



The Expanding Role of Marine Aquaculture and Fisheries Enhancement in Sustainable Fisheries

Ken Leber
Center for Fisheries Enhancement



Will the Oceans Help Feed Humanity?

Duarte et al., 2009

- ✱ By 2050, the human population is projected to reach 9,200 million, which is within estimates of the maximum carrying capacity of the planet.
- ✱ A fundamental question for science is whether it is possible to increase food production enough to feed a human population of that magnitude

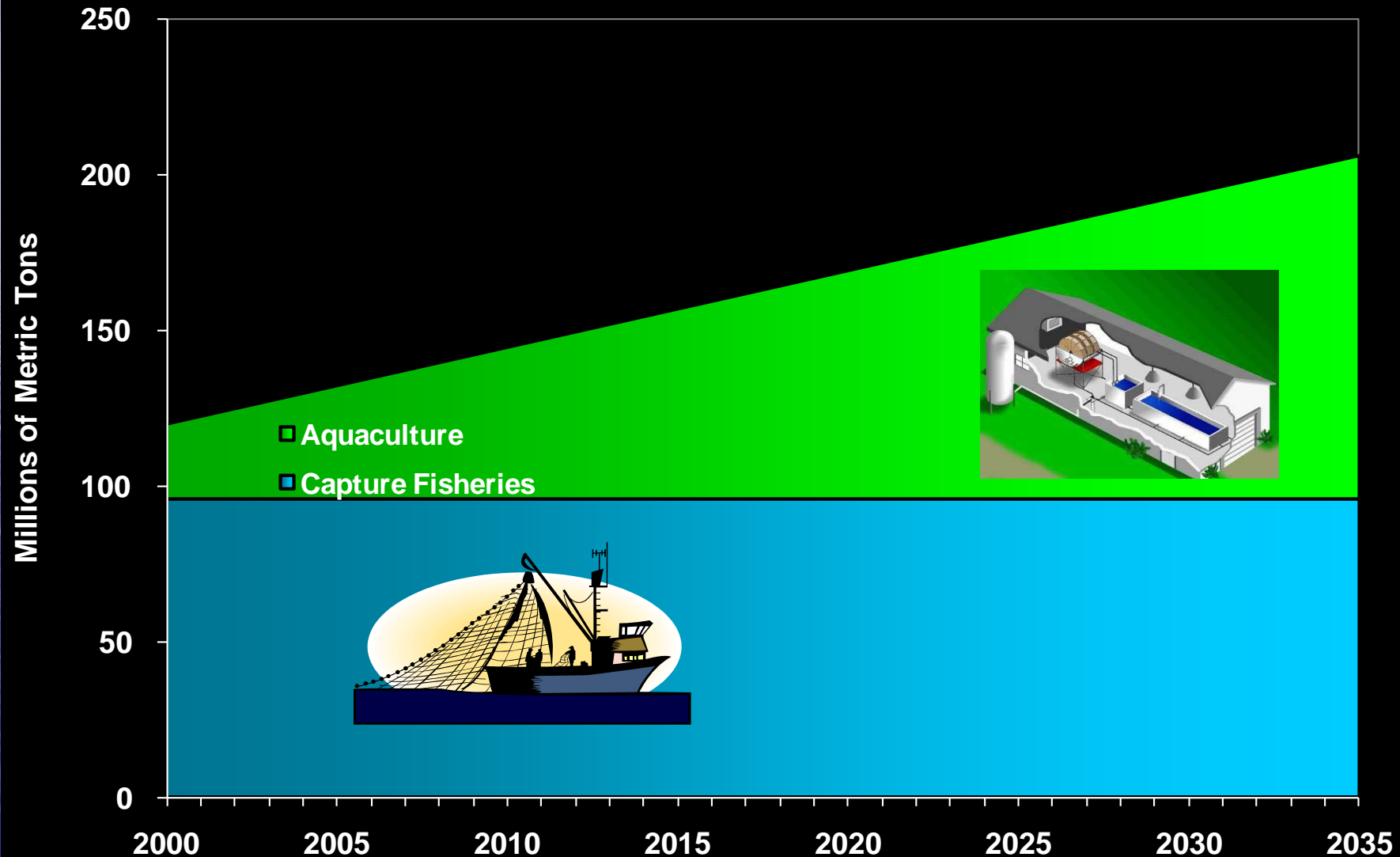
Ceilings to Agricultural Food Production

- Fresh water is increasingly being used for non-food production (biofuels, cotton, etc.)
- Climate Change will increase droughts
- Crop and grazing areas will have to increase 50% to 70% to feed the population expected by 2050 (but cannot)
- Yet crop area fell from .5 to .25 ha per capita from 1960 to 2000

★ These trends show it is likely that Earth's capacity to support the human population may be reached within the next 3 decades at population levels below currently proposed estimates.



The Rise of Aquaculture: Projections for Global Seafood Production

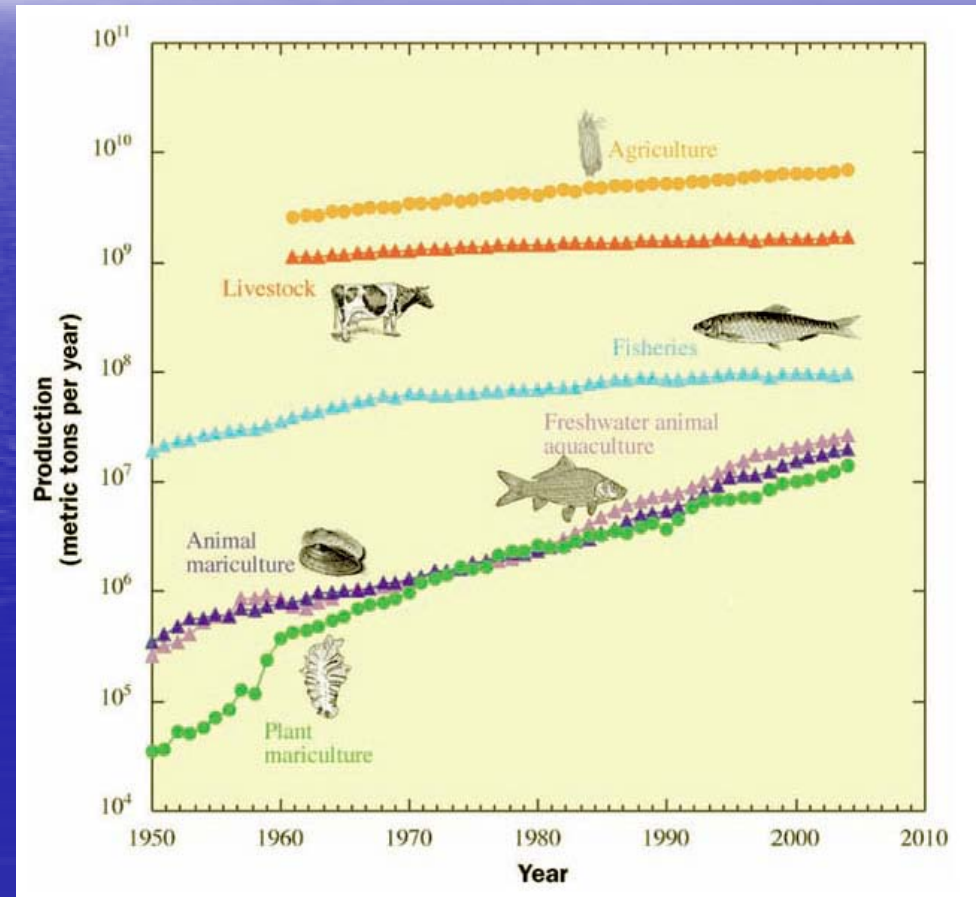


Growth in Capture Fisheries Has Ceased and Yields are Even Declining

- Declining fisheries yield can be reversed by a set of policy actions:
 - Reduced fishing effort
 - Shift in catches and consumption to small pelagics
 - Major expansion of marine reserves
 - Incentives for sustainable fishing habits
- Such policies may allow catches to remain sustainable or even recover some

