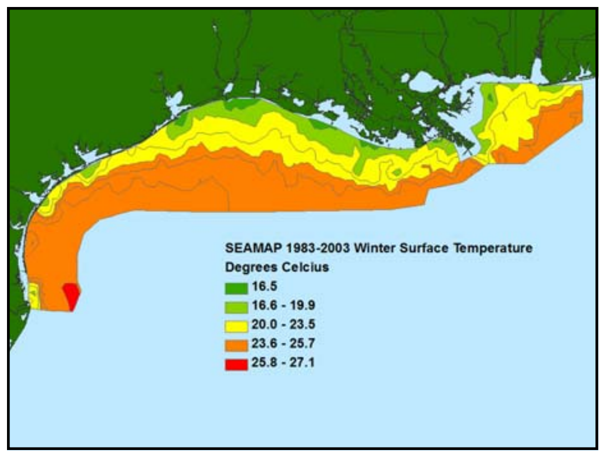
Site Selection Criteria

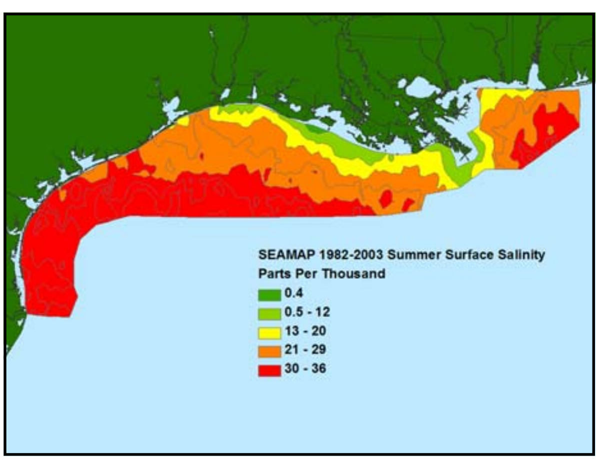
- Water Depth
- Currents
- Water Quality (dissolved O_2, temp, salinity)
- Sediment Distribution

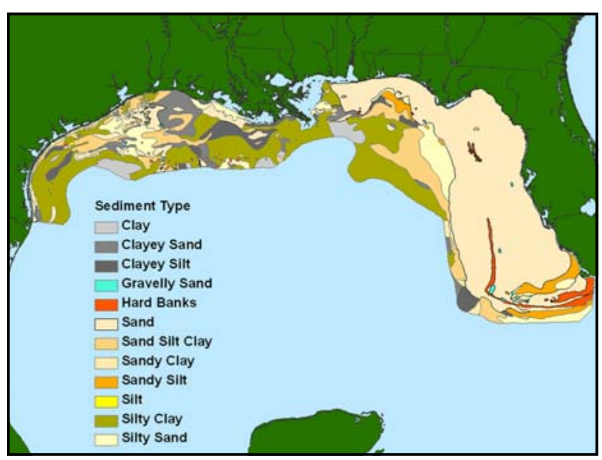

Gulf of Mexico Bathymetry
10 meters


Gulf of Mexico Currents
Velocity cm/sec
0.0389 - 8.2182
8.2183 - 16.6390
16.6391 - 26.5676
26.5677 - 44.3147
44.3148 - 142.7480


SEAMAP Summer Bottom Dissolved Oxygen 1982 - 2003
mg/L
0.0 - 2.0
2.1 - 4.0
4.1 - 6.0
6.1 - 8.0
8.1 - 10.0

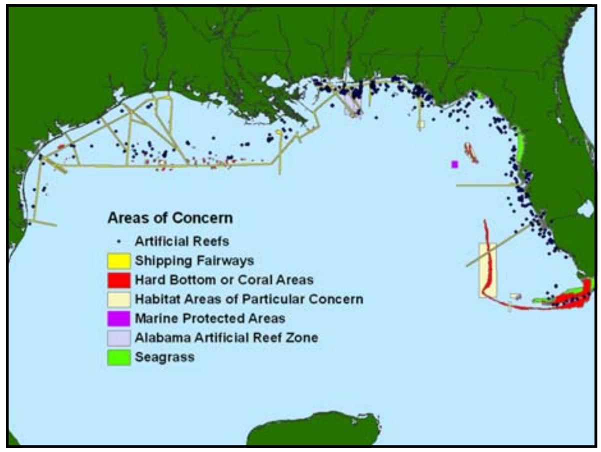

SEAMAP 1983-2003 Winter Surface Temperature
Degrees Celcius
16.5
16.6 - 19.9
20.0 - 23.5
23.6 - 25.7
25.8 - 27.1


SEAMAP 1982-2003 Summer Surface Salinity
Parts Per Thousand
0.4
0.5 - 12
13 - 20
21 - 29
30 - 36


Sediment Type
Clay
Clayey Sand
Clayey Silt
Gravelly Sand
Hard Banks
Sand
Sand Silt Clay
Sandy Clay
Sandy Silt
Silt
Silty Clay
Silty Sand

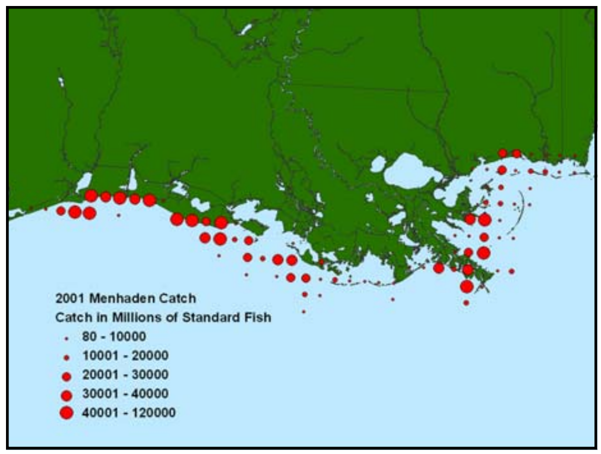
Site Selection Considerations

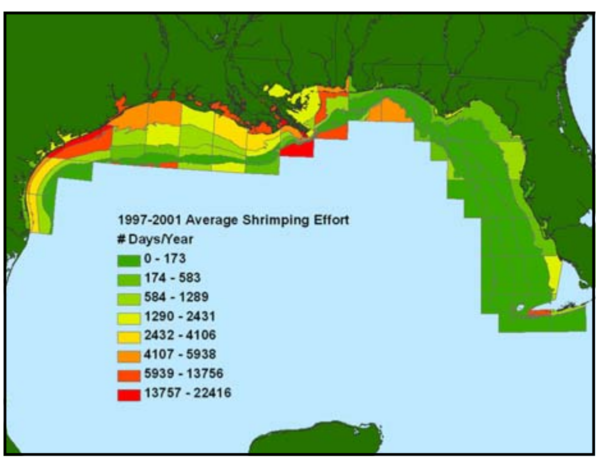
- Facility cannot be located within 1 mile of any shipping fairway
- Facility cannot be located within 1 mile of any artificial reef site
- Facility cannot be located within 5 miles of any marine protected area
- Facility cannot be located within 5 miles of any coral reef or hardbottom areas
- Facility cannot be located within 5 miles of any HAPC defined by the Gulf of Mexico Fishery Management Council
- Facility cannot be located within 5 miles of any seagrass areas

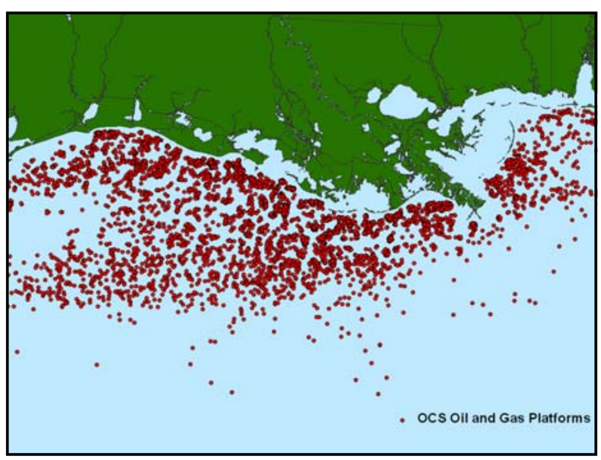


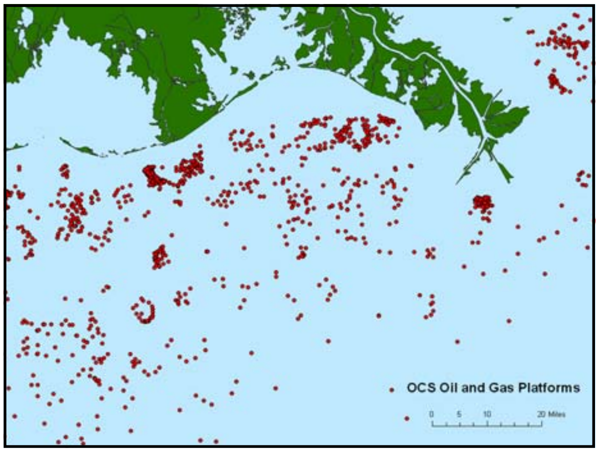
Site Selection Considerations

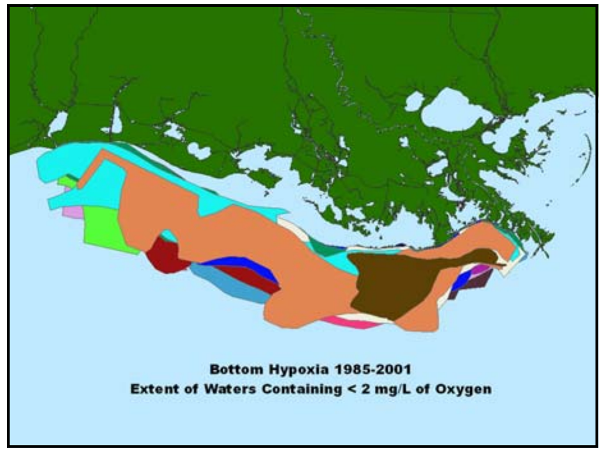
- Facility site should not conflict with traditional highly fished areas
- Facility should not conflict with other uses (oil and gas exploration, dredge disposal areas, military activity zones) of the outer continental shelf
- Might be advantageous for the facility to be collocated with an oil or gas platform
- Facility should not be located in areas that experience frequent hypoxia
- Facility should not be located in areas that experience frequent red tides

