U.S. AQUACULTURE: THE PAST, TODAY AND THE FUTURE …

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Aquaculture/Aquatic Livestock Committee
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Aquaculture is defined as the farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated (FAO, 2006)
1762, overfishing had eliminated striped bass and sturgeons from the Exeter River, New Hampshire

1776 The United States officially declares independence from the British Empire

1790 dams blocked the spawning runs of the alewife and destroyed the fishery at Exeter River
Rise of US Aquaculture

- 1812 Fishery science began in the U.S.
  - Philadelphia Academy of Science
  - curriculum in aquaculture for undergraduates at Cornell University.

- 1831 - 1872 early descriptions of rearing fish in US involved introduction of the common carp into US waters by private residents.

- 1853 two Cleveland physicians, Theodatus Garlick and H. A. Ackley, performed the first successful artificial fertilization of fish eggs in the United States in 1853.
Early US Aquaculture

- 1864 Seth Green - 1st trout hatchery Caledonia, New York.

- 1870 the culture and sale of brook trout. Also Atlantic salmon, American shad, lake trout, largemouth bass, lake whitefish, and yellow perch were being cultured in hatcheries within 19 of the then 37 states.

- 1871 newly formed American Fish Culturists' Association lobbied Congress to create the Commission on Fisheries, Spencer Baird first Commissioner.
Early US Aquaculture

- 1882 report to Congress, carp fingerlings distributed to applicants in every state and territory in the U.S. in 1478 counties.

- Nutrition - one of the main issues by fish culturists
  Early feeds - raw or cooked fish; boiled lean meat; egg yolk; liver; clabbered milk; a mixture of ground heart, liver, and lungs of beef and pork; and live minnows, worms, and insects (including maggots).

- Early 1900’s fisheries upper education programs expanded.
Early US Aquaculture

- 1932 Auburn University, began experimenting with fish in small ponds in Alabama. Cornell University established fisheries program.

- 1934 Auburn began research on the culture of goldfish, fathead minnows and golden shiners as market potential realized for baitfish.

- 1900 – 1930 fish transportation moved from rail (fish cars) to truck and air.

- 1950s U.S. Department of Agriculture encouraged farmers to build ponds to conserve soil and water. The potential for these ponds to support sport fishing was quickly realized.
Early US Aquaculture

- 1958 first dependable dry-pellet diet for trout.

- 1950 - 1960, annual trout production was estimated at 2 million #/year / essentially no production of channel catfish.

- 1963 – 1969 surface area for catfish ponds expanded from 948 to 16,000.

- 1966 Fish farming became the fastest growing segment in agriculture in the state of Arkansas. Chanel catfish moved from sport fish to food fish.

- 1970 Mississippi became the largest catfish producing state.

- 1985: 49,000 ha in catfish ponds, a 300-fold in 25 years.
Aquaculture Legislative History

- 1954: Saltonstall-Kennedy Act provides authority for NOAA to support fisheries research and development including harvesting, processing, aquaculture, marketing, and associated infrastructures.

- 1968: National Sea Grant College Program Act provides NOAA with authority to conduct research, extension, education, and communications to achieve a sustainable environment and to encourage the responsible use of America's coastal, ocean, and Great Lakes resources, including support for aquaculture.

- 1973: Endangered Species Act requires NOAA to take various actions to protect and recover all threatened and endangered species under the Department of Commerce. This includes actions to address potential impacts from marine aquaculture facilities.
1980: National Aquaculture Act established the policy that it is our nation's interest, and it is the national policy to encourage the development of aquaculture in the United States.

- Secretary of Commerce is authorized to provide advisory, educational, and technical assistance and to encourage the implementation of aquaculture technology in rehabilitation and enhancement of publicly owned fish and shellfish stocks, and in the development of private commercial aquaculture enterprises.

1985: National Aquaculture Improvement Act amended one section of the national aquaculture act. (3) Section 2 (a)(7) of the National Aquaculture Act of 1980, 16 U.S.C. 2801, was amended by this act by inserting "scientific" before "economic", and by inserting "the lack of supportive government policies" immediately after management information.
• Caged aquaculture operations in the Great Lakes are currently limited by available technology and suitable sites.

• The aquaculture industry is interested in achieving economically-viable and environmentally-sustainable operations.

• Both the aquaculture industry and governments want to limit water quality and habitat impacts.