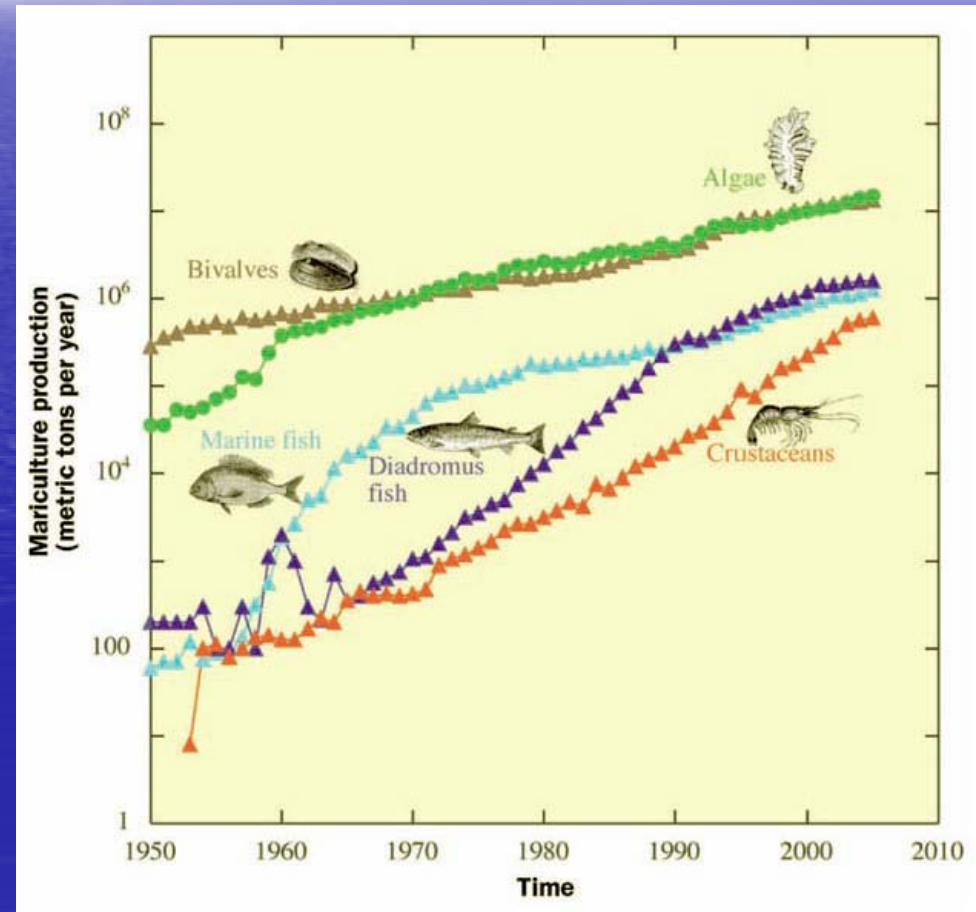
The Rise of Aquaculture

- In contrast, aquaculture production has been doubling each decade and now provides 40% of aquatic food products
- This 7%/yr growth far exceeds growth in land-based food production (2%/yr)



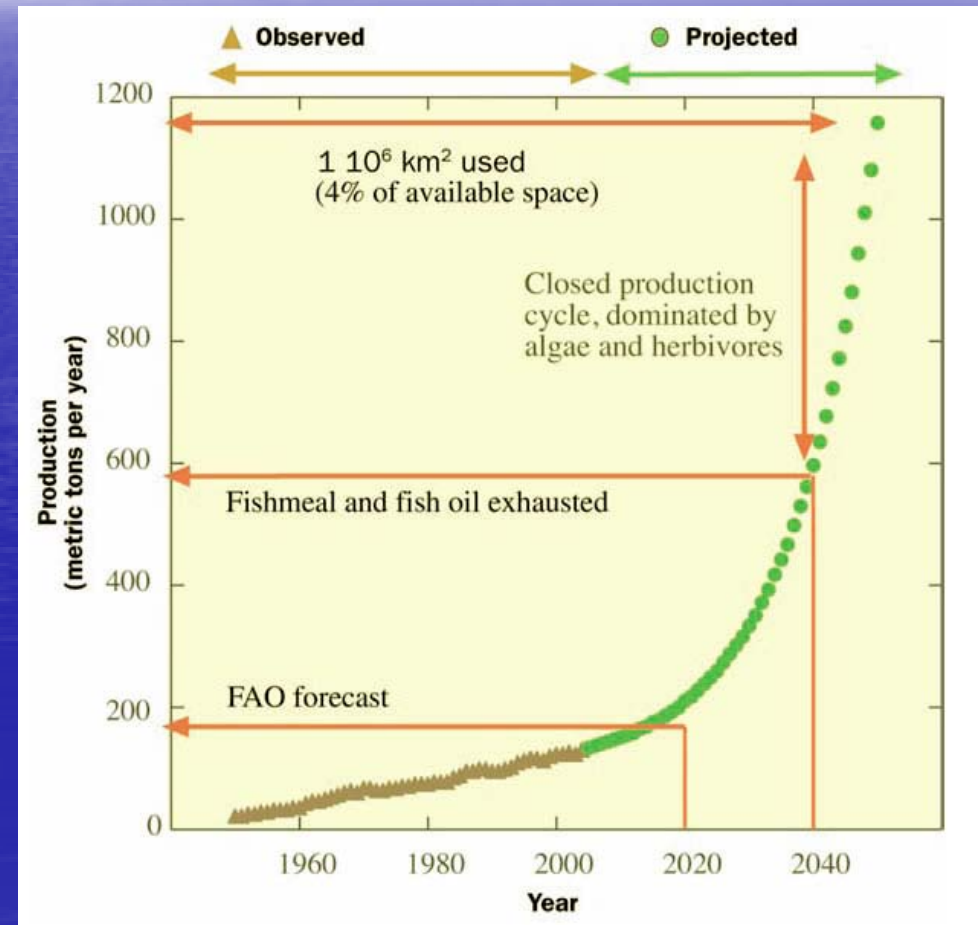
Mariculture is on the Rise

- As fresh water aquaculture is increasingly constrained, space & water availability will likely drive aquaculture growth towards mariculture in the long term
- FAO forecasts mariculture will produce 54 to 70 million metric tons by 2020



There are Some Major Bottlenecks: Feed, Space and Environmental Hazards Must be Overcome

- Maximum possible yield of fishmeal will cap mariculture production at 450 to 500 million tons/yr by 2040
- And agriculture substitutes will already have space and water constraints
- **Aquaculture must close the production cycle** as agricul. did in the 20th Century



Increase Efficiency by Lowering the Trophic Level Produced by Aquaculture

- 3 to 7 times as much primary productivity is required to achieve the same yield as in 1 trophic level below
- Mariculture is now at a mean trophic level of 1.898, well below 3.2 of capture fisheries, but above the 1.03 for agriculture & livestock



Current Directions

Extensive & Semi-Intensive
Production Strategies

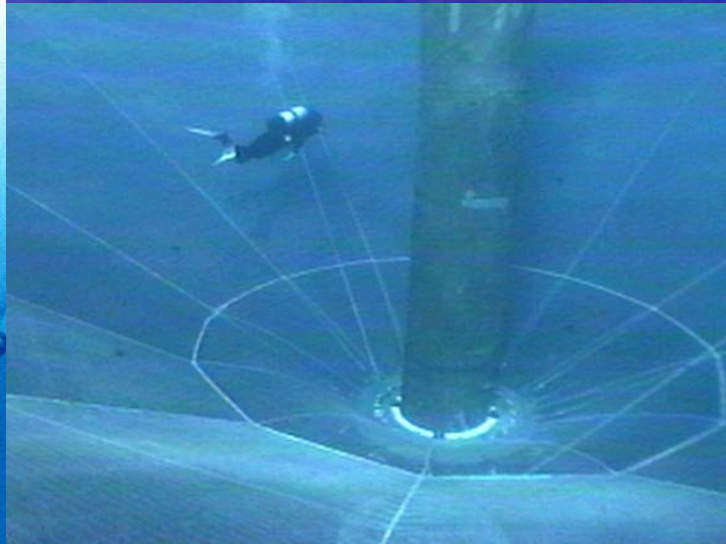
Pond & Nearshore
Cage & Shellfish
Culture

Open/Flow-Through
Pond and Tank
Systems



Future Directions

- Intensive Production Strategies
 - Offshore Cages
 - Enclosed Recirculating Production Facilities



Center for Aquaculture Research and Development



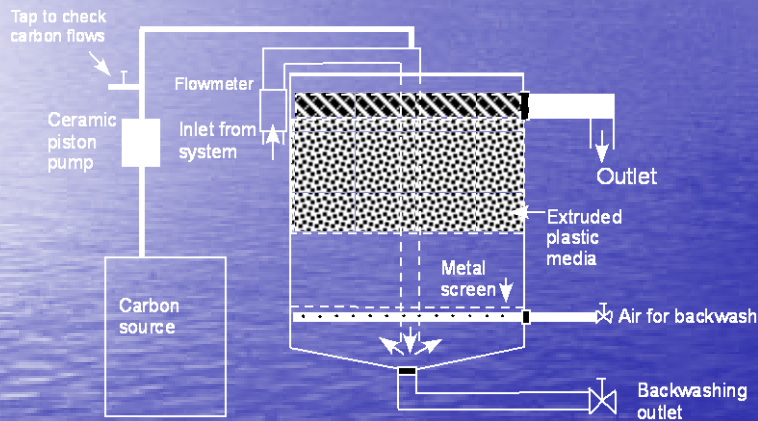
The mission of CARD is to develop innovative, and cost-effective methods to produce aquatic species for food, and for fisheries and habitat restoration