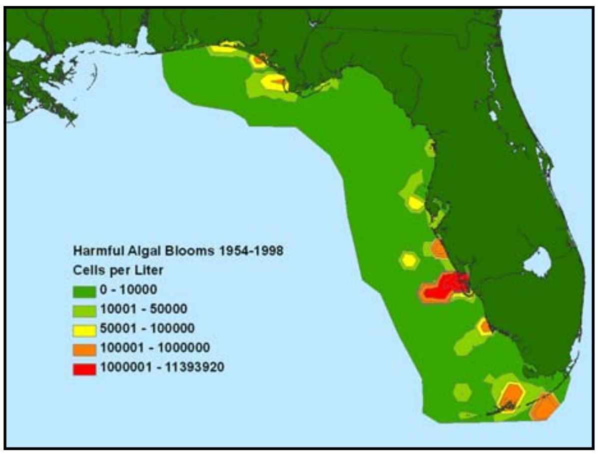






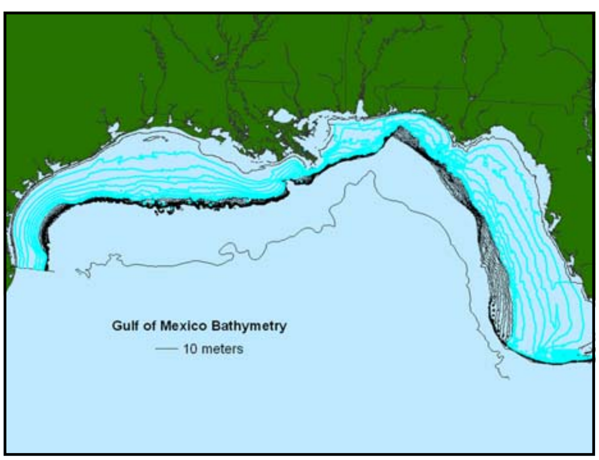


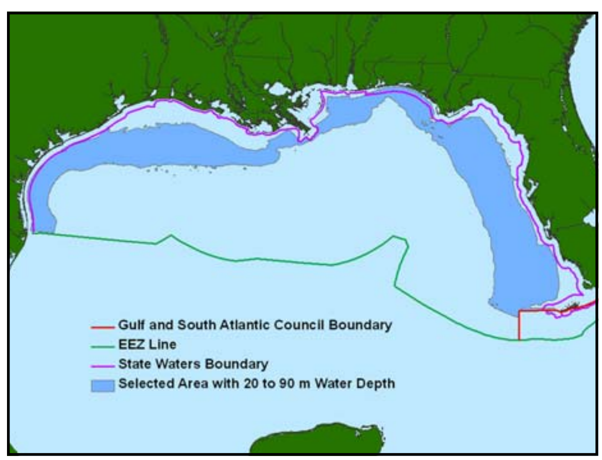




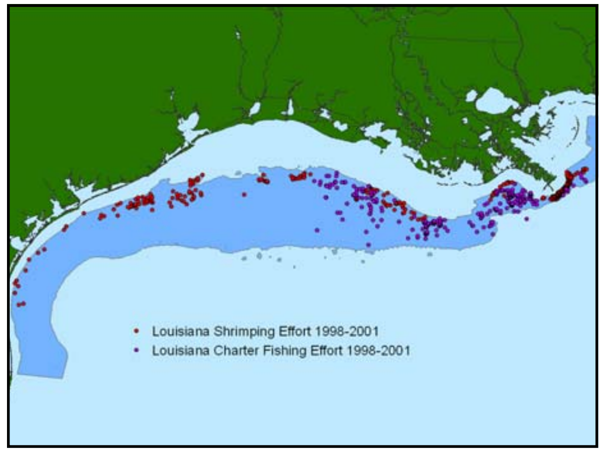
Other Considerations

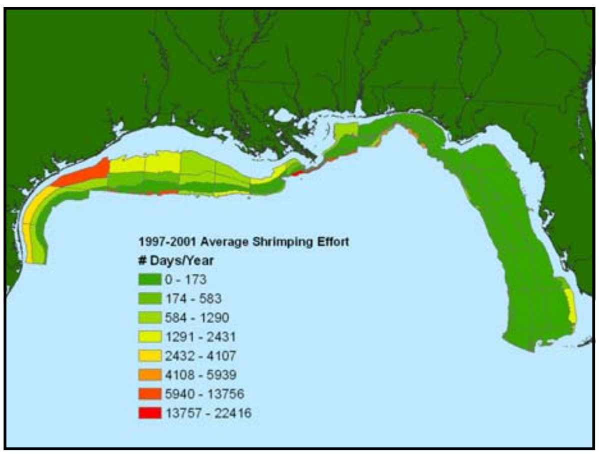
- For storms, half the cage should be halfway under the mid-depth of the water
- Need 30 feet of clearance underneath bottom of cage
- Need at least 0.5 knot current (1 knot = 0.514 m/s or 1.15 mph) to avoid anoxia or waste accumulation
- Sustained 2 knot current makes managing cages difficult
- Need at least 100 foot water depths

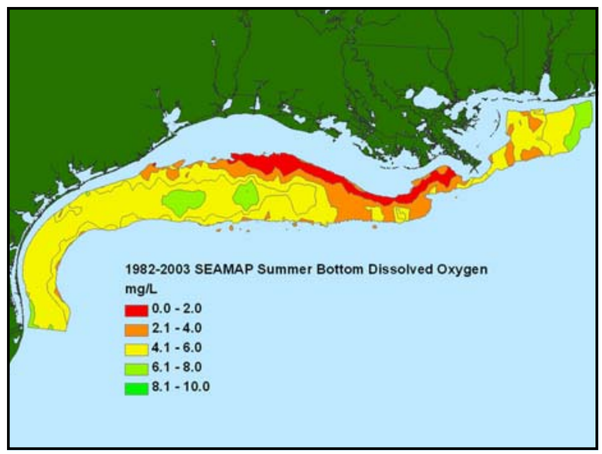


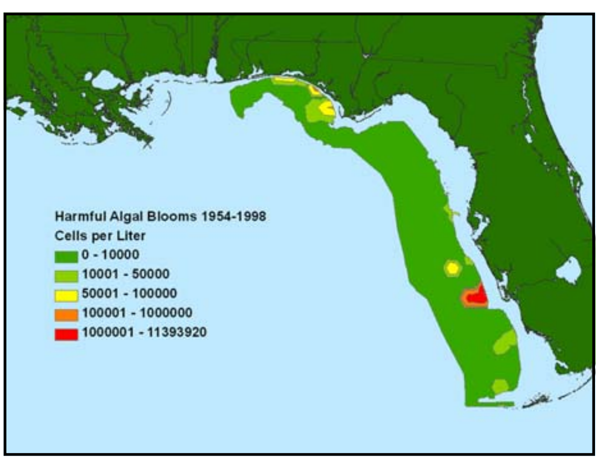


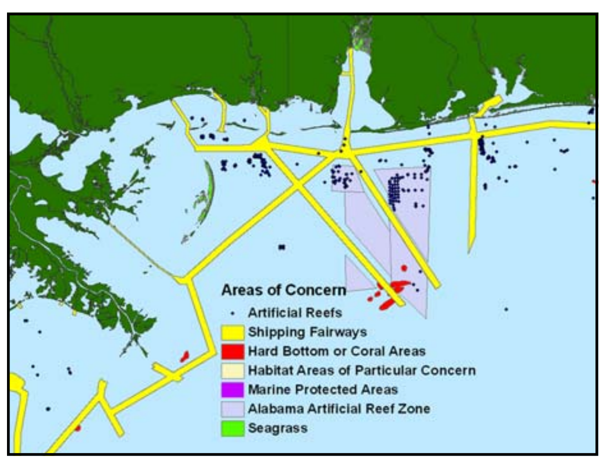

Sediment Type
Clay
Clayey Sand
Clayey Silt
Gravelly Sand
Hard Banks
Sand
Sand Silt Clay
Sandy Silt
Silt
Silty Clay
Silty Sand

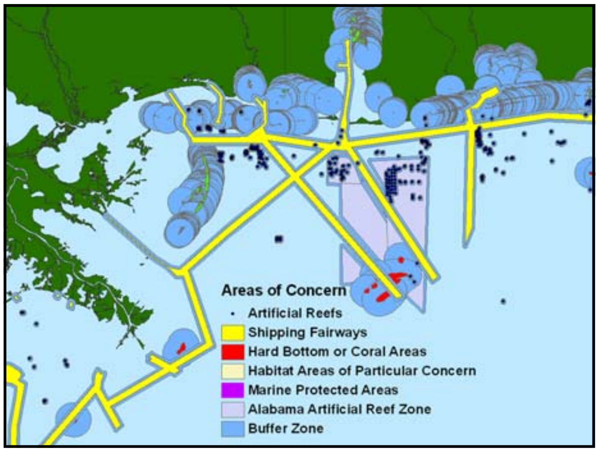

Louisiana Shrimping Effort 1998-2001
Louisiana Charter Fishing Effort 1998-2001

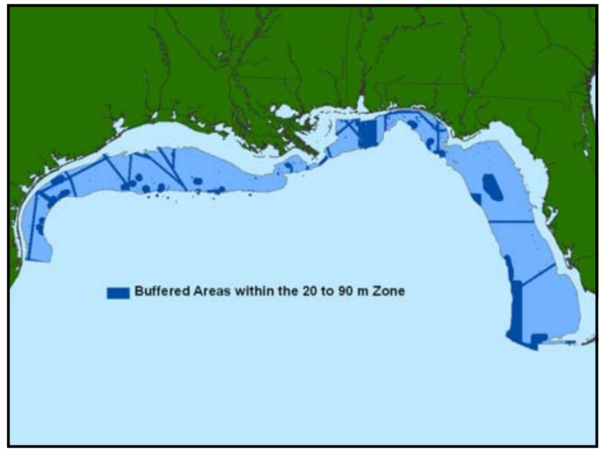

1997-2001 Average Shrimping Effort
Days/Year
0 - 173
174 - 583
584 - 1290
1291 - 2431
2432 - 4107
4108 - 5939
5940 - 13756
13757 - 22416

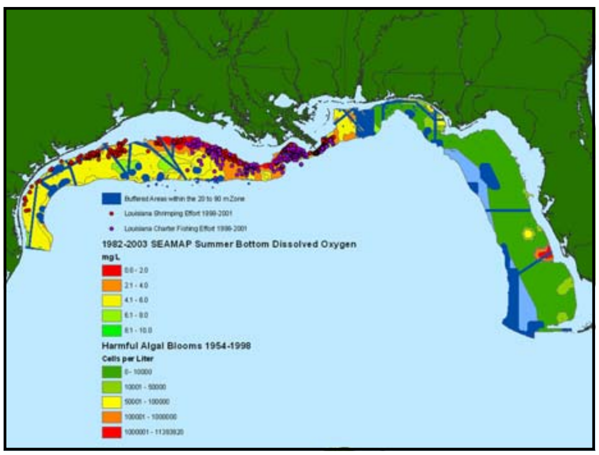

1982-2003 SEAMAP Summer Bottom Dissolved Oxygen
mg/L
0.0 - 2.0
2.1 - 4.0
4.1 - 6.0
6.1 - 8.0
8.1 - 10.0

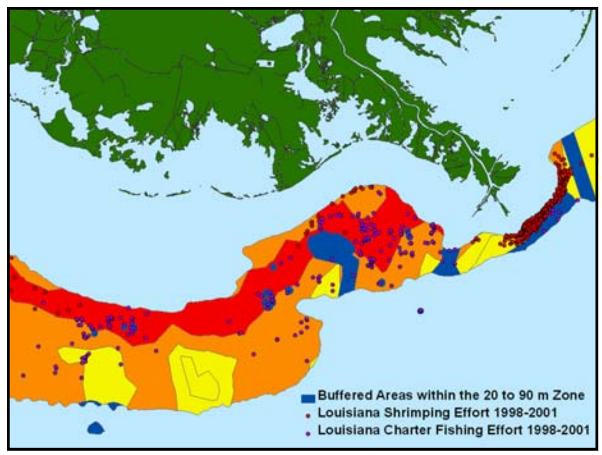

Harmful Algal Blooms 1954-1998
Cells per Liter
0 - 10000
10001 - 50000
50001 - 100000
100001 - 1000000
1000001 - 11393920


Areas of Concern
Artificial Reefs
Shipping Fairways
Hard Bottom or Coral Areas
Habitat Areas of Particular Concern
Marine Protected Areas
Alabama Artificial Reef Zone
Seagrass


Areas of Concern
Artificial Reefs
Shipping Fairways
Hard Bottom or Coral Areas
Habitat Areas of Particular Concern
Marine Protected Areas
Alabama Artificial Reef Zone
Buffer Zone


Buffered Areas within the 20 to 90 m Zone


1982-2003 SEAMAP Summer Bottom Dissolved Oxygen
Harmful Algal Blooms 1954-1998
Cells per Liter