• Neither caged nor land-based aquaculture is expected to grow substantially.
US Shellfish Production

U.S. Aquaculture Production: Shellfish Species

- MILLION LB
- MILLION $
- DEF MIL $
US Rainbow Trout Production

Qty and Value (food size)

Million lbs

Million $

1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011

Courtesy: Clear Springs Foods, Inc.
US Baitfish Production

Qty and Value

- Million lbs
- Million $

US 2007 Agriculture Census

$1.0-1.4 Billion

Source: 2007 USDA Census of Agriculture
Includes State, Federal and Tribal Hatcheries
US 2012 “Best Estimate”

Percentage in value of production

- Catfish: 29%
- Shellfish: 40%
- Tilapia: 8%
- Salmon: 10%
- Trout: 8%
- Baitfish: 5%
- Tilapia: 8%
2010 Value Aquaculture Worldwide

China 49%
Asia (w/o China) 32%
Europe 8%
Americas (-US) 7%
US 1%
Africa 2%
Oceania 1%

Total $119 Billion USD

Source FAO 2013 database
US Aquaculture Today

- 70 national fish hatcheries
- 300 state hatcheries
- 4,000 commercial aquaculture facilities
US Aquaculture Today

Source FAO 2013 database
Global Aquaculture Africa, Americas, Asia, Europe, Oceania

Source FAO 2013 database
Aquaculture Today – a Diversity of Opportunities

• Production of aquatic organisms for human consumption;
• Compensate or strengthen the natural population;
• Production of bait fish,
• Production of aquarium fish,
• Mussels for the pearl industry
• Algae for chemical, medicine and food industries
• Research
• Water purification
• Control of aquatic weeds and pests.
Salmon Ranching - Alaska

- 1971 Alaska Legislature created the Fisheries Rehabilitation Enhancement and Development (FRED) Division within ADF&G

- 1974 the legislature passed the Private Nonprofit (PNP) Hatchery Act.

- 1988 the legislature authorized operation of state hatcheries to be contracted to PNP hatchery corporations.

Source: NOAA
Pond and Flow Through Systems
Solids Clarifier

Settling basin and siphon

Serial Re-Use Discharge

Microscreen drum filter
Shellfish aquaculture currently makes up about two-third of U.S. marine aquaculture. Pictured here is oyster aquaculture in Tomales, California. Credit: NOAA
Recirculating Aquaculture Systems

New ADFG Anchorage Salmonid RAS Facility
Blue Ridge Aquaculture, Virginia, USA
largest-producing indoor fish farm in the world
Live feed systems
Rotifers, monia, copepods, etc…

• New algal strains high in DHA for enhancement of live feeds
• Freeze dried algae for ponds and green water systems
• Computer automated marine larvae feeding systems
• Rotifer counter for first feeding (Norway)
• Artemia nauplii rotating drum filters (Taiwan)
• Disinfection methods for live feeds (Scotland)
Aquaponics Systems

integrated systems combining fish, water gardening plants, vegetables, effluent treatment,…
AQUACULTURE OF BIOMEDICAL SPECIES

Sponges, soft corals, tunicates, and bryozoans, have been harvested for key compounds extracted for medical and cosmetic uses.

Treatment of cancer, infectious diseases, inflammation, and enhancing immune response.

Study effects of disease – e.g. zebrafish
Aquaculture - Today

- Aquaculture accounts for 50% of all seafood consumed in the World, and the proportion is growing quickly!

- Global Aquaculture Production is valued at $100 Billion.

- US Aquaculture production is currently just under $1 Billion.
Aquaculture - Today

- US Consumers eat an average of 15 lbs. of fishery products per capita.

- 2010 USDA Dietary Guidelines for Americans recommends 26 lbs seafood annually per capita.

- Global per capita consumption of seafood is 17kg (34 lbs)

- Americans consumed 4.7 billion pounds of seafood in 2011, 91% of which was imported (86% in 2010).
U.S. Economic Impact

- Farm-gate value: $0.94 Billion
- Total value: $5.6 Billion
- 181,000 full-time jobs
- One of the fastest growing sectors of U.S. agriculture since 1980’s

Source: FAO Fishstat Plus Version 2.30 & Economic-wide impacts of U.S. aquaculture
The current US trade deficit in fisheries products is $10.9 Billion.
Emerging/Non Traditional in US

- Caviar/roe
- Cobia
- Sea Bass
- Meagre
- Sea bream
- Grouper
- Pompano
- Yellow and Bluefin Tuna
Emerging

- Algae
- Sea Vegetables
  - Sea cucumbers
  - Kelp
  - Nori
  - Dulse
Hot Research Areas

- Breeding for Omega-3s Norway
- IMTA Integrated Multi-Trophic Aquaculture
- Nutrition Nutrition Nutrition
Hot US Issues

- Aquaponics
- Sustainability
- Energy
Trends RAS

- Denitrification
- Microbial flocs
- De-phosphorus flocculation
- “Zero discharge”
Hot US Issues