Mote Aquaculture Research Park: 2009



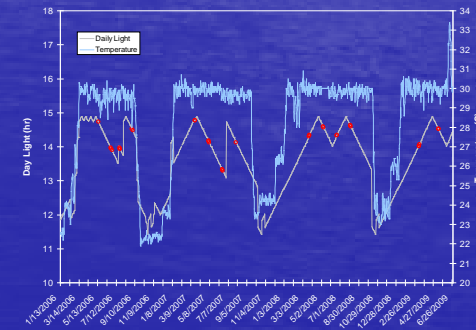
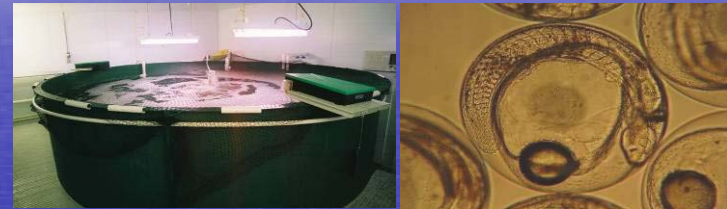
Aquaculture Research at MAP

Design & Evaluation of Commercial-Scale Denitrification



Evaluating the Effect of Larval Diets on Growth & Survival

Closing the Life Cycle for New Marine Fish Species



Commercial Demonstration at MAP



Marketing Sustainable Seafood
Products to U.S. Consumers



Petrossian

Freshwater Aquaculture Filtration

(mechanically filter & reuse 85-90% of water per day)



Integrating Aquaculture & Agriculture (passively filter remaining 10-15% using plants)

- Cleaning up wastewater & producing aquatic plants for habitat restoration
- Additional income stream for agriculture & aquaculture industries



Inland Marine Aquaculture Filtration

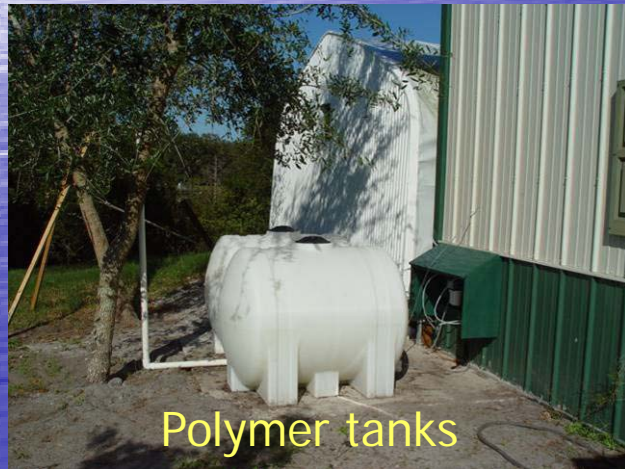
(Mechanically filter & reuse 100% of water)



- Include a primary & wastewater treatment system
- Accommodate small (~1") & later larger (~ 9") juvenile marine fish



Wastewater Filtration System Components



Blue revolution

The promise of fish farming



Promoting the Growth of Mariculture is the Responsibility of All of Society

- Society must be prepared to face major social changes required to adapt to the coming major revolution in food production
 - Acknowledge we cannot depend on other countries to supply our protein in the US
 - Adapt to eating more seafood 1 trophic level lower in the food chain
 - Recognize and move at the “Speed of Need” to develop mariculture responsibly in the US
 - Acknowledge that our grandchildren are facing food shortages in their lifetime
- Parallel actions are needed to restore declining fisheries yields
 - Increase incentives for sustainability through catch shares and limited entry
 - Quit fishing the top of the food web
 - Allocation of space to Marine Protected Areas, as we did our National Parks
 - Develop responsible marine stock enhancement capability to restore depleted stocks
- These changes depend on social and political leadership, informed by the best available independent scientific knowledge

Marine Fisheries Enhancement

- ✱ Stock enhancement and conservation hatcheries were partially enabled by aquaculture in the 20th century, but their potential was retarded by the absence of fisheries science in their conduct
- ✱ Finally, this field is progressing in the 21st century, but needs to be much more fully developed.

Florida - the Tourist Capital of the World

- ✴ Florida is the top travel destination in the world
- ✴ 76.8 million visitors per year with a \$57 billion annual impact on the state economy
 - ✴ University Research = \$500 million / yr
 - ✴ Space Industry = \$4.5 Billion / yr
 - ✴ Florida Sportfishing = ??? / yr

Sportfishing Economic Output

- ✱ **Sportfishing = \$7.5 Billion / yr !**
 - ✱ **Saltwater sportfishing alone = \$5.1 B / yr**
- ✱ **Now have 2,767,000 anglers in Florida**
 - ✱ **Florida has 2,002,000 Saltwater anglers**
 - ✱ **650,000 of those fish freshwater, too**
 - ✱ **885,000 are from out of state**
- ✱ **Anglers fish 46,311,000 angler-days / yr**
 - ✱ **24,512,000 days in saltwater**

Population will Continue to Increase

☀ 18,770,000
in April 2010

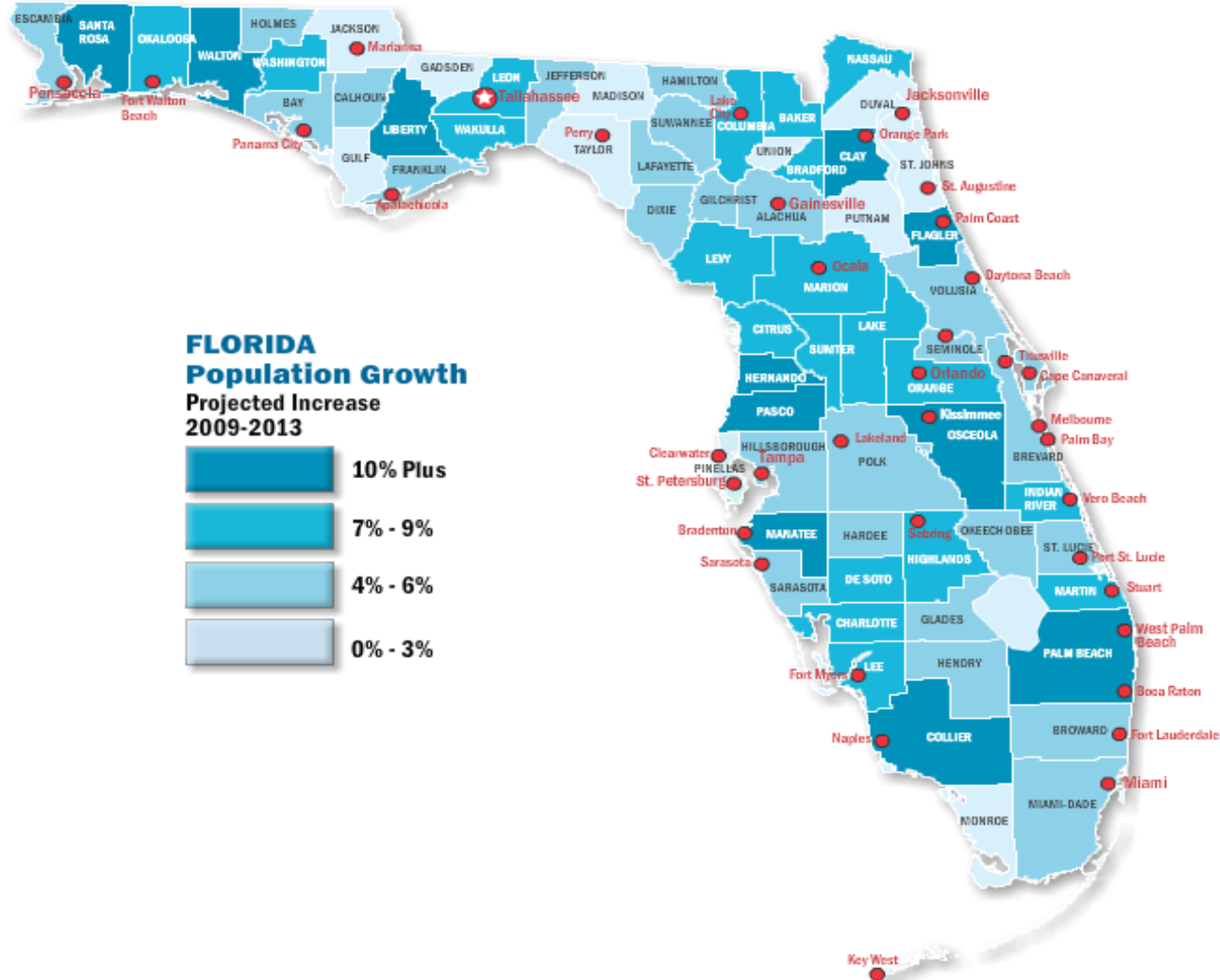
☀ ~ Zero growth
for now, but
21,300,000
by 2020 (~12%)

☀ 37,000,000
by the time my
grandson (now 1)
retires (at 67)

ECONOMIC YEARBOOK 2009

Map: Fla. Population Growth by County

This is a Flash map. To Zoom In, right click (on a PC), or control-click (on a Mac.)