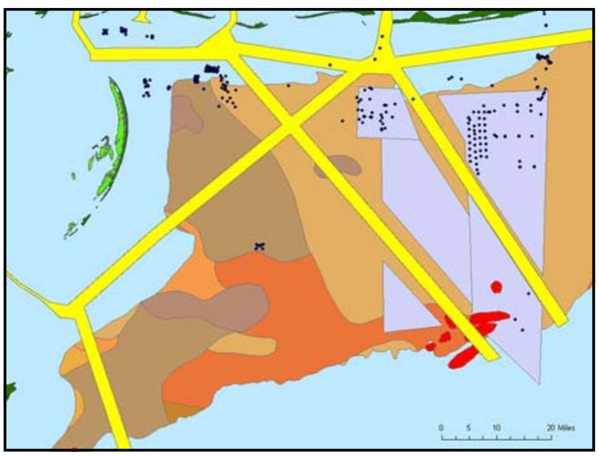

Buffered Areas within the 20 to 90 m Zone
Louisiana Shrimping Effort 1998-2001
Louisiana Charter Fishing Effort 1998-2001


0 5 10 20 Miles


0 5 10 20 Miles

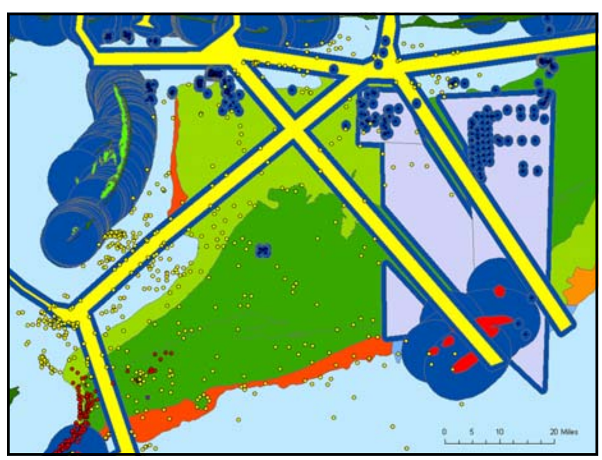

0 5 10 20 Miles

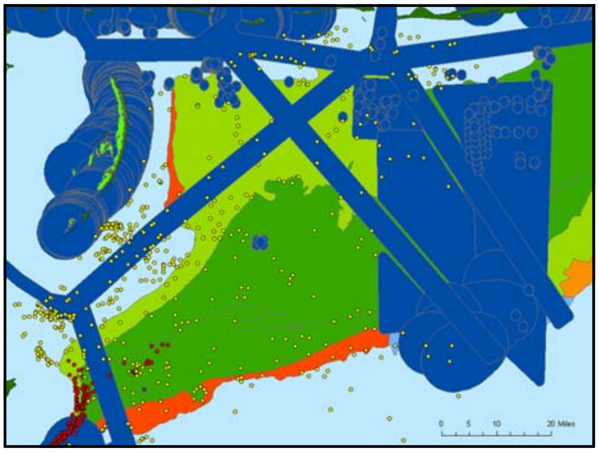

0 5 10 20 Miles


0 5 10 20 Miles


0 5 10 20 Miles


0 5 10 20 Miles


0 5 10 20 Miles



Conclusions

- A GIS can be used to help develop aquaculture zones in the Gulf of Mexico, but the GIS is only as good as the data in it
- Experts need to develop siting criteria guidelines to determine where aquaculture facilities should and should not be located
- Siting criteria can then be used in the GIS to help map areas suitable for offshore aquaculture

Appendix E

The full list of FGC (Fish and Game Commission) standards for submerged lands leases are listed below.

Environmental Factors Considered in Marine Finfish Aquaculture Management (S.B. 201)

(1) Appropriate areas for siting marine fin fish aquaculture operations to avoid adverse impacts, and minimize any unavoidable impacts, on user groups, public trust values, and the marine environment.
(2) The effects on sensitive ocean and coastal habitats.
(3) The effects on marine ecosystems, commercial and recreational fishing, and other important ocean uses.
(4) The effects on other plant and animal species, especially species protected or recovering under state and federal law.
(5) The effects of the use of chemical and biological products and pollutants and nutrient wastes on human health and the marine environment.
(6) The effects of interactions with marine mammals and birds.
(7) The cumulative effects of a number of similar fin fish aquaculture projects on the ability of the marine environment to support ecologically significant flora and fauna.
(8) The effects of feed, fish meal, and fish oil on marine ecosystems.
(9) The effects of escaped fish on wild fish stocks and the marine environment.
(10) The design of facilities and farming practices so as to avoid adverse environmental impacts, and to minimize any unavoidable impacts.

Standards for Fish and Game Commission Leases and Regulations (S.B. 201)

(1) The lease site is considered appropriate for marine fin fish aquaculture in the programmatic environmental impact report if prepared and approved by the commission pursuant to Section 15008.
(2) A lease shall not unreasonably interfere with fishing or other uses or public trust values, unreasonably disrupt wildlife and marine habitats, or unreasonably harm the ability of the marine environment to support ecologically significant flora and fauna. A lease shall not have significant adverse cumulative impacts.
(3) To reduce adverse effects on global ocean ecosystems, the use of fish meal and fish oil shall be minimized. Where feasible, alternatives to fish meal and fish oil, or fish meal and fish oil made from seafood harvesting byproducts, shall be utilized, taking into account factors that include, but need not be limited to, the nutritional needs of the fish being raised and the availability of alternative ingredients.
(4) Lessees shall establish best management practices, approved by the commission, for each lease site. Approved best management practices shall include a regular monitoring, reporting, and site inspection program that requires at least annual monitoring of lease sites to ensure that the operations are in compliance with best management practices related to fish disease, escapement, and environmental stewardship, and that operations are meeting the requirements of this section. The commission may remove fish stocks, close facilities, or terminate the lease if it finds that the lessee is not in compliance with best management practices, that the lessee's activities have damaged or are damaging the marine environment, or that the lessee is

not in compliance with this section. The commission shall take immediate remedial action to avoid or eliminate significant damage, or the threat of significant damage, to the marine environment.

(5) Before issuance of the lease, the lessee shall provide baseline benthic habitat and community assessments of the proposed lease site to the applicable regional water quality control board or the State Water Resources Control Board, and shall monitor the benthic habitat and community during the operation of the lease in a manner determined by the regional board or the State Water Resources Control Board. The regional board and the State Water Resources Control Board may establish and impose reasonable permit fees to pay for the costs of administering and conducting the assessment and monitoring program.

(6) Fin fish numbers and density shall be limited to what can be safely raised while protecting the marine environment, as specified by the terms of the lease, subject to review and amendment by the commission.

(7) The use of all drugs, chemicals, and antibiotics, and amounts used and applied, shall be minimized. All drugs, therapeutic substances, and antibiotics shall be used and applied only as approved by the United States Food and Drug Administration for marine fin fish aquaculture. The lessee shall report that use and application to the commission on a regular schedule, as determined by the commission, but no less than annually, that shall be included in the terms of the lease. The commission shall review those reports on a regular basis and at least annually.

(8) The commission shall require all farmed fish to be marked, tagged, or otherwise identified as belonging to the lessee in a manner determined appropriate by the commission, unless the commission determines that identifying farmed fish is unnecessary for protecting wild fish stocks, the marine environment, or other ocean uses.

(9) All facilities and operations shall be designed to prevent the escape of farmed fish into the marine environment and to withstand severe weather conditions and marine accidents. The lessee shall maintain records on all escapes in a manner determined by the commission. In the event of more than de minimis escapement, the number of escaped fish and the circumstances surrounding the incident shall be reported immediately to the commission, and the lessee shall be responsible for damages to the marine environment caused by those escaped fish, as determined by the commission.

(10) The lessee shall, at a minimum, meet all applicable requirements imposed by the State Water Resources Control Board and the regional water quality control boards, and shall prevent discharges to the maximum extent possible. Monitoring and testing of water quality shall be required on a regular basis as deemed appropriate by the State Water Resources Control Board or the regional water quality control boards. All inspection and monitoring reports and other records, and all data on the discharge of chemical and biological pollutants shall be kept on file and available for public review.

Appendix F

Open Ocean Aquaculture in the Santa Barbara Channel: An emerging challenge for the Channel Islands National Marine Sanctuary report's ten specific recommendations, excerpted and summarized below, stem from, and aim to actuate, a precautionary approach to open ocean aquaculture in the Santa Barbara Channel area surrounding the Channel Islands National Marine Sanctuary.

Rec. 1: In recognition of the ecological importance of coastal pelagic fisheries, and the increasing pressure a growing fin fish aquaculture industry will likely exert on these stocks locally and abroad, CINMS staff and stakeholders should support a minimization of wild fish inputs for proposed fish farm operations, whether as whole fish, or feed comprising fishmeal and fish oil ingredients, and advance disclosure of feed sources and impact analysis on feed production. In addition, CINMS should support research and sound management of California coastal pelagic species.

Rec. 2: Proposed farming of non-indigenous or genetically modified (GM) fish in the Santa Barbara Channel region should be rejected by CINMS resource managers and stakeholders. While certain theoretical genetic modifications could be considered precautionary (such as engineered infertility or disease resistance), tremendous uncertainty surrounds this technology and the potential impacts from genetically modified escapees interbreeding with Sanctuary-area wild stocks. Until more certainty exists, disallowing GM stocks remains the most precautionary and appropriate approach to protect Sanctuary resources and existing uses.

Rec. 3: To protect wild stocks from the spread of parasites and pathogens associated with commercial fish farming, CINMS stakeholders and resource managers should evaluate OOA facility proposals with specific, science based criteria for the maximization of the health of farmed fish, and the minimization of potential for the facilities to act as pathogen and parasite incubators.

Rec. 4: a) CINMS resource managers and stakeholders should support the array of aquaculture approaches that minimize water quality degradation from untreated discharges often associated with fish farming. These include use of closed systems, cultivation of shellfish and integrated polycultures rather than fin fish, use of plant based, rather than fish or animal-byproduct based feeds, abstaining from use of chemical pesticides and pharmaceuticals, and deliberate siting in areas of oceanographically high pollution absorption capacity and low habitat value. b) CINMS staff should require that during environmental review, fish farm applicants 1) demonstrate that fish farm discharges won't impair CINMS water quality, and 2) analyze and disclose potential cumulative impacts to CINMS-area resources from fish farm proliferation and other factors.

Rec. 5: Best available technologies and deliberate siting of aquaculture facilities should be required to minimize entanglement, migration disruption, attraction, and habitat abandonment, that fish farms are documented to cause among marine wildlife.

Rec. 6: In line with the recommendations outlined by the WHOI Marine Aquaculture Task Force, CINMS stakeholders and staff should be resolved that any future aquaculture facilities in the Santa Barbara Channel region be sited deliberately, based on specific, science-based criteria, and robust data demonstrating that the chosen location is optimal for avoiding or minimizing adverse effects on Channel and Sanctuary resources and uses, rather than sited opportunistically based solely on the existence of useful infrastructure.

Rec. 7: CINMS staff and stakeholders should actively participate in federal policy development and rulemaking on aquaculture, and leverage existing research and policy recommendations to influence these federal processes to ensure protection of natural resources, existing uses, and goals of the local Sanctuary management and the National Marine Sanctuary Program.

Rec. 8: To protect resources under NMSP jurisdiction from potentially deleterious aquaculture practices within and around CINMS boundaries, CINMS staff should adopt the Sanctuary regulatory updates comprising Proposed Actions 3, 4, and 12 of the Draft Management Plan/Draft Environmental Impact Statement

Rec. 9: CINMS staff and stakeholders should formally acknowledge California's current leadership in marine fin fish aquaculture management, support and leverage the State's existing standards for aquaculture siting, operations, and reclamation, and, in the absence of a federal framework, generally encourage extension of the state's standards and policies as established by the Sustainable Oceans Act into the federal waters of the EEZ.