- Shellfish industry
  + 12.8% annual increase 1998 - 2008

- Catfish industry
  - 32% 2007 to 2011

- AIS / ANS
  - Asian Carp
    - Grass carp (most states sterile only)

- Regulations Regulations Regulations Regulations
Is it in the national interest to significantly increase aquaculture production?
- Less fishing
- Do not see much of PETA
  - should expect issues in EU to move in.
- Strong momentum for aquaponics
- More opportunity for locally grown products
- Rising concerns for safe and healthy seafood
- BUT – also overwhelming influence of cheaper available seafood
Trends in US Aquaculture

- Major producers tend to be older in age and highly productive new facilities are rare.
- Increased burden due to restrictive regulations.
- Financing through lenders extremely difficult to obtain.
Regulatory Trends

- Regulation through restriction rather than promotion

- Increasing use of regulations,
  - especially Lacey
  - Complex and redundant
US public laws and acts for invasive species

- **Lacey Act** 1900
- **NANPCA** 1990
- **National Invasive Species Act (NISA)** 1996
- **Executive Order 13112** 1999
- **Asian Carp Prevention and Control** 2010
# NCR States Live Fish Importation Health Certification Guide

<table>
<thead>
<tr>
<th>State (links to summaries)</th>
<th>OIE Blue Book</th>
<th>Import Permit</th>
<th>Listed VHS at-risk state</th>
<th>Salmonids (testing - see below *)</th>
<th>VHS for susceptible species from non at-risk states</th>
<th>Baitfish</th>
<th>Cool/warm water fish species</th>
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Footnotes and salmonid testing requirements provided below [here](http://www.ncrac.org/roadmap/regulations.html)
Michigan Permits

MDARD
- Aquaculture Facility Registration, 1 month
- Aquaculture Research Permit, TBD
- Prior Entry Permit, < 1 week
- Private Stocking/Public Waters, <15 days

DNR
- Salmonid Importation, <30 days
- Wholesale Minnow Dealer License, <15 days

DEQ
- NPDES, 180 days
- Groundwater Discharge, 180 days
- Water withdrawal, 180 days
- Wetland, Inland Lakes & Streams, 2-6 months
- Non-Community Water Supply
- Potable, well construction
- NPDES – Construction, upon receipt
- Soil/Sediment Control: local government, TBD
- Great Lakes Bottomland, TBD

Federal
- Bird/Wildlife Depravation
- As needed, USDA WS & DOI F&W

New/Expanding Facility: Priority Permits

MI Water Discharge

Discharge outlet

See the MADA Act of 1996, List of Species – Appendix C

To a private or municipal water treatment facility

Ground discharge

Irrigation of effluent on cropland

To “Waters of the State”

Yes

No

No State/DNR permitting needed, proceed to discharge load arrangement with your discharge

Advance to Groundwater Discharge

???? Can we address in Irrigation GAAMP???

NPDES Process

Advance to NPDES Permit Application, via the DEQ Surface Water Assessment Section

Free to operate without NPDES discharge permit

This process/rule could benefit from an assessment tool

http://www.michigan.gov/deq/0,4561,7-135-3313_3686_3728---,00.html - see Part 4 & Part 8 Rules – bottom right

Note – unresolved is the question about if the addition of treatment chemicals will require NPDES permitting

Projected Facility production of >100,000 lbs of fish or > 20,000 lbs coldwater fish of aquatic species annually

Irrigation of effluent on cropland

???? Can we address in Irrigation GAAMP???

To “Waters of the State”

Yes

No

Advance to Groundwater Discharge

Free to operate without NPDES discharge permit

Project end
Bunker survival mode / under the radar??

Waiting to see what the next regulation to be proposed is going to be

Food fish production being seriously outpaced by other countries

Trends towards decreases in recreational fishing likely to add additional burden to baitfish sectors
Trends in Commercial Aquaculture and Baitfish Sectors

- Seeking legitimacy
  - Certifications
  - Best Management Practices
  - Biosecurity Plans
  - AIS HACCP
    - Certification?
      - e.g. certifiable body /3rd party

- Industry asking/should have a seat at the table
USDA Agriculture Research Service 2007

“Aquaculture will be the most likely source of food fish going into the 21st century. With increasing seafood demand and declining capture fisheries, global aquaculture production will have to increase by 500 percent by the year 2025, to meet the projected needs of a world population of 8.5 billion.”
A World in Crisis?

Number of hungry people in the world 2010

Total = 925 million

- Developed countries: 19
- Near East and North Africa: 37
- Latin America and the Caribbean: 53
- Sub-Saharan Africa: 239
- Asia and the Pacific: 578

Source: FAO.
Areas of Physical and Economic Water Scarcity


FAO Projections 2050

Global population (billion)

Fertility rate
- Current
- High
- Medium
- Low

Global water capacity

Meat production is growing fast in the developing countries...