So, how can we sustain fisheries and maintain the current quality of fishing

How is fish abundance maintained?

- ★ Fishery managers control total catch by controlling fishing effort with regulations -- seasonal closures, size and catch limitations, number of angler licenses (and incentives -- catch shares).
- ★ Fishery managers could protect & restore essential fish habitat (increasingly - MPAs)
- ★ Fishery managers could increase the number of new young fish (recruits) by stocking hatchery-reared fish



“A Responsible Approach to Marine Stock Enhancement” *

Stay Within Context of Fisheries Management Plan:

- 1. Prioritize Species for Enhancement**
- 2. Make a Stocking Plan that Fits with & Helps Achieve the Goals of the Fishery Management Plan, and Identify the Expectations**

Develop Sound Enhancement Strategy:

- 3. Define Quantitative Measures of Success**
- 4. Use Genetic Resource Mgmt. to Prevent Deleterious Effects**
- 5. Use Disease and Health Management**
- 6. Consider Ecological, Biological, & Life-History Patterns**
- 7. Identify Hatchery Fish & Assess Stocking Effects**
- 8. Use an Empirical Process to Define Optimal Release Strategies**
- 9. Identify Economic & Policy Guidelines (with greater stakeholder involvement in planning and guiding SE programs)**
- 10. Integrate Adaptive Management**

(* Blankenship & Leber, 1995)

PDF is online at StockEnhancement.org/science/publications.html



Updated “Responsible Approach to Marine Stock Enhancement” *

Stage 1: Initial Appraisal & Goal Setting

1. **Analyze the fishery system**
2. **Engage stakeholders & develop a rigorous & accountable decision-making process**
3. **Quantitatively assess fishery & the potential contribution of enhancement, harvest & habitat management to fisheries management goals**
4. **Prioritize and select target species and stocks for enhancement**
5. **Define enhancement system designs suitable for the fishery & management objectives**
6. **Assess economic and social benefits and costs of enhancement**
7. **Develop effective institutional arrangements**

Stage 2: Research & Technology Development & Pilot Studies

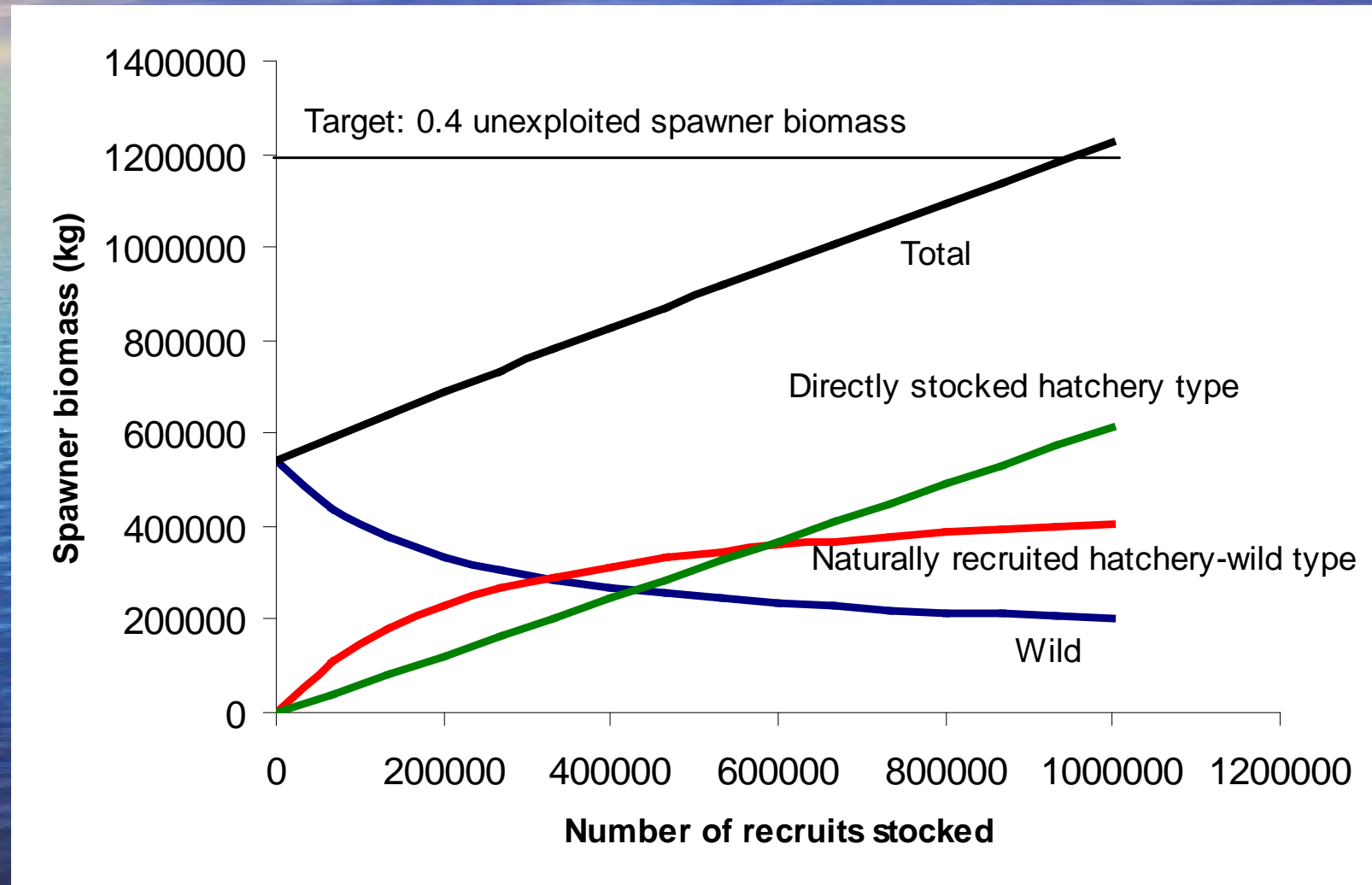
8. **Develop appropriate husbandry systems**
9. **Use genetic resource management to avoid deleterious genetic effects**
10. **Use disease and health management**
11. **Ensure that released hatchery fish can be identified**
12. **Use an empirical process for defining optimal release strategies**

Stage 3: Operational Implementation & Adaptive Management

13. **Define quantitative measures of success**
14. **Assess ecological impacts**
15. **Use adaptive management to resolve critical uncertainties**

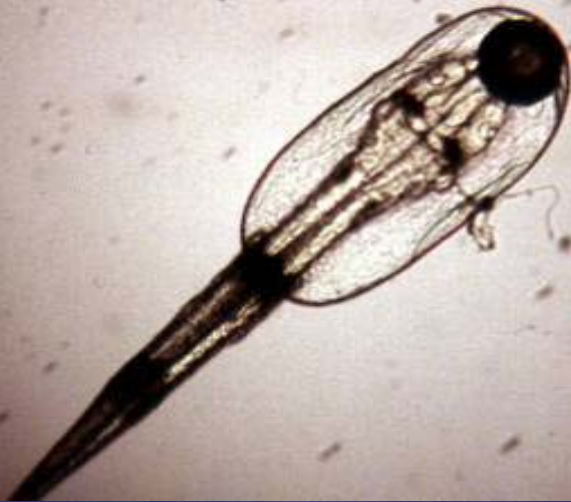
(* Lorenzen, Leber and Blankenship, 2010)

Effect of Enhancements, harvest and habitat management should be modeled, a priori, and integrated into the decision making process



System Design affects production efficiency & fitness of released fish

- Sourcing of broodstock
- Production of 'wild-like types'
- Minimize domestication