Rec. 10: To best ensure that Sanctuary regulations are upheld and its natural resources and existing uses protected, CINMS staff should participate, consult and comment *directly* in the permitting processes for any future Santa Barbara Channel region aquaculture facility proposals, rather than as a subsumed member of NOAA. Concurrently, the SAC should uphold its general mandate by reviewing application materials for future fin fish aquaculture proposals and formally advising CINMS staff on the Council members' findings and concerns.

Commercialization of White Seabass Aquaculture, Pilot Program Out-Grow to Market

Saltonstall-Kennedy
Final Report
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Abstract

The culture potential of white seabass (*Atractoscion nobilis*) has been under investigation for more than fifteen years, as part of an experimental stock enhancement program in southern California. The purpose of this project was to determine if cage culture technologies could be adapted to grow white seabass to a marketable size in an offshore, semi-exposed location. The project was also designed to evaluate the marketability of sub-adult, farm-raised white seabass, and to tag and release a portion of the fish into the ocean. The results of this study suggest that cage culture of white seabass is technologically, biologically, and economically feasible on a large scale and in a semi-exposed location. Additional research is required to test the economic model developed in this study. To do this, an offshore location will need to be identified where economies of scale can be achieved. Here, in addition to the technical challenges associated with severe weather conditions, researchers will have to overcome previously uncharted regulatory concerns and potential user conflicts.

Executive Summary

The culture potential of white seabass (*Atractoscion nobilis*) has been under investigation for more than fifteen years, as part of an experimental stock enhancement program in southern California. The purpose of this project was to determine if cage culture technologies could be adapted to grow white seabass to a marketable size in an offshore, semi-exposed location. The project was also designed to evaluate the marketability of subadult, farm-raised white seabass, and to tag and release a portion of the fish into the ocean.

The results of this study demonstrate that white seabass are biologically well suited for cage culture. A survival rate of greater than 95% was attained during the study period of sixteen months. Fish health was generally good, with only a mild outbreak of gill flukes requiring treatment. Fish grew from approximately 40 to 720g, which was slower than desired but to be expected due to the cold water ("La Niña") oceanographic conditions. Fish were harvested at a final density of 12.3kg/cubic meter.

Farm-raised white seabass received good reviews from industry professionals when rated for appearance, taste, texture, freshness, and ease of processing. When asked how much they would be willing to pay per kg of whole fish and how many kg per week they would purchase, local wholesaler responses ranged from \$4.40-\$6.60 per kg and 23-2,270 kg per week, respectively.

An economic model was developed using observed biological values (e.g. growth, conversion) and operating expenses (e.g. labor, food, capital) to estimate costs, and market responses to estimate revenues. Using an annual production of 230mt as a starting point, our model predicts a 19-59% return on an initial capital investment of approximately \$600,000 and annual operating budget of approximately \$1.16 million U.S.

Additional research is required to test the economic model developed here. The next phase of research will undoubtedly involve site identification and permitting for an exposed, offshore location where economies of scale can be achieved.

Purpose

Statement of the problem

White seabass has a high commercial and recreational value, and strong name recognition in the California seafood industry. Since 1984, California has had an experimental enhancement program that, along with other management measures, is intended to aid in the restoration of the white seabass stock. This program was greatly expanded in 1995 with the completion of a production scale hatchery operated by Hubbs-Sea World Research Institute (H-SWRI) under contract to the California Department of Fish and Game (CDF&G).

Since 1990, volunteer groups have been operating small-scale growout facilities along the southern California coast in which newly weaned and tagged (coded wire tags) fingerlings are raised for release. However, there have been no attempts to carry the technical work further and evaluate the feasibility of farming white seabass commercially.

The impediments to expanding the marine aquaculture industry in California are many. Entrepreneurs (i.e., potential aquaculture industry investors) are unwilling to risk the large sums necessary to obtain permits and to develop the culture knowledge, risk factors and solid financial feasibility details required to justify the development of white seabass farming. Thus, Saltonstall-Kennedy funding was requested to compliment other support to establish and operate a demonstration farm using “salmon style” cages modified for the study area and biological requirements of white seabass.

Goals and objectives

The **primary** goal of the project was to evaluate the feasibility of growing white seabass (*Atractoscion nobilis*) in semi-exposed net cages and to determine their marketability. (This project builds upon established hatchery production and fingerling growout for marine enhancement.)

The primary goal was to be accomplished through completion of the following objectives:

1) Evaluate and implement cage culture operations that promote the economically effective growout of healthy and vigorous fish;
2) Quantify technical and economic factors for full-scale commercial production in definitive terms;
3) Involve key agency personnel so they understand the nature of marine fish farming and thereby lessen agency obstacles in obtaining permits for large scale farms;
4) Produce a farm manual and economic feasibility report;
5) Conduct the project in a manner that will avoid any significant environmental impacts resulting from operation of cage rearing facilities; and
6) Evaluate the potential market for various size classes of cultured fish by selling to wholesalers, restaurants and live fish markets, and producing a market analysis.

The **secondary** goal of the project (and a requirement to obtain fingerlings from the state) was the production of 200mm (TL) white seabass for enhancement.

Approach

Species selection and biology

Taxonomy and description

The white seabass (*Atractoscion nobilis*) is the largest member of the family sciaenidae living along the Pacific coast of North America. The adults have blue-gray dorsal surface and silver underbelly while in the water. Freshly harvested fish exhibit a beautiful purple iridescence that is often observed along the dorsal surface. Younger fish often have several dark vertical bars.

Distribution and abundance

Historically, white seabass have been found from Magdelena Bay in Baja California Mexico to Juneau, Alaska. In recent years their northern distribution has been significantly reduced north of Point Conception. In California, white seabass are caught primarily during the spring and summer months.

Biology

White seabass grow as large as 40.8kg in weight and may reach 1.5m in length. These fish are believed to live 20-30 years. Sexual maturity is reached in 3.5-4.5 years. Spawning occurs in the spring and females are capable of spawning multiple times in one season. Depending on the size of the female, 0.4-1.5 million eggs may be released per spawn. White seabass eggs are pelagic, approximately 1.2mm in diameter, and hatch within two days at 17°C.

White seabass are piscivorous, schooling fish that typically inhabit nearshore coastal waters.

Diseases and disease control

Among the more common infectious diseases affecting white seabass are (1) protozoans, primarily *Costia sp*., *Uronema sp*., *Hexamita sp*., *Cryptocaryon irritans*; (2) bacteria, primarily *Flexibacter maritimus*; and (3) invertebrate parasites, primarily monogenean trematodes. Among these pathogens, *F. maritimus* is the most common and difficult to eradicate. Infections by this organism occur frequently after handling the fish and may result in lesions and fin rot. Among the non-infectious diseases, gas bubble disease is often severe in shallow water systems that are not adequately degassed, including floating raceways in natural water bodies.

Avoiding disease through good practices of stress management is the preferred disease control technique. In the event of a disease outbreak several chemical treatments are available. The only drug approved by the FDA is formalin. Others such as copper sulfate ($CuSO_4$), and hydrogen peroxide (H_2O_2), fall into the FDA's category of low regulatory priority substances. The antibiotic "Romet B" is available through veterinary prescription. The efficacy of the antibiotic oxytetracycline as a feed additive and chloramine "T" are also being evaluated by H-SWRI under the federal government's Investigational New Animal Drug (INAD) program.

Aquaculture potential

The white seabass has been the focus of aquaculture research for nearly 20 years. To date, interest in this species has centered on stocking juveniles into the ocean. The white seabass was selected as the primary candidate for stock enhancement because the species was (1) endemic to the area; (2) depleted; (3) highly valued by sport and commercial fishers; and (4) closely related to other species (i.e. red drum) being successfully cultured in other regions.

Many of the selection criteria used to evaluate species for stocking are relevant to selecting new species for commercial farming trials. Because white seabass are endemic to the area, they should be well suited to the environmental conditions that they will be exposed to in the cages. The depleted status of wild populations, coupled with its value as food fish, suggests that farm-raised animals may be highly desirable, especially when wild fish are unavailable.

Laboratory spawning of white seabass was first successful in 1982. Since that time the culture techniques for mass production of fingerlings have largely been developed. Larval and early juvenile rearing is conducted in land based systems (flow-through and recirculating) and juvenile growout is conducted in cages. While most fish are released at a size of approximately 80g, one group was cultured in a raceway for more than two years, reaching a final size of 1.56kg at 25.7 months.

Site selection and permitting

Our criteria for selecting a site for this project included (1) excellent water quality with adequate depth (>12m); (2) good infrastructure support; (3) minimal user conflicts; and (4) minimal permitting requirements. Based on these criteria, a site was selected at the entrance to Catalina Harbor, on the northwest side of Catalina Island (Figure 1). By siting the project within an existing mooring lease area, user conflicts were negligible and permitting requirements were reduced – specifically those typically required by the U.S. Army Corps of Engineers and the U.S. Coast Guard. Within the mooring lease area, we selected a location at the extreme southern edge where boat traffic and anchorage was infrequent except during holiday weekends. Water depth at this location was 15-18m. The site was protected on three sides by the Island relief, with full exposure only from the south.

Figure 1. Aerial photographs of site selected for the cage system.

Because the project location at Catalina Island was on a water site maintained and operated by collaborative organizations (Catalina Island Company and Doug Bombard Enterprises), local permits or approvals were not difficult to obtain. The project applied to the **California State Lands Commission** for approval of a "new" use for the Catalina Island Company/Doug Bombard Enterprises leasehold. The existing cage systems, operated by the volunteer angler groups, require only a permit from the **California Coastal Commission (CCC)**. A facilitated permit process previously approved by the Commission allowed for the immediate installation of another cage system at Catalina Island provided that monitoring and reporting criteria for the existing enhancement program were met. The **California Department of Fish and Game (CDFG)** had already authorized the installation of the proposed cage system. A letter of permission was required and obtained from the U.S. Army Corps of Engineers to moor the cages in a navigable waterway.

System design and construction

Cages

The cages used in this study were selected because of their solid performance history relative to cost. The performance standards were adjusted to reflect the semi-exposed nature of the site. The design criteria also reflected the research-nature of the project, where adequate platforms for observation were desirable. The system consisted of four separate cages 10x10x7m deep each. The cages were affixed to a central walkway (2.1x26.4m), resulting in a total system footprint of approximately 700 square meters. In addition to the central walkway, a 0.8m wide walkway encompassed each cage. The cages and central walkway pontoons were constructed of 25cm diameter polyethylene. Styrofoam plugs were placed inside the pipe to ensure buoyancy should leaks occur. All joints and end caps were fused together. Walkways were constructed using stainless steel hardware and marine grade pressure treated lumber (Figure 2).

Both fish containment nets and predator nets were suspended from the handrails of each cage. The handrails extended around each cage on either side of the walkways and were elevated

Figure 2. Construction of cages.

approximately 1m above the water line. The containment net was suspended on the inside handrail and the predator net was hung from the outside handrail. This configuration effectively eliminated the risk of fish jumping out or predators jumping in. Each predator net encompassed a single containment net so each cage could function independently from the others if there was a desire to move one or more of them to another location.

Two different mesh sizes were selected for the containment nets - one to accommodate the size of fish at stocking and a larger mesh for harvest-size fish. Confusion with the net manufacturer resulted in the shipment of nets with smaller mesh panels than desirable. Instead of receiving 1.3 and 2.5cm block netting, we received netting with 0.6 and 1.3cm mesh. In order to keep the project on schedule, we had to utilize the fine mesh nets. The smaller mesh allowed us to experiment with stocking smaller fish but also increased the rate of fouling and associated frequency of net changes. The predator nets were constructed of 6.3cm block mesh panels.

Both sets of nets were weighted using plastic jugs filled with gravel. Attachment rings were conveniently located along the perimeter of each net and in the center. The amount of weight was adjusted as needed by adding or removing jugs to the nets.