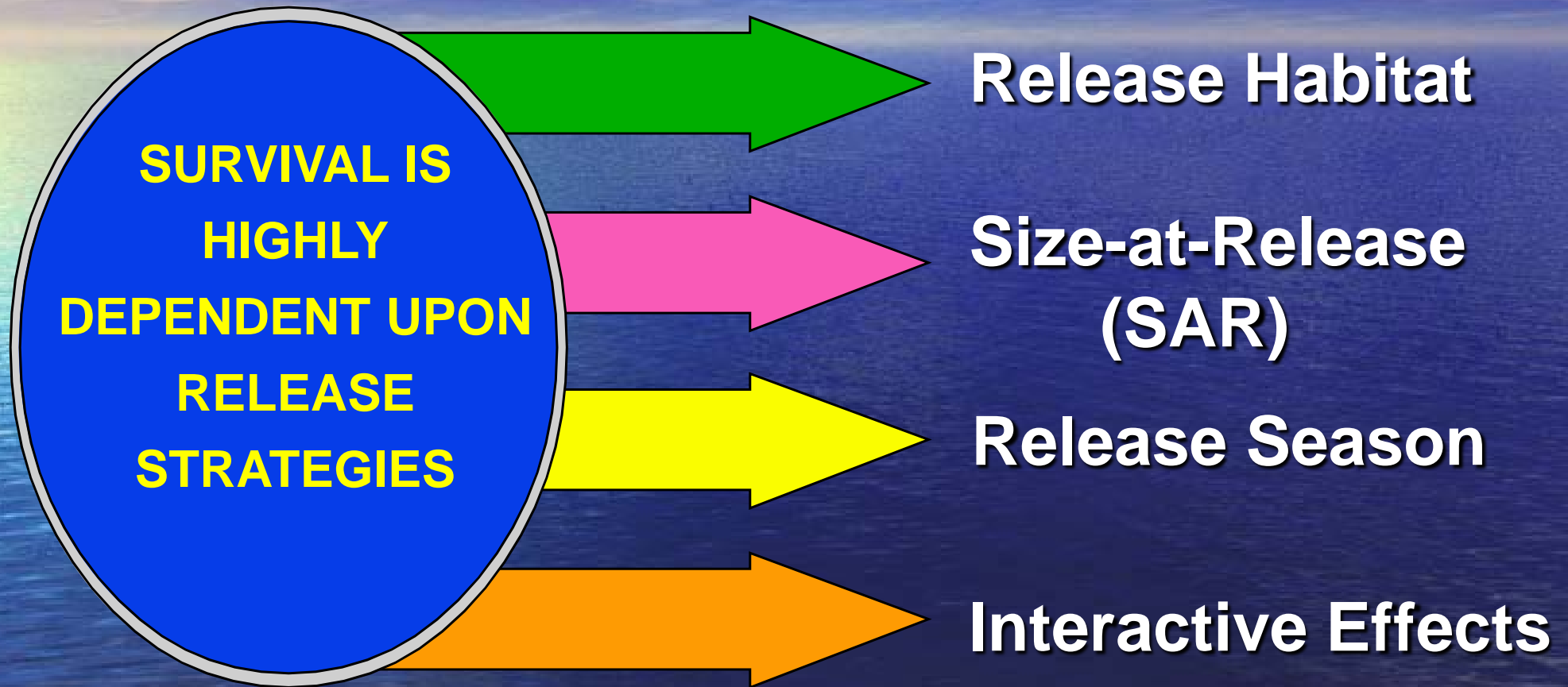
Genetic Management Is Essential

- ✱ **Avoid transfer of exogenous alleles**
- ✱ **Avoid change in gene frequencies**
- ✱ **Avoid inbreeding and outbreeding depression**

Virtually all aspects of enhancement research and management require the ability to identify released fish



Results of Pilot Studies to Optimize Release Protocol



Field Experiments to Maximize Survival



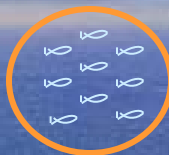
Pilot Releases
to Assess
Stocking
Effectiveness

Release Design

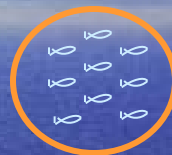
Day 1: Stocked Acclimation pens



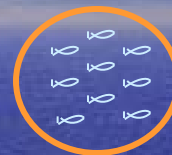
NCO



NCL

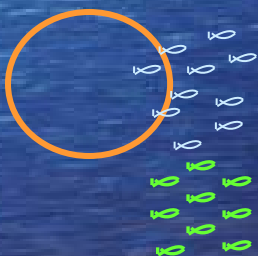


CCL

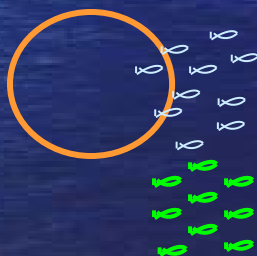


NCM

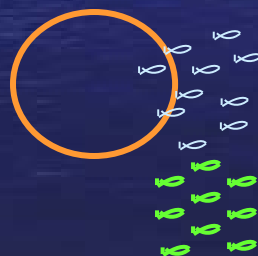
Day 3: Released snook from acclimation pens
& also Stocked non-acclimated snook



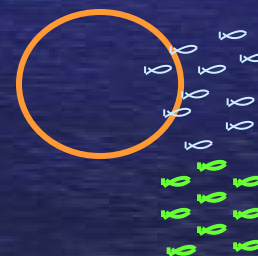
NCO



NCL



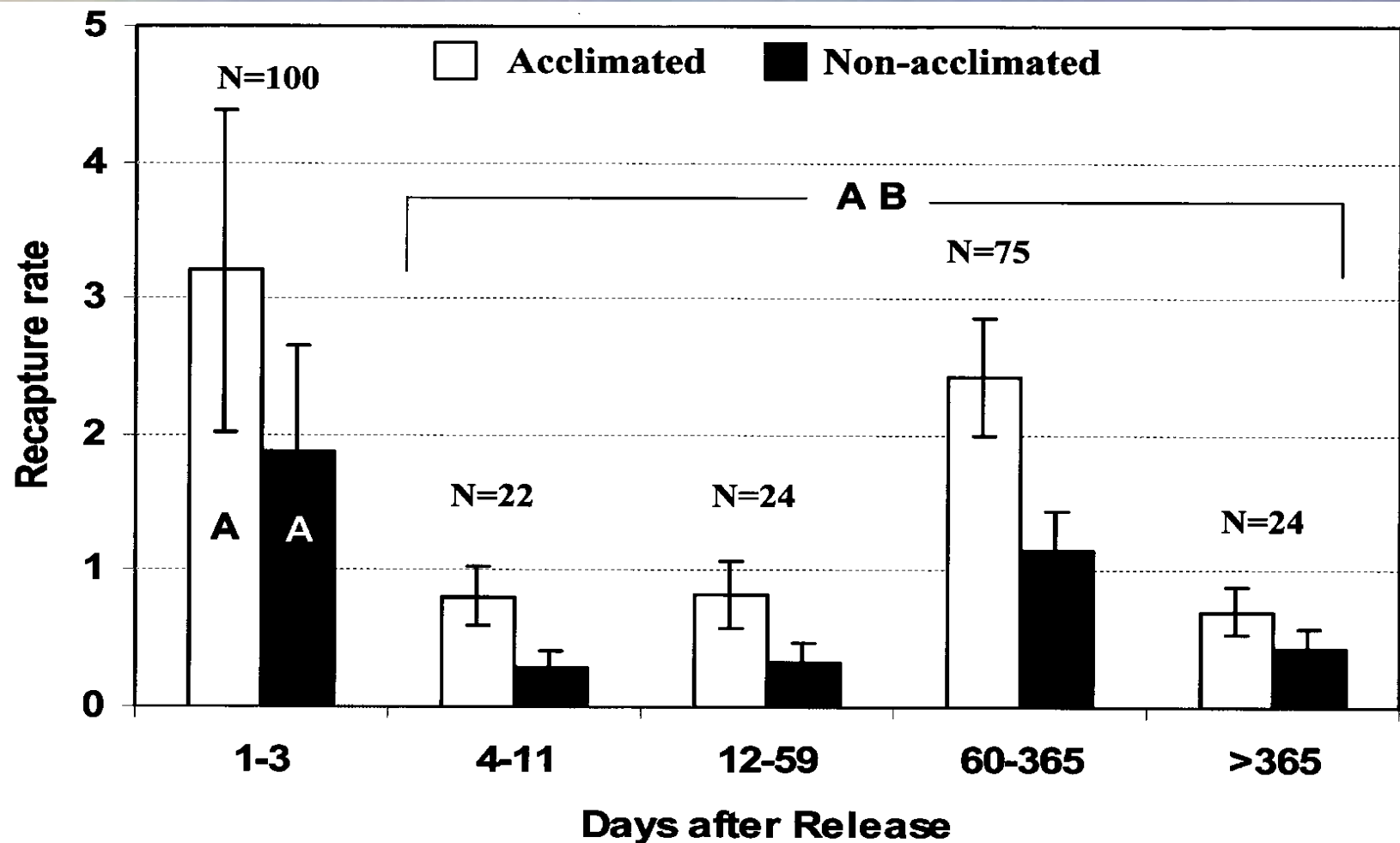
CCL



NCM

Replicated this experiment 3 times

Acclimation effect on recapture rate Of hatchery-released snook



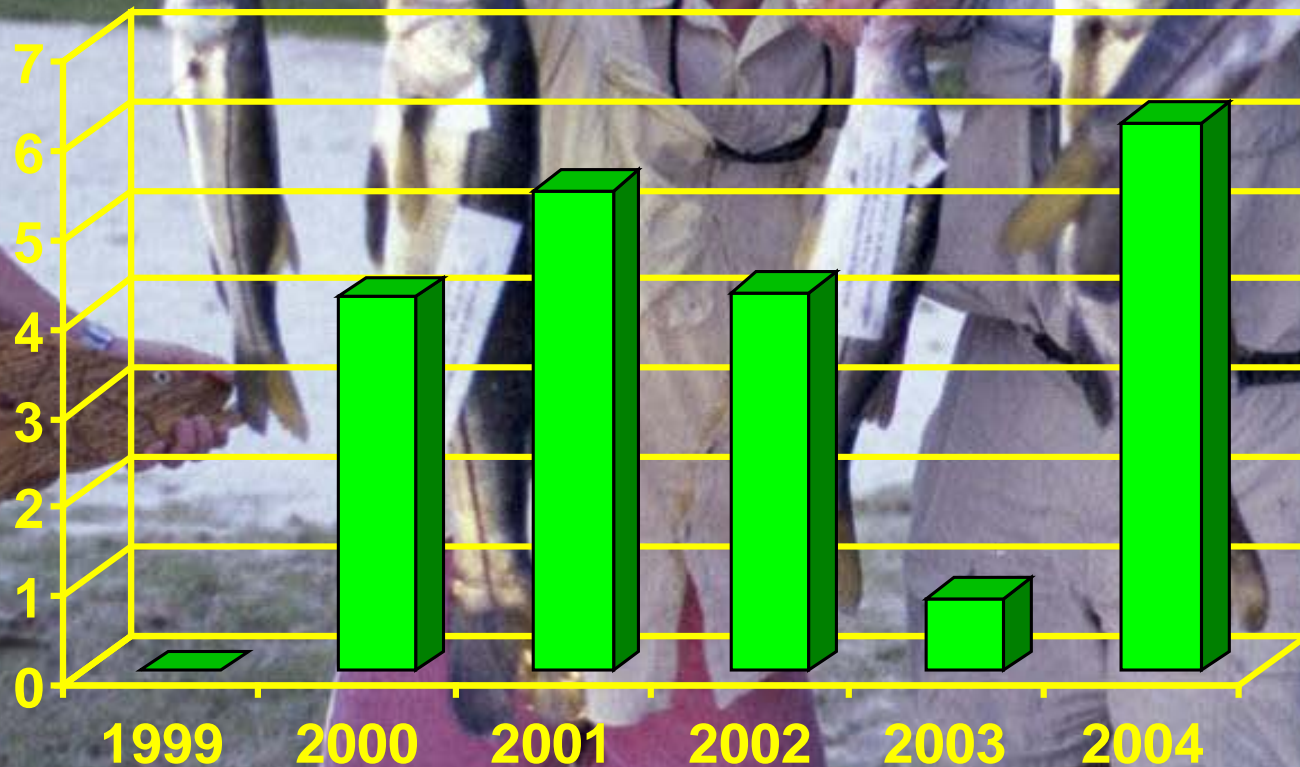
...assess enhancement Effectiveness

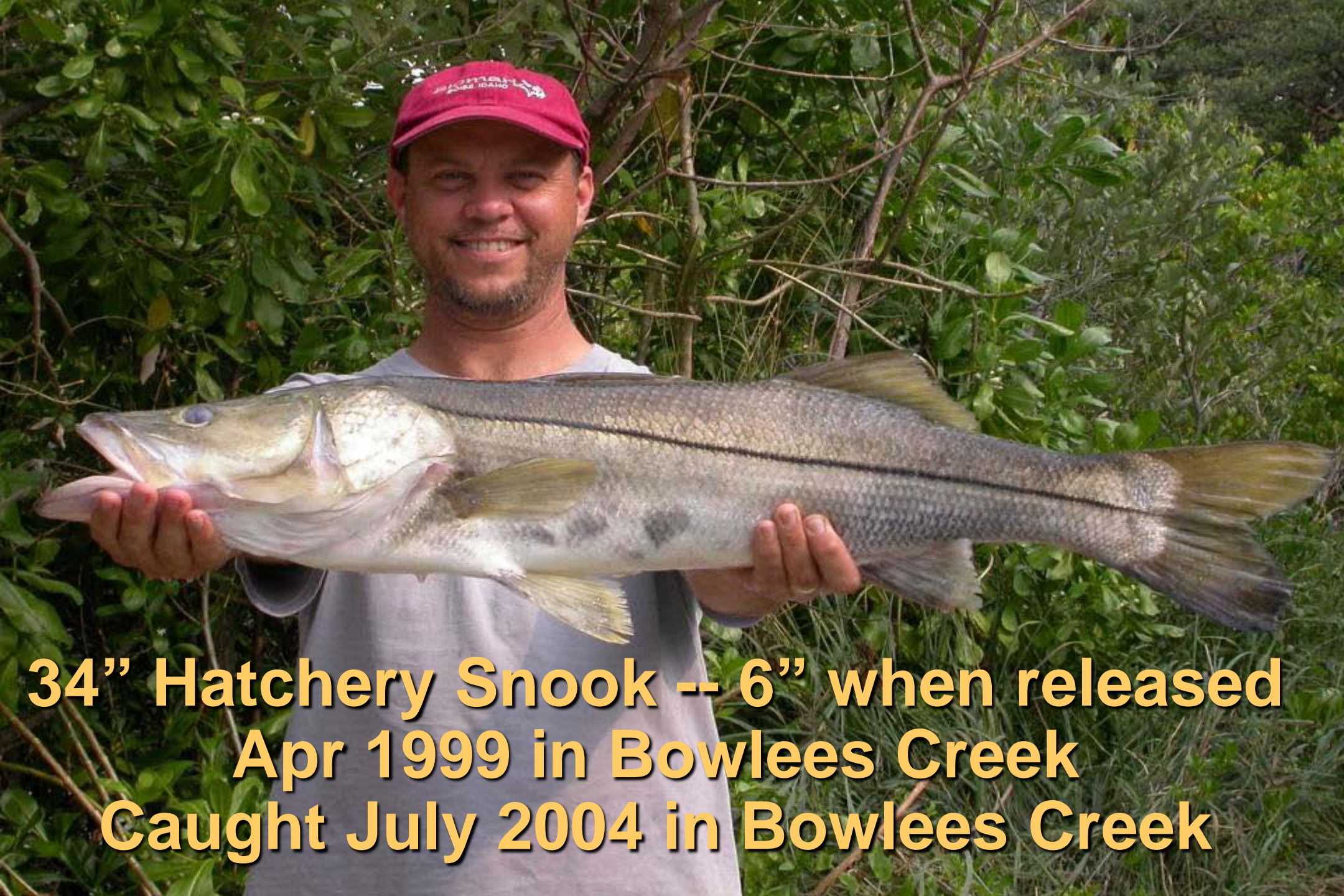




Small-scale stocking clearly making a contribution to a valuable fishery in Florida