Mooring

The cages were moored using pairs of Danforth anchors on each end of the system. The cages were oriented toward the south where the harbor entrance allowed full exposure to the ocean swell. The forward Danforths were 227kg each while the stern anchors were 136kg each. A combination of chain (1.9 and 3.2cm) and heavy line (2.5cm) extended from the anchors to a mooring buoy. A single line was then extended from each mooring buoy to a double line harness attached to the cage on the outer side and the central platform on the inside (Figure 3).

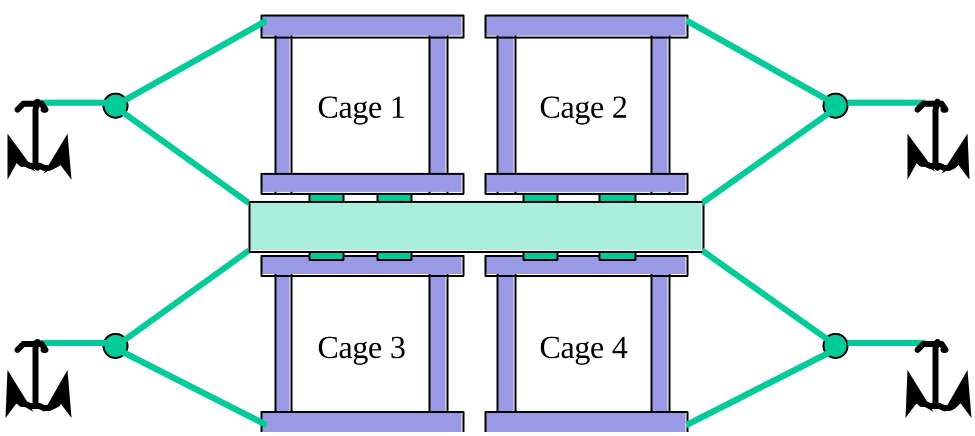

Figure 3. Mooring diagram for (4) cage system.

Fish transport and stocking

Two groups of fish were transported to the cages on the same date. The first group consisted of more than 20,300 juveniles with an average weight of 2.5g (77 d). The second group was older (169d) and larger (39.4g) but fewer in number (12,600). Both groups of fish were delivered by truck to a nearby harbor where they were sluiced by gravity into separate holding wells on board a commercial bait-hauling vessel. The fish were then transported directly to the cages. The two groups of fish were stocked into two separate cages using the same technique used to offload baitfish. A knotless mesh seine was used to crowd fish to the surface where they were again sluiced out a pipe into the cages (Figure 4).

Figure 4. Fish transport to the cages.

Operational considerations

Food shipment and storage

Food was shipped to the island using a variety of means, including both commercial and non-commercial support vessels. Once on the island, the food was stored in a non-insulated shed at Wells Beach. Small food storage containers (200L) were also available on the cage platform. Food was loaded from the storage shed, into a truck, and then into a small skiff for delivery to the cages once or twice each week.

Biofouling and net changes

In order to maintain good water exchange through the cages, containment nets were rotated as needed - generally every six weeks. This was accomplished by stitching one side of the fouled net to the corresponding side of the clean net. Once the nets were attached, the old net was pulled out from under the fish and the fish swam into the clean net. The two nets were then detached and the fouled net left to dry. Predator nets were not cleaned during the course of this study because they were more difficult to access and no replacement nets were purchased.

Security and predators

A technician who lived aboard his own private sailing vessel provided on-site security. The vessel was moored to the cages except during infrequent but severe weather conditions, when it was moved further into the harbor for shelter. Additional security was provided by the local harbor patrol.

Potential fish and mammalian predators were controlled by encircling each fish containment net with a heavy gage predator net. The predator net extended well above (1m) the water line. Avian predators were excluded by stretching a net across the top of each cage and marking them with brightly colored ribbons. All nets were checked routinely for holes or signs of wear.

Routine maintenance

Surface and subsurface (SCUBA) surveys were conducted at least once per week to evaluate the structural integrity of the cages, mooring, and nets. Regular maintenance was also required to keep the truck and skiff operational for moving food and personnel.

Culture

Water quality

Critical water quality parameters were monitored routinely. Water temperature, salinity and dissolved oxygen were recorded several times per week using a portable electronic meter (YSI model 85, see Appendix A). Water temperature was also logged continuously using a data logger (Onset Computer, data shown in Figure 9).

Food and feeding

Fish were fed by hand to satiation twice per day. Feeding periods were adjusted to match activity patterns that occurred at dawn and dusk. The feed used throughout the study was a commercially available, (Marine Grower, Moore-Clark, Inc.) extruded, sinking pellet ranging in size from 2.5-8.0mm. The diet was formulated to contain 50% protein and 14% fat.

Growth and yield

At intervals of approximately six weeks, a subsample of fish from each group was anesthetized using MS-222 and weighed and measured (Figure 5). The length of each fish was measured to the nearest 1.0mm. Whenever possible, fish were weighed individually. Because the floating platform was generally unstable, bench-type scales did not function accurately and so batch weights were taken using a hanging scale. Weights were measured to the highest accuracy possible under the prevailing conditions. This was $\pm$0.1-1.0g for individual weights and $\pm$28g for the batch weights.

Figure 5. Weighing and measuring juveniles.

Estimates of yield were obtained by processing fish and weighing selected body parts separately. This was performed by our staff and also by some of the commercial processors.

Health and survival

The number of mortalities was counted each week. This number was then deducted from the estimated number of fish stocked into each cage to estimate the weekly population level. At the end of the study, all remaining fish were counted and this final number was compared with the expected number remaining based on weekly patterns of mortality.

The health of the fish was monitored routinely by visual inspection and interpretation of behavior. Visual inspections were performed during diving surveys and also during subsampling for growth measurements. If patterns of behavior (i.e. reduced feeding) suggested health problems, subsamples of fish were collected using a net and examined more closely.

Fish tagging and harvesting

Fish were harvested for market surveys as needed. Generally these fish were put directly on ice and transported in coolers. Occasionally, fish were transported live to the hatchery and then harvested as needed from pools. Fish harvested for market were tagged individually using numerically coded operculum tags (Ketchum Mfg.) for live fish. Records of the fish codes, numbers of fish, delivery date and destination were recorded for all fish and copies sent to local Department of Fish and Game enforcement agencies.

At the termination of this study, fish not needed for market studies were anesthetized and sorted for tagging prior to their release (Figure 6). Fish not suited for release were placed in small isolation nets within the larger containment nets. The reason fish were rejected for release was recorded for all fish examined (See Health and Survival Section). The remaining fish were tagged using coded wire tags and released (Figure 6).

Figure 6. Tagging fish for release.

Market survey

In order to evaluate the marketability of farm-raised white seabass, several taste-testing events were organized for the public. In addition, samples of fish were provided to local wholesale and retail establishments for evaluation by their staff and patrons. Survey forms were handed out with the samples in an attempt to gather information of a consistent format. All fish were supplied whole and on ice (Figure 7).

Figure 7. Harvesting and test marketing.

Technical Findings

Accomplishments

Site selection and permitting

The site selected for this study worked well from a technical standpoint. Water quality and depth were more than adequate resulting in production of healthy, vigorous fish. Several severe storms "tested" the integrity of the system but in general the site remained calm. The permitting process, well streamlined from our stock enhancement program, was relatively short.

System design and construction

Technically, the cage and mooring system performed as designed for the site selected. Severe weather during the first quarter after its deployment challenged the structural integrity of the system, but the system held together well. Damage that did occur was restricted to the rigid wooden walk platforms.

Several modifications to the mooring system were required after the first spring. The forward mooring buoys were replaced with larger ones to prevent them from submerging during high-velocity current conditions. Strings of marker buoys were extended on the surface from the mooring buoys to the cages to reduce the likelihood of boats maneuvering between the two and getting entangled in subsurface mooring lines. The eastern-most stern anchor was repositioned after it moved under the strain created by severe wind conditions from the east (Santa Anas).

Operational considerations

Predator control and security systems worked well. The only breach in security occurred when a harbor seal learned how to get through the predator net to feed on larger, wild fish that were trapped between the predator and containment nets. This situation was corrected by re-stitching the gaps in the net and discouraging the harbor seal from returning.

Biofouling of the containment nets was a manageable problem during the course of this study. By changing the nets periodically good water exchange was permitted. Fouling could have been reduced further in the latter stages of the study if nets with larger mesh sizes were purchased. No contingency was made to manage biofouling of the predator nets, and by the end of the study, this was a significant problem (Figure 8; see below).

Figure 8. Biofouling of nets.

Significant problems

By the end of the study, biofouling of predator nets was so severe on some of the cages that the buoyancy of the cages was in jeopardy. Net cleaning was difficult because of the large surface area of the predator nets, and the lack of replacement nets or a net cleaner. The mooring lines also passed through the mesh of the predator nets where they were attached to the pontoons. This further hampered any attempt to exchange nets. This problem could be rectified by implementing one or more of the following (1) using mesh of larger size since only marine mammals were identified as serious threats; (2) having a replacement net available and improved ability to exchange them; (3) using a commercially available net cleaner[1;] or (4) moving fish from one cage to another so that both sets of fouled nets (containment and predator) could be removed and cleaned[2].

Recommendations for additional work

The most obvious need for additional work would be to attempt to repeat this study in a

[1] Net cleaners would need to be evaluated since they may not be effective against a surface that is not taut.

fully exposed environment testing the efficacy (structural and operational) of different but appropriately designed systems. Semi-exposed sites such as that used in this study are rare in southern California, and not well suited for expansion to commercial scale. Systems tested under conditions of full exposure should include both surface and subsurface designs with special attention given to control of biofouling, and methods of feeding and feed monitoring.

Any evaluation in a more exposed location would also lead to a more comprehensive and realistic permit process. Since this project was sited within an existing mooring lease area, user conflicts were minimized. Defining an appropriate process for identifying and permitting open water sites for aquaculture would be a valuable undertaking.

Biological Findings

Accomplishments

This project clearly demonstrated that white seabass could grow and remain healthy and vigorous for extended periods while being confined at relatively high density in a cage. The harvest density at the end of the project was greater than 12kg/cubic meter.

Food and feeding

On the relatively small scale of this project, feeding by hand worked well. Fish were observed to feed most aggressively at dawn and dusk - especially at dawn. During the daylight hours, fish remained deep in the water column. As daylight faded the fish would swim up to the surface to take the feed as it hit the water. Feeding to satiation was generally possible based on the behavior of the fish. However, during the colder winter months the activity of the fish decreased and we found that we were greatly overfeeding them (see problems below). Underfeeding of white seabass is often associated with a condition we call "gray head", where a patch of gray skin is observed on the top of the head. The direct cause of this condition is not known precisely, but it believed to be associated with increased aggressiveness and interaction among fish. This condition

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[2] Dropping the nets to the bottom to be "biologically cleaned" was not attempted during this study.

was observed for a short period during this study but was corrected by increasing the feeding level.

Growth, yield, and conversion efficiency

As expected, growth was found to be highly dependent on water temperature (Figure 9). A La Niña event during the second half of this study resulted in unseasonably cold water, so the final size at harvest was smaller than desired, given the age of the fish (Figure 10). Using linear regression methods, the relationship between temperature and growth could be described accurately (Figure 11). This relationship provides a powerful predictive tool for production and feed management. A maximum growth stanza of 1.7% (weight gain per day) was observed during August and September of 1998 (Table 2). This period of growth was associated with the highest water temperatures observed during this study - averaging approximately 20°C. Growth was slowest (0.11%) during February and March of 1999 when average monthly water temperatures were 13.8 and 14°C, respectively.

The fillet yield from farm-raised white seabass was approximately 42% without skin or pin bones. The comparable yield for larger, wild fish was reported to be approximately 36% (pers.