PERCENT HATCHRY FISH

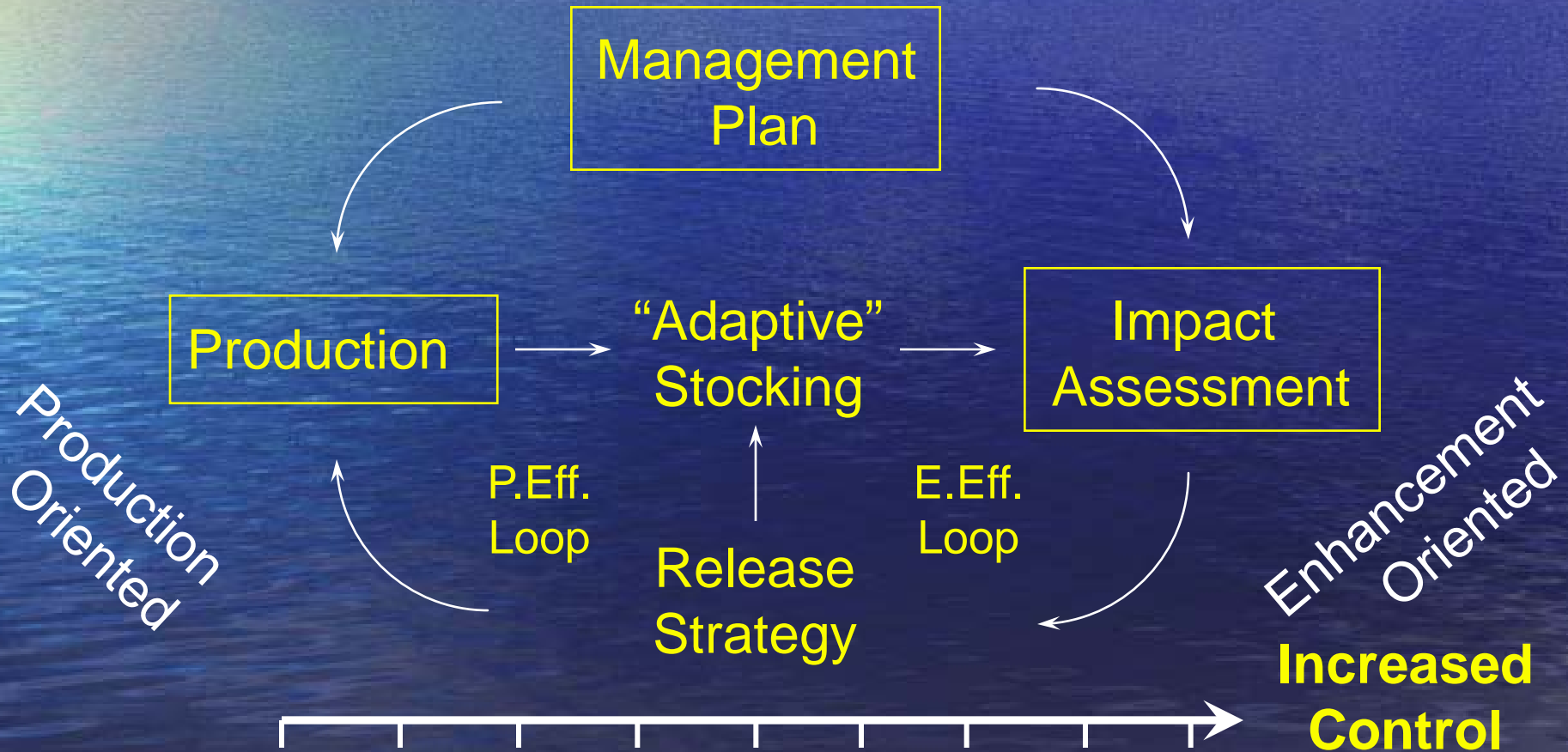




**34" Hatchery Snook -- 6" when released
Apr 1999 in Bowlees Creek
Caught July 2004 in Bowlees Creek**

Adaptive Management is Crucial

Recognize “Production - Enhancement”
management dichotomy



Responsible Approach Update

- ✱ We have provided a set of issues that need to be addressed if enhancements are to be developed or reformed responsibly
- ✱ The new responsible approach differs from its predecessor in that it takes a broad systems view of enhancements and accords equal weight to the dynamics of their biological and human components
- ✱ It requires an integrated, quantitative and participatory analysis of the contribution enhancement could make to fishery management goals, which should be conducted at the very beginning of any enhancement initiative



**SCORE
Consortium**

- Mote Marine Laboratory
- NMFS NW Fisheries Science Center
- University of New Hampshire
- University of Southern Mississippi
- Hubbs-SeaWorld Research Institute (coming soon)

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NOAA NMFS
&
NOAA Aquaculture



Conferences, Symposia, Workshops on Stock Enhancement

International Symposia on Stock Enhancement and Sea Ranching

[\[about this symposium series\]](#)

2010 — 4th International Symposium on Stock Enhancement and Sea Ranching

***Spring, 2011, Shanghai Ocean Fisheries University, Shanghai, China**

A Special Symposium in conjunction with the 9th Asian Fisheries and Aquaculture Forum

*(Revised dates)

2010 — Cultured Aquatic Animals: Use and Implications for Stock Enhancement, Fisheries Management, and Species Diversity

March 1 - 5, 2010, San Diego, California, USA

A Special Symposium in conjunction with [AQUACULTURE 2010](#)

2006 — 3rd International Symposium on Stock Enhancement and Sea Ranching

Seattle, Washington, USA, September 2006

- **NEW** The **Proceedings** were published in "Reviews in Fisheries Science" in 2008

2002 — 2nd International Symposium on Stock Enhancement and Sea Ranching

Kobe, Japan, February 2002

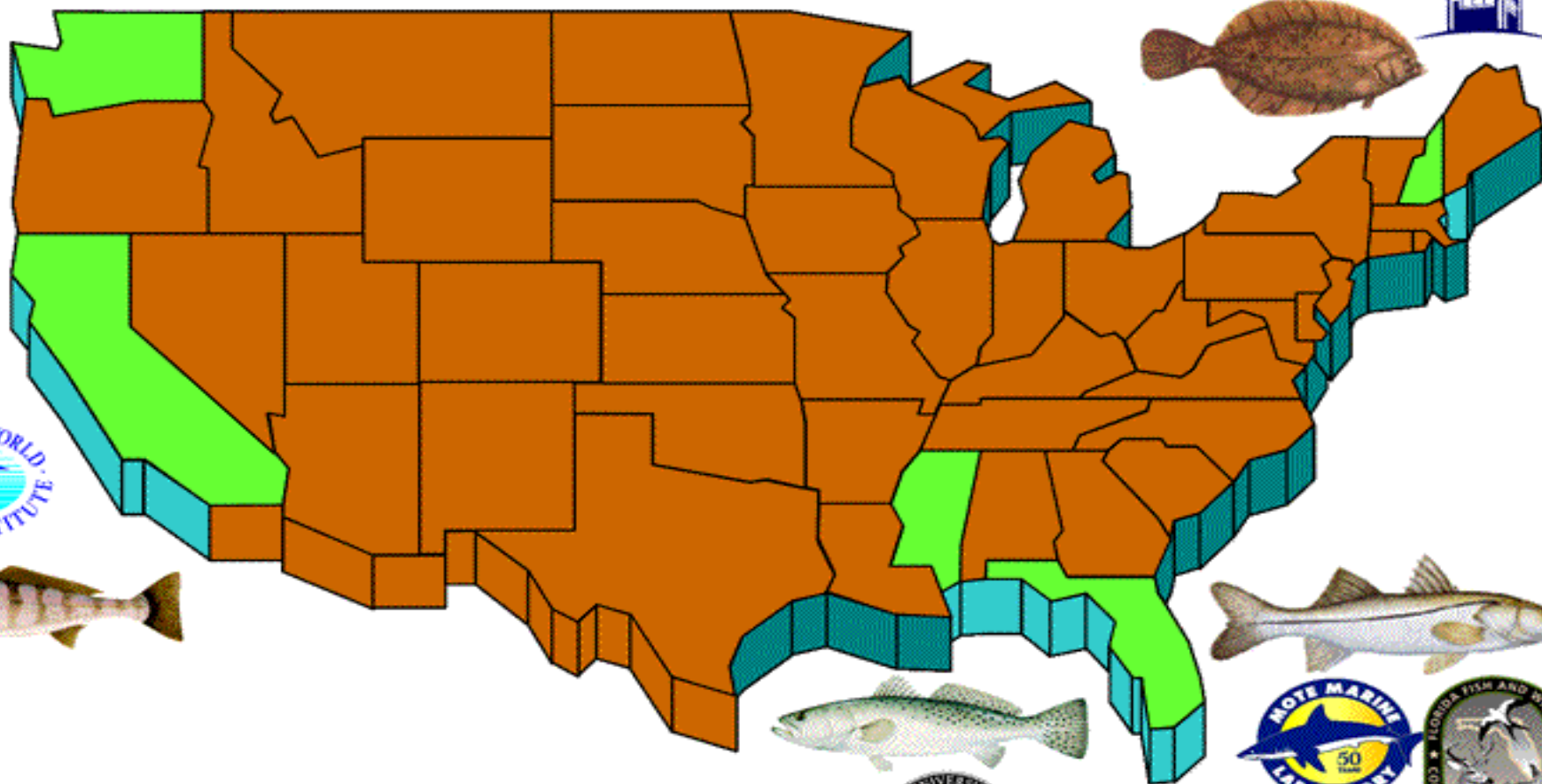
- The symposium proceedings were published by Blackwell Science in 2004

1997 — 1st International Symposium on Stock Enhancement and Sea Ranching

Bergen, Norway, September 1997

- The symposium proceedings were published by Blackwell Science in 1999

SCORE TEAM



SCORE Consortium

- Mote Marine Laboratory
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- University of New Hampshire
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Marine Stock Enhancement Projects in the USA

Hatchery Reform Movement

- Puget Sound and Coastal Washington Hatchery Reform Project
- Hatchery Scientific Review Group (HSRG) - an independent scientific panel

Marine Stock Enhancement Research & Development

Most non-salmonid marine stock enhancement in the USA is research oriented, with an emphasis on gaining better understanding and greater control of stocking effectiveness.