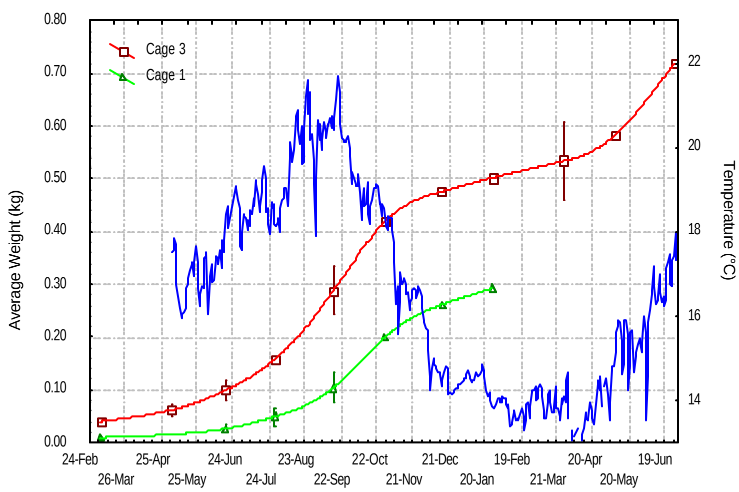

Figure 9. Daily growth in relation to temperature.

comm., Craig Ghio, Ghio's SeaFood).

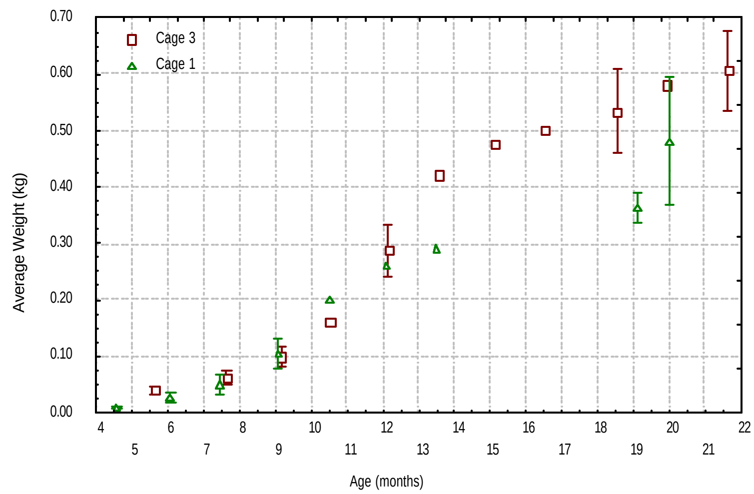

Figure 10. Age-specific growth pattern.

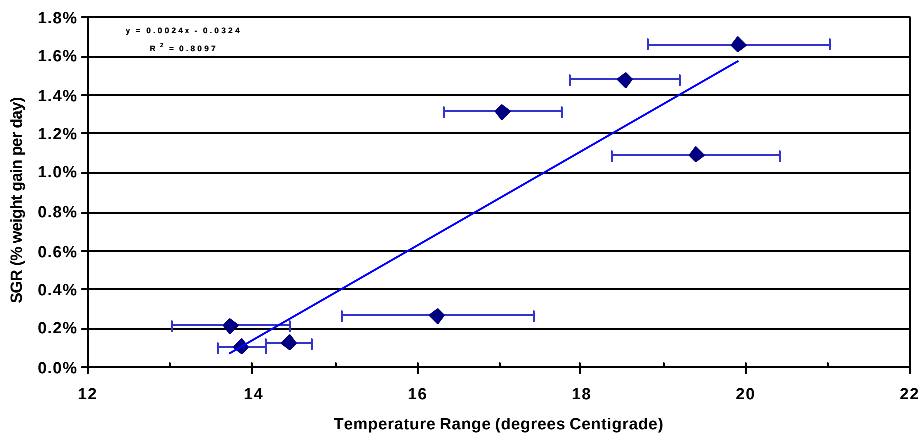

Figure 11. Relationship between temperature and growth.

Although rates of food conversion (FCR) were variable during the course of this study, most of the variability was associated with overfeeding during the colder, winter months. When the fish were active their level of satiation was easier to interpret, resulting in more efficient feeding. During this period (March-October), feed conversion rates ranged from 1.7 to 2.6 with an average of 1.9 (Table 1).

Table 1. Summary growth, survival, and feeding data for Cage 3.

Instantaneous Sampling Data								*Between Sampling Summary*		
Sampling Date	**Age (days)**	**Population (#)**	**Survival (%)**	**TL (mm)**	**Individual Wt (g)**	**Density (kg/m3)**	**Biomass (kg)**	**Feed Used (kg)**	**FCR**	**Growth (%wt/day)**
03/05/98	169	12,637	100.0%	159.4	39.4	0.71	498			
05/04/98	229	12,570	99.5%	188.4	62.0	1.11	779	736	2.62	0.95%
06/19/98	275	12,556	99.4%	225.2	99.5	1.78	1,249	798	1.70	1.32%
07/30/98	316	12,538	99.2%	265.3	160.0	2.87	2,006	1,291	1.71	1.48%
09/16/98	364	12,392	98.1%	317.2	287.8	5.09	3,566	2,385	1.53	1.66%
10/29/98	407	12,329	97.9%	357.7	423.0	7.45	5,215	3,150	1.91	1.09%
12/15/98	454	12,290	97.8%	377.4	476.3	8.36	5,853	3,975	6.23	0.27%
01/26/99	496	12,234	97.5%	391.0	501.9	8.77	6,140	3,000	10.48	0.13%
03/27/99	556	11,969	97.3%	391.6	534.3	9.14	6,395	3,080	12.06	0.11%
05/08/99	598	11,951	97.1%	405.7	582.3	9.94	6,959	1,490	2.64	0.21%
06/28/99	649	11,912	96.8%	431.4	720.6	12.26	8,584	1,694	1.04	0.47%
								21,599		

Health and survival

Generally, the health and survival of fish was excellent once they became acclimated to conditions in the cages. Extremely high mortality was observed during the first few weeks after transport among the group of smaller fish (see "Significant Problems" section below). Survival among the larger fish was excellent, with more than 95% surviving during the course of the study. The difference between the expected number of fish surviving (based on counts of daily mortalities) and the actual number remaining was less than 3% for the larger fish. This variation could readily be explained by error associated with estimating the number of fish originally stocked into the cage.

During the final quarter of this study, the smaller fish became heavily (90%) infested with gill flukes (*Cynoscionicola pseudoheterocantha*) resulting in pale gills and a corresponding slight increase (1-2 fish per day) in mortality (Figure 12). Interestingly, the larger fish, being held at a

Figure 12. Primary health problems encountered during study period - gill flukes and eye abrasions.

much higher density, only became lightly (3%) infected. The heavily infected fish were treated within a week of noticing the outbreak. The treatment involved transferring the fish to a plastic liner (6.7 x 2.4 x 1.8m deep; 8 mil. thickness) that was partially submerged in one of the cages. The liner was impermeable so an effective bath treatment could be carried out. Hydrogen peroxide was tested on small numbers of fish at 150 and 250ppm for one hour. The 150ppm treatment was found to be 100% effective on the subsample, so that dosage was applied to the entire group. Mortality after the treatment averaged 5 fish per day for almost four weeks, but the gill flukes did not return.

The presence of visible health problems or physical abnormalities was evaluated closely during the tagging process. During the first tagging period, a total of 6,483 fish were individually inspected and sorted. Only those fish that were clearly healthy were tagged for release. Other fish were isolated in a smaller containment net. A total of 16 health code categories are traditionally used in our program. These specific categories can generally be consolidated into as few as five general categories. These categories include (1) trauma to the eye; (2) deformity of the jaw; (3) deformity of the spine; (4) abbreviation of the opercula; and (5) lesions of the skin. Of the 6,483 fish sorted in the first batch, 12.2% were not fit for release. Of those not suited for release, the majority (78%) had damage to their eyes. This was followed in prevalence by abbreviated opercula (8%), lesions of the skin (8%), and deformity of the jaw (3%) and spine (2%).

Significant problems

Overfeeding

Excessive feeding during the cold winter months was a significant problem because we overestimated the level of activity of the fish. Aside from activity patterns, we did not have a method of evaluating feed wastage (e.g. underwater video camera, waste collection system under the nets). The overfeeding problem was readily corrected with improved understanding of the relationship between temperature and growth. Feeding levels were adjusted to reflect a FCR of 2.0 at a predicted level of weight gain based on water temperature.

Fish size at stocking

The greatest disappointment during the project was the high mortality suffered by the group of small fish immediately after transport. We feel that the transport conditions were excellent in terms of the volume available and water exchange rate inside the bait boat's holding tanks. The fish went off feed immediately after stocking and most did not recover. Even those fish that survived showed an increased level of physical abnormalities that were likely associated with early malnourishment. It is possible that the fish were not sufficiently weaned at the hatchery to feed aggressively enough in such a large cage. Future attempts to stock small fish might incorporate a "stocking net" of lesser volume to improve observation and feeding. It might also be beneficial to immerse the fish in a bath treatment (i.e. Fritzguard) immediately after transport to control stress and stimulate mucous production.

Recommendations for additional work

Feed formulation

Because of its importance to the biological welfare of the fish and the economic viability of any cage farming operation, food type (nutritional requirements) and feed management need to be fully understood in order to be successful. From a biological standpoint, a food type and feeding regime should be developed that yields optimum fish growth and performance (e.g. stress resistance) and a biochemical composition that is preferred by the consumer. The composition of the feed affects not only the growth and performance of the fish, but also the cost of the food and the flavor of the fillet. In order to maintain operational efficiency, food cost and fish performance must be balanced. Laboratory studies would be required to formulate an optimum feed. Suggestions for additional research designed to optimize feeding regimes for white seabass (feed management and rates of conversion) are dealt with separately in the economics section below.

Fish size at stocking

The value of fingerlings is directly proportional to their size, and the cost to grow fish in a hatchery is more than that for cages. In order to improve economic efficiency, it would be valuable to know what the minimum stocking size for cage culture is.

Economic Findings

Accomplishments

Market survey

A total of 600 fish were harvested for market evaluation during this project. Fourteen establishments were offered fish to evaluate. The evaluation sites were located in either San Diego County (78%) or Los Angeles (22%). Among these establishments, five were restaurants with two of the restaurants specializing in sushi. One supermarket was approached because they also offer live fish. Three establishments offered restaurant and market services. Two "wholesale-only" companies were offered fish as well as three wholesale establishments that were directly connected to both a retail market and restaurant (Table 2).

Survey forms were offered to each of the establishments, including several restaurants for

Table 2. Participants in white seabass market survey.

Establishment	Market Type	City
Vien Dong III	Supermarket	San Diego
Pelly's Fish Market & Café	Market/Restaurant	Carlsbad
Point Loma Seafood	Market/Restaurant	San Diego
Fish Market	Market/Restaurant	Del Mar
Chesapeake Bar & Grill	Restaurant	Encinitas
Samurai	Restaurant	Solana Beach
Café Japengo (Hyatt)	Restaurant	La Jolla
Armstrong Seafood	Restaurant	Avalon
Pacifica	Restaurant	Del Mar
Chesapeake Fish Company	Wholesale	San Diego
J & D Seafood	Wholesale	San Pedro
Pacific Shellfish Company	Wholesale/Market/Restaurant	Pacific Beach
Santa Monica Seafood	Wholesale/Market/Restaurant	Los Angeles
Ghio's Seafood	Wholesale/Restaurant	San Diego

consumer feedback (Appendix B). The number of people responding to the survey forms was generally poor. However, adequate information was attained to forecast the market potential of this species and areas where further research is needed.

In general, the responses received were positive. By far the most common criticism from representatives of the industry was the relatively small size of the fish. With a 40% fillet yield, the majority of fish evaluated were yielding only one meal portion per fish instead of two (one meal from each fillet). Single meal portions are 170-227g (6-8oz) which would require a whole fish weighing 0.85-1.1kg (1.87-2.5lb) at 40% yield. The small size of the fish was strictly a function of the limited duration of the study and not a reflection of the growth potential of the fish or economics of the project.

Responses regarding the quality of the fish were highly variable but also generally very positive. When asked to rate appearance, taste, texture, freshness and ease of processing, the majority of industry representatives responded with "good" to "excellent" ratings. Ratings for "ease of processing" were the most variable and occasionally received poor or fair ratings due to the small size of the fish and the difficulty removing pin bones (Figure 13). When asked how much they would be willing to pay per kg of whole fish and how many kg per week they would purchase, wholesaler responses ranged from $4.40-$6.60 per kg and 23-2,270 kg per week, respectively.

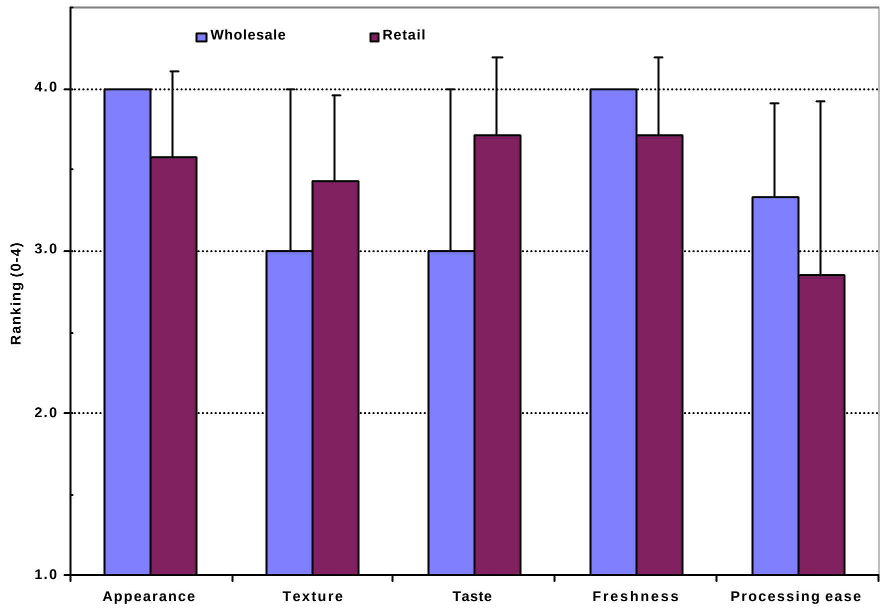

Figure 13. Industry rating of whole white seabass.

In addition to the survey we performed, one of San Diego's most well known seafood distributors (Ghio's Seafood) and associated restaurant (Anthony's Fish Grotto) conducted an independent survey. The results of this survey are presented in Appendix C and summarized below. After eating the farm-raised seabass, patrons were offered a piece of wild white seabass. Of 62 patrons responding, 68% preferred the wild seabass.

"Overall the fish received a lukewarm reception. Though it was impeccably fresh, it

> *had just a little off flavor reminiscent of Tilapia and other fresh water farmed fish. It didn't seem to have the taste of the sea. Guests were excited to try the product, and really tried to like it, based on its origin. I felt the Hubbs Seabass Project had very solid recognition among fish loving locals. Overall, I think the fish may be quite marketable if the flavor issue can be resolved. Price doesn't seem to be a problem at the restaurant level. By the way, seabass sold for $21, while salmon was $22, swordfish was $26, Ahi was $26 and halibut was $24."* - Craig Ghio, owner, Anthony's Fish Grotto.

Economic evaluation

In order to evaluate the economic feasibility of a white seabass farming operation, we considered both the costs of production and anticipated market value and volume requirements. Observed values for production variables (e.g., rate of growth relative to temperature, harvest density, food conversion efficiency) were used to estimate the costs (capital and operating) for rearing marketable sized white seabass (e.g., dimension of cages, number of cages required, total feed required). As described previously, we also conducted a market survey of restaurant and fresh fish wholesalers to estimate the potential market value and demand.

Table 3 lists the values used in evaluating the economic feasibility of farming white seabass. All of the values for estimating costs are based on observations made during the study period. The scale of production was set at 230mt per year which is not unreasonable given that one wholesaler estimated that he could market approximately 2,000kg per week. The same owner estimated an ex-vessel value of $6.00 per kilogram whole fish.

Using the values listed in Table 3, we estimate that a capital investment of approximately $600,000 would be required to purchase and install the equipment necessary to culture 230mt per year. Similarly, we estimate operating expenses to be approximately $1.16 million per year. Figure 14 summarizes the distribution of those operating costs.

Comparing the total estimated production costs of $1.16 million per year against anticipated revenues of $1.38 million would result in a profit return of approximately 19%. This estimate, of course, is highly dependent on the actual physical characteristics (water temperature, distance to market, etc.) of the farming site. However, this simple analysis does demonstrate that a larger scale system could be profitable if it is sited in an area that is suited to the biological needs of the fish and the operational needs of the business.

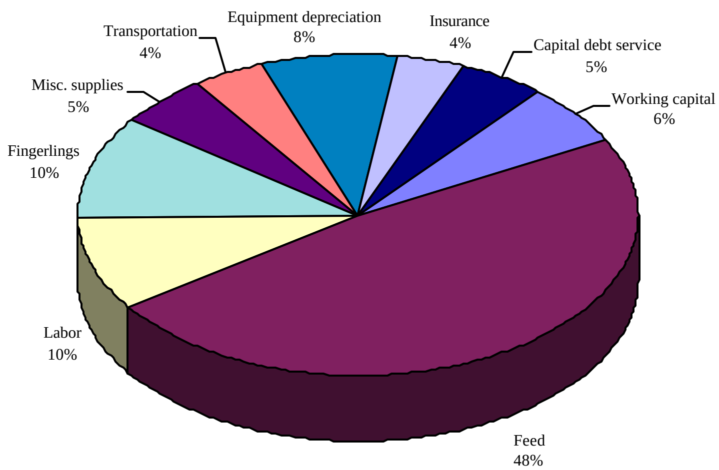

Figure 14. Summary of operating costs derived from economic model.

Table 3. Data used to develop economic model.

Description		Value	Units	Data Source
Annual Production		230,000	kg per yr	assumed
Number of Crops		12	per year	assumed
Cage Number		2	per crop	assumed
		24	per year	assumed
Cage Volume		700	cubic m	observed
Harvest Density		12.26	kg per cubic m	observed
Harvest Weight		0.80	kg per fish	observed
Growout Survival		96.8%		observed
Food Conversion Coeff		2.0	kg feed per kg fish	observed
Whole Fish Value	$	6.00	per kg	observed
Food Cost	$	1.21	per kg	observed
Cage Volume		781	cubic m	calculated
Stocking Number		24,883	fish per crop	calculated
Harvest Number		24,095	fish per crop	calculated
		298,594	fish total	calculated
Harvest Biomass		19,167	kg per crop	calculated

Significant problems

Among the problems experienced during the economic evaluation, coordination of the marketing survey was difficult and the return rate of survey forms was disappointingly low. Related to this was the timing of the survey, which unfortunately coincided with record catches of wild white seabass resulting in a flooded market and record low ex-vessel prices ($1.50 per kg). The market survey was also somewhat compromised by our inability to grow the fish to a larger size because of time constraints.

Recommendations for additional work

It is obvious from Figure 14 that the greatest contribution to the cost of the operation is food (almost 50%). A significant limitation to the culture of marine fish species in the United States is the lack of a domestic supplier of fish feeds formulated for marine species. This limitation is the direct result of a lack of market demand. Since the market for marine fish feeds is so limited, U.S. companies are reluctant to dedicate mill time to their production. Our experiment used a marine diet developed in Hawaii for mahimahi, and currently manufactured by Moore-Clark, Inc. Milling costs for this feed totaled $1.21 per kilogram. We have experimented with other diets that are available for approximately $0.81 per kilogram. Although these diets were adequate for culturing smaller fish, they have not been tested for commercial application.

Also, as shown in Figure 9, growth was significantly influenced by water temperature. Conducting the experiment through both El Niño and La Niña years may have complicated the results of the experiment. Even though we did obtain good temperature-dependent growth information during the experimental period, we were not able to evaluate the effect of daily ration (i.e., percent body weight fed per day) on growth. Additional experiments need to be conducted in the laboratory before a protocol for optimizing feed utilization can be developed.

As an example, if the feed conversion efficiency could be improved by 25%, then the predicted profit return would increase from 19% to 36% and feed costs would decrease to 41% of total production expenses. Similarly, if a less expensive feed was shown to be effective, profit would increase from 19% to 42% and relative food costs would decrease to 39%. Combining both improvements would result in a profit of 59% and a decrease in food costs to 32% of total operating costs. Clearly, further research is needed to improve feed utilization and thereby lower overall food costs.

Several consumers familiar with white seabass stated that the flesh, although firm and otherwise desirable, was lacking in the traditional "wild" flavor of white seabass. Because of this, additional research to determine the effects of lipid content of the diet and the effects of temperature on lipid content in the fillet would be valuable. This research could lead to protocols that would allow a commercial farmer to manipulate the flavor of their product directly.

Evaluation

Achievement of goals

The **primary** goal of the project was to evaluate the feasibility of growing white seabass (*Atractoscion nobilis*) in semi-exposed net cages and to determine the marketability. We achieved our primary goal by completing each of the objectives listed below.

1. We successfully *evaluated and implemented cage culture operations that promoted the economically effective growout of healthy and vigorous fish*. This was demonstrated by a high survival rate (>95%), absence of technical failure, and acceptable harvest density of greater than 12kg/cubic meter.
2. We quantified *the technical and economic factors for full-scale commercial production in definitive terms* by incorporating observed production values (technical and biological) with results of a marketing survey into a production model. The next phase of research should be to test the production model.
3. We did involve key agency personnel, so they would understand the nature of marine fish farming and thereby lessen agency obstacles in obtaining permits for large-scale farms. However, larger, commercial farms would encounter a much more rigorous permitting process. This would occur because a commercial-scale system will need to be sited in exposed waters that are not currently permitted for

such activities and user conflicts will undoubtedly arise. The next phase of research should be to establish a farm in such a location and to streamline the permitting process along the way.

4. We *produced a farm manual and economic feasibility report.* The farm manual was written by the farm manager during the course of the study and, for that reason, is very site-specific. However, the basic terminology and operational considerations are covered in detail. The economic feasibility report (included in the text of this document) was developed in the form of an economic model that incorporates observed production values (technical and biological) with results of a marketing survey. The economic feasibility report indicates that 230mt could be cultured and sold at a profit of approximately 19-59%.

5. We *conducted the project in a manner that avoided any significant environmental impacts resulting from operation of the farm.* Success in achieving this objective was evident by the large number of native fish and invertebrate species that lived around the farm during the study period (Figure 15 and Appendix D). Cursory dive surveys did not reveal evidence that the bottom sediment or faunal composition had been altered. There were no incidences of accidental entanglement in the nets by any fish, bird or marine mammal.

6. We *evaluated the potential market for various size classes of cultured fish by providing fish to wholesalers, restaurants and live fish markets, and we produced a preliminary market analysis*. Our marketing survey demonstrated that there is a substantial local market for farm-raised white seabass, especially fish 1-1.2kg. Additional marketing research is needed to identify market potential beyond southern California. Further research may also be required to improve the flavor of farmed white seabass.

Figure 15. Fish commonly associated with cages (see also Appendix C.).

The **secondary** goal of the project (and a requirement to obtain fingerlings from the state) was to produce a portion of the juvenile white seabass for enhancement. We also accomplished this goal by releasing more than 10,000 tagged fish. The fish were released at a much larger size than originally intended in order to maintain the cages at high density while we continued to obtain important technical and biological information.