Research Consortia

- Alaska King Crab Research, Rehabilitation & Biology Program (AKCRRAB)
- Blue Crab Advanced Research Consortium (BCARC)
- Science Consortium for Ocean Replenishment (SCORE)
- Oyster Gardening on the US East Coast | Gulf Coast | West Coast (search Shellfish Aquaculture)

Agencies

- Alabama Department of Conservation and Natural Resources
- Florida Fish & Wildlife Conservation Commission | Florida Marine Fisheries Enhancement Initiative
- Georgia Department of Natural Resources | Red Drum Enhancement: A Responsible Approach
- Maine Department of Marine Resources / University of Maine | UM Lobster Institute | Lobster Stocking
- Maryland Department of Natural Resources
- Massachusetts Division of Marine Fisheries
- Mississippi Department of Marine Resources | Seatrout Population Enhancement Cooperative
- National Oceanic and Atmospheric Administration (NOAA), US Department of Commerce
 - NOAA-Aquaculture: Aquaculture for Stock Enhancement
 - NOAA-Fisheries: NMFS' Historical Involvement in Stock Enhancement
 - NOAA-Fisheries Alaska Fisheries Science Center
 - NOAA-Fisheries Northwest Fisheries Science Center Manchester Research Station
 - NOAA-Fisheries Northeast Fisheries Science Center Milford Laboratory
 - NOAA-Fisheries Aquaculture in the Northeast Region
 - NOAA-Chesapeake Bay Office
 - NOAA-Sea Grant Alaska / Univ. Alaska Fairbanks
 - NOAA-Sea Grant Delaware / Center for Inland Bays Oyster Gardening
 - NOAA-Sea Grant Maine / Bigelow Laboratory for Ocean Sciences
 - NOAA-Sea Grant Maryland
- Northwest Indian Fisheries Commission
- South Carolina DNR Marine Resources Research Institute | Red Drum
- Texas Parks and Wildlife - Sea Center Texas

Universities and Research Laboratories

- Delaware Estuary Program (Partnership for the Delaware Estuary) Oyster Restoration
- East Coast Oyster Gardening Programs
- Hubbs-Sea World Research Institute
- Mote Marine Laboratory - Center for Fisheries Enhancement | Marine Stock Enhancement | Center for Coastal Ecology Scallop Project
- North Carolina State University | Summer Flounder | Blue Crab | Lip Franchiser



SCORE

SCIENCE CONSORTIUM FOR OCEAN REPLENISHMENT

StockEnhancement.org/science/publications.html

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SCORE
Scientist's
Publications




Indicates
Score Project


- Responsible approach to stock enhancement
- Stock enhancement books & journal proceedings
- Population dynamics and assessment
- Stakeholder effects on enhancement outcome
- Identifying hatchery fish
- Release magnitude effects on survival
- Contribution to spawning stocks, offspring & fisheries
- Impact of release strategies on costs
- Size-at-release effect
- Release habitat effect

Publications on Stock-Enhancement by SCORE Scientists

Responsible approach to stock enhancement

Blankenship, H. L. and K. M. Leber. 1995. A responsible approach to marine stock enhancement. In Uses and effects of cultured fishes in aquatic ecosystems. American Fisheries Society Symposium 15:165-175.  [>>read now...](#)

Bell, J.D., D.M. Bartley, K. Lorenzen and N.R. Loneragan. 2006. Restocking and stock enhancement of coastal fisheries: Potential, problems and progress. Fisheries Research. 80: 1-8.  [>>read now...](#)

NEW Bell, J.D., K.M. Leber, H.L. Blankenship, N.R. Loneragan and R. Masuda. 2008. A new era for restocking, stock enhancement and sea ranching of coastal fisheries resources. Reviews in Fisheries Science 16: 1-8.  [>>read now...](#)

NEW Lorenzen, K. 2008. Understanding and managing enhancement fisheries systems. Reviews in Fisheries Science 16: 10-23.  [>>read now...](#)

Stock enhancement books and symposium proceedings

NEW Johann D. Bell, Kenneth M. Leber, H. Lee Blankenship, Neil R. Loneragan, Reiji Masuda and Geraldine Vander Haegen (Editors). 2008. A New Era for Restocking, Stock Enhancement and Sea Ranching of Coastal Fisheries Resources. (Proceedings of the 3rd International Symposium on Stock Enhancement and Sea Ranching) Reviews in Fisheries Science, Volume 16 Issue 1-3. [View on-line abstracts...](#)

Leber, K. M., S. Kitada, H.L. Blankenship and T. Svåsand. 2004. Stock Enhancement and Sea Ranching: Developments, Pitfalls and Opportunities. 2nd Edition. Blackwell Publishing, Oxford. 562 pp. [Preview](#) at Blackwell's web site for the book

Bartley, D.M. and K.M. Leber, Editors. 2004. Case Studies of the Effectiveness of Stocking Aquacultured Fishes and Invertebrates to Replenish and Enhance Coastal Fisheries. Fishery Technical Paper No. 429. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. 213 pp. [View electronic version...](#)

Nakamura, Y., J.P. McVey, K. Leber, C. Neidig, S. Fox, and K. Churchill, (eds.). 2003. Ecology of Aquaculture, Coastal Fisheries, and Stock Enhancement of the Thirteenth U.S.



Florida's Marine Fisheries Enhancement Initiative

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Florida Marine Fisheries Enhancement Initiative

Strengthening the Future for Sportfishing Along Florida's Vast Coastal Waterways.

A Brief Description

The Florida Marine Fisheries Enhancement Initiative is a multi-year, multi-partner program vital to sustaining our saltwater sportfish populations and the natural habitats of our precious marine life.

Our first saltwater hatchery helped keep the red drum population healthy and available in the Tampa Bay area. New technology and scientific insight have enabled the construction of even more effective marine enhancement centers that can provide a variety of game fish, at different stages of development.

THE BIG THREE



Red Drum



Snook



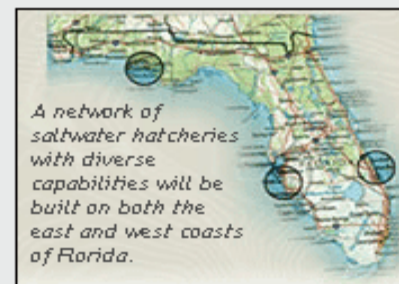
Spotted Sea Trout

To help bolster Florida's sportfish populations that will otherwise be reduced by current demand, fishery scientists and managers advise creating a series of strategically networked hatcheries and grow-out facilities on both the Atlantic and Gulf coasts. This network, combined with parallel habitat restoration, will be most the efficient model for sustaining healthy sportfish populations.

Florida is the most popular sportfishing destination in the country and that popularity contributes almost \$8 billion to Florida's economy annually. Maintaining healthy fish populations and habitats is critical to the continuation of that success. That is why we urge everyone who lives, works or plays in our beautiful state to help us make this initiative a reality and **Support Florida Sportfish**.

A Team Effort

Construction of these innovative marine propagation and ecosystem restoration facilities will only be possible through teamwork. In addition to the partners already involved in the initiative, the team must include support from government, non-profit, academic and private fisheries research institutions-and from concerned citizens and other stakeholders. We also want to work with interested communities to design a localized program that can involve all interested residents. Your contributions are vital. Donations can be in the form of time, money, or property.



A network of saltwater hatcheries with diverse capabilities will be built on both the east and west coasts of Florida.

[Http://www.fmfei.org](http://www.fmfei.org)

Questions?