Dissemination of results

Copies of this report may be obtained from the National Marine Fisheries Service. We will also be producing a compact disc format report that incorporates graphic representations of the results as well as video images of the research program. The results will also be presented at several regional and national conferences during the next year.

Conclusion

It is a readily accepted fact that our oceans will no longer be able to provide the fish that people have grown accustomed to eating. Many fisheries are already overexploited, and management policies track behind the rate of exploitation such that many fisheries continue to be over harvested and left in a diminished state. Expanding market demand in the U.S. is resulting in increased exploitation of fisheries by other nations to provide imports to our country, which adversely impacts the national trade deficit.

In addition, the expansion of capture fisheries is having an increasing impact on non-targeted, or by-catch, species. Significant financial effort is now required to explore the impacts that non-discriminate gear types (e.g. gill nets and long lines) are having on protected and endangered species (e.g., harbor porpoise, leatherback turtles, right whales) and other fish species that are simply discarded. Aquaculture as a growing source of fish protein is recognized as being the primary alternative to the diminishing productivity of the world's poorly managed wild fish stocks.

If marine aquaculture is to expand in the U.S., it will be in direct competition with other uses of shoreline property. The use of floating cages is a well established culture technology, but development of protected embayments and their watershed has resulted in not only competition for space in the water, but also in contamination of the water itself. This program chose a remote location on an off-shore island where competition for space was minimized and the water quality was know to be reliably free of most coastal pollution. However, even though it is remote, the expansion of operations at this location beyond this experimental level would be deemed unacceptable to local resource managers. The need for clean water combined with the scarcity of space in the near-shore zone, requires the advancement of open-ocean culture technology.

Many of the fresh water species now being commercially cultured were originally cultured for fisheries enhancement purposes. This list includes catfish, trout, and striped bass. Relative to marine species, red drum have been cultured for stocking programs for decades and are now being farmed commercially.

In addition to the scientific and economic data provided by this project, we hope that we have successfully increased the public awareness regarding the need to advance the development of marine aquaculture within our nation's territorial waters.

Acknowledgements

This project was made possible by a grant from National Oceanic and Atmospheric Administration's Saltonstall-Kennedy program, and was administered by the National Marine Fisheries Service's Southwest Regional office in Long Beach, CA. Matching funds were contributed by California Department of Fish and Game's Ocean Resources Enhancement and Hatchery Program (OREHP), Hubbs-Sea World Research Institute, and Forster Consulting. Logistical support was graciously provided by Bombard Enterprises, Two Harbors Enterprises, the Wrigley Marine Science Center, and the Southern California Marine Institute. Volunteer support was also provided by the staff of the Wrigley Marine Science Center and employees of the Catalina Island Seabass Fund. The investigators would like to thank Stephan Leuthi, the project's primary technical assistant, for his dedication and interest in the success of this research project. We would also like to thank Bill Jacobson of the NMFS Regional Office in Long Beach for his help in management of the grant.

Appendix A.

Sample of daily log sheet for each cage

Appendix B.

Informational bulletin and survey forms for test-marketing.

MARKET AND CONSUMER PREFERENCE SURVEY FOR FARM-RAISED WHITE SEABASS

Researchers at Hubbs-Sea World Research Institute (H-SWRI), in cooperation with the National Marine Fisheries Service and the California Department of Fish and Game, are conducting a unique study to determine the feasibility of farming white seabass to market size. H-SWRI has been involved in stocking this species into the ocean as part of the Ocean Resources Enhancement and Hatchery Program for almost 20 years. Researchers involved with this feasibility study hope that ocean farming will yield future economic benefits to southern California and also help to conserve native stocks that may otherwise continue to be over-harvested.

Farm-raised fishery products offer the advantages of year-round availability and guaranteed freshness. The fish being evaluated from this study are grown in net cages in the pristine waters off Catalina Island. The siting and design criteria for this facility ensures maximum water exchange which in turn yields strong, healthy fish. The fish are hand-fed each day with a high protein, all-natural feed. Harvesting can be performed as needed to ensure freshness. In addition to direct marketing, researchers plan to release a minimum of 50% of the fish from each group into southern California waters to help replenish ocean stocks.

While H-SWRI researchers are demonstrating the technical and biological feasibility of culturing these fish, feedback from consumers and seafood industry representatives is needed to complete the economic feasibility aspects of this study. Thank you for participating in this exciting project.

Consumer Questionnaire

Evaluator Name _______________ Evaluation Date _____________

Company Name _______________

How often to you eat seafood each month?

π 0-2 times π 3-6 times π >6 times

Where do you usually purchase your seafood?

π restaurant π supermarket π fish market π catch my own

What types of seafood do you typically eat?

π crustaceans (e.g. shrimp, lobsters)

π molluscs (e.g. clams, oysters)

π fish (e.g. salmon, sea bass)

Have you ever eaten white seabass?

π yes π no π don't know

Does knowing that you are eating a farm-raised product and not further exploiting the ocean's resources influence your decision to buy it?

π yes π no π don't know

How would you rate the following?

Appearance:

π poor π fair π good π excellent

Texture:

π poor π fair π good π excellent

Taste:

π poor π fair π good π excellent

Freshness

π poor π fair π good π excellent

Would you eat farm-raised white seabass again?

π yes π no π don't know

Additional comments: ____

Retail Market Questionnaire

Evaluator Name _______________ Evaluation Date _____________

Company Name _______________

What is your relationship to the seafood industry (markets or restaurants)?

π owner π manager π chef π waiter

Does your establishment ever offer white seabass?

π yes π no π don't know

Have you ever eaten white seabass?

π yes π no π don't know

What other farm-raised seafood products does your establishment offer? ____

____

How would you rate the following for farm-raised white seabass?

Appearance:

π poor π fair π good π excellent

Texture:

π poor π fair π good π excellent

Taste:

π poor π fair π good π excellent

Freshness

π poor π fair π good π excellent

Ease of processing

π poor π fair π good π excellent

Owners or Managers:

What price would your establishment be willing to pay for fresh, whole farm-raised white seabass? $________ per pound

Assuming a consistent supply, what volume of product would you estimate your establishment would want? ____ pounds (whole fish) per week

Additional comments: ____
____

Wholesale Market Questionnaire

Evaluator Name _______________ Evaluation Date _____________

Company Name _______________

What is your relationship to the seafood wholesale industry?

π owner π manager π processor

Does your establishment ever process and distribute white seabass?

π yes π no

What other farm-raised seafood products does your establishment offer?
____
____

How would you rate the following for farm-raised white seabass?

Appearance:

π poor π fair π good π excellent

Texture:

π poor π fair π good π excellent

Taste:

π poor π fair π good π excellent

Freshness

π poor π fair π good π excellent

Ease of processing

π poor π fair π good π excellent

Owners or Managers:

What price would your establishment be willing to pay for fresh, whole farm-raised white seabass? $_______ per pound

Assuming a consistent supply, what volume of product would you estimate your establishment would want? ____ pounds (whole fish) per week

Additional comments: ____
____
____

Appendix C.

Results of independent survey conducted by Ghio's Seafood.

Appendix D.

Fish and invertebrates associated with cages.

Phylum	*Species List*	Common name
Porifera	*Leucandra heath*	Sponges
	Leucetta lasangelensis	
	Aplysina fistularis	
	Ophlitaspongia pennata	
Cnidarian	*Corynactis californica*	Anenomies
	Anthopleura spp.	
	Plumularia spp.	Hydroids
	Tubelaria crocea	
	Eudendrium californicum	
Platthelminthes	*Polyclad spp.*	Flatworm
Annelida	*Spirobranchus spinosis*	Christmas Tree Worm
Mollusca	*Mytilus californicus*	Blue Mussel
	Mytilus edulis	Bay Mussel
	Petracola carditideous	Nestling Clam
	Hinnites giganteus	Rock Scallop
		Pacific Pearl Oyster
	Serpulorbis squamigerus	Worm Shell
	Lithopoma andosum	Wavy Turbansnail
	Astraea undosa	
	Kelletia kelletii	Whelk
	Crepipatella lingulata	Slipper Snail
	Collisella pelta	Limpet
	Notoacmea spp.	
	Loligo opalescens	Market Squid
	Octopus rubescens	Octopus
	Spurilla oliviae	Nudibranchs
	Hermisenda triopha	
	Navivax inermis	
Polychaeta	*Anaitides medipapillata*	Polychaete Worms
	Arctonoe spp.	Scale Worm
	Serpula vermicularis	
Arthropoda	*Lepas anatifera*	Goose barnacle
	Megabalanus californicus	Barnacle
	Tetraclita rubescens	
	Alpheus clamator	Snapping Shrimp
	Lysmata californica	Rock Shrimp
	Hemisauilla ensiaera californien:	Jumbo Prawn
	Caprella spp.	Skeleton Shrimp
	Pugettia producta	Northern Kelp Crab
	Taliepus nuttallii	Southern Kelp Crab
	Pachygrapsus crassipes	Shore Crab
	Loxorhynchus crispatus.	Decorator Crab
	Dilumnus spinohirsatus	Hairy Crab
	Cancer oregoniensis	Cancer Crab
	Pelia tumida	
	Fabia subquadrata	
	Orchestoidea spp.	
	Oligochinus spp.	
	Pannulirus interruptus	California Spiny Lobster
Echinodermata	*Strongylocentrotus purpatus*	Purple Urchin
	Ophiothrix spiculata	Brittle Star
	Astropecten armatus	
	Parastichopus parrimensis	Sea Cucumber
Urochordata		Stalked Tunicate
	Styela monteryensis	
	Styela plicata	
	Pyura mirabilis	
	Botryllus spp	Colonizing Tunicate
	Didemnum carnulentum	
	Botrylloides spp.	

Species	Common Name	Adult	Juvenile
Urolophus halleri	Round Stingray	x	
Platyrhinoidis triseriota	Thornback	x	
Myliobatiscalifornica	Bat Ray	x	x
Squatina californica	Pacific Angel Shark	x	
Heterodontus francisci	Horn Shark	x	
Cephaloscyllium ventriosum	Swell Shark	x	x
Mestelus henlei	Brown Smooth hound Sha	x	
Sardinops sagax	Sardine	x	x
Atherinops affinis	Topsmelt	x	x
	Jacksmelt	x	
Trachurus symmetricus	Jack Mackerel	x	x
Scomber japonicus	Greenback Mackerel	x	x
Cypseluruscalifornicus	Flying fish	x	
Anisotremus davidsonii	Sargo	x	
Hypsypops pubicundus	Garibaldi	x	
Chromis punctipinnis	Blacksmith	x	x
Medialuna cliforniensis	Blue Perch	x	x
Girella nigricans	Opaleye	x	
Caulolatilus princeps	Whitefish	x	x
Heterostichus rostratus	Kelpfish		
Oxyjulis californica	Senorita	x	
Halichoeres semicinctus	Rock Wrasse	x	
Semicossyphus pulcher	Sheephead	x	x
Hypsoblennius gentilis	Bay Blenny	x	x
Lythrypnus dalli	Blue Banded Goby	x	
	Cabezon		
	Pacific Sanddab	x	
Pleuronichthys coenosus	CO Sole	x	
Paralichthys californicus	California Halibut	x	x
Sphyraena argentea	California Barracuda	x	
Umbrina roncodor	Yellowfin Croaker	x	
Atractoscion nobilis	White Seabass	x	
Paralabrax clathrutus	Calico Bass	x	
Paralabrax nebulifer	Sand Bass	x	
Stereolepis gigas	Giant Seabass	x	
Sebastes paucispinis	Bocaccio		
Scorpaena guttata	Scorpionfish	x	
Seriola dorsalis	Yellowtail		
Sarda chiliensis	Bonita	x	