- East and Southeast Asia
- Latin America and the Caribbean
- Near East and North Africa
- South Asia
- Sub-Saharan Africa

Source: The State of Food and Agriculture. Livestock in the balance (FAO 2009)
<table>
<thead>
<tr>
<th>Commodity</th>
<th>Carbon Footprint (Kg CO2/kg edible)</th>
<th>Energy Use (MJe/kg edible)</th>
<th>Source</th>
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<tr>
<td>Pork, Sweden</td>
<td>5.9</td>
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<td>2.7</td>
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<tr>
<td>Salmon, Norway</td>
<td>2.9</td>
<td>40</td>
<td>Winther et al (2009)</td>
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</tbody>
</table>
Protein Conversions and Efficiencies

Protein conversion from grain (protein to protein)

1 kg fish – 13.5 kg grain
1 kg pork – 38 kg grain
1 kg beef – 61 kg grain

Protein efficiency values for major food commodities (%)

Source: Hall et al. 2011, Blue Frontiers
Health Risks -vs- Benefits

- Salmon, Atlantic, farmed*
- Salmon, Atlantic, wild*
- Oysters, Pacific**
- Rainbow trout, farmed*
- Oysters, eastern, wild**
- Salmon, Pacific***
- Rainbow trout, wild*
- Tilefish*
- Tuna, white, canned
- Swordfish*
- Shark
- Pollock, Atlantic*
- Flounder/sole*
- Halibut, Atlantic and Pacific*
- Oysters, eastern, farmed*
- Scallops, bay and sea (100g)
- Crab, king**
- King mackerel*
- Ocean perch, Atlantic*
- Shrimp, mixed*
- Clams, mixed*
- Cod, Pacific*
- Tuna, light canned
- Haddock
- Catfish, wild*
- Catfish, farmed*
- Cod, Atlantic*
- Lobster, northern**

Mercury (µg) vs. Omega-3 Fatty Acids: EPA/DHA (grams)

*Cooked, dry heat; **Cooked, moist heat; ***EPA/DHA is a composite from chum, coho, and sockeye salmon
Attributes of Fish as Food Source

- High-value protein.

- High in Polyunsaturated omega-3 fatty acids (docosahexaenoic acid -DHA and eicosapentaenoic acid - EPA).

- Low in saturated fats, carbohydrates and cholesterol.

- Contains a wide range of essential micronutrients (vitamins A, B, D) and minerals (calcium, iodine, zinc, iron and selenium.)

Small quantities of fish can have a significant positive nutritional impact by providing essential amino acids, fats and micronutrients that are scarce in vegetable-based diets.
Evidence of beneficial effects of fish consumption in relation to:
- coronary heart disease
- stroke
- age-related macular degeneration
- mental health
- growth and development, in particular for women and children during gestation and infancy for optimal brain development of children.
China: Feeding the Beast

China’s Future Seafood Demand
Increase of 6 to 65 million metric tons

*Metric Tons Whole Weight

- Seafood diet*
- Diet change
- Increased calories*
- Population growth
- 2005 total

*Source: Int’l Institute for Applied Systems Analysis

Growing *per capita* seafood consumption

FAO, Seafood summit.org
US Consumption Share

Per capita availability (lbs)

Source USDA (2010)
Global Trends – should expect!

- Increasing seafood consumption
- Increasing seafood production
- Increasing pressure from environmental groups
- Regulations – health and importation
- Animal Welfare
- Aquaculture and seafood certification programs “Eco-labels”
  - Examples, MSC, GAP, Whole Foods
Global Trends – should expect!

- Investments in Aquaculture coming from a diverse set of investors and sources.

- Mature Facilities
- Wild Harvest
- Seafood Processing
- Venture Capital
- Ag Protein
- Equity Funds
- Private Equity
US Aquaculture – Future?

Blue Bayou

- Slight expansion of shellfish industry
- Small hobby fish farms and aquaponics thrive
- Little realized ROI

Fish the Other Other White Meat

- Regulatory clarity / streamlined
- US major exporter fish and shellfish
- US per capita consumption in line with rest of the world
- Multi-billion $ industry

Left Behind

- Limited expansion shellfish industry
- Catfish continuous decline
- Deficit $100+ Billion
- US shortage of seafood

Stuck in Second Gear

- Slight expansion of shellfish industry
- Small hobby fish farms and aquaponics thrive
- Little realized ROI

Graph:

- US Seafood Imports
- US Seafood Exports
- US Seafood Trade Deficit

Billions of Dollars

0 5 10 15 20
Questions?

Aquaculture Information List Serve

http://www.ncrac.org/

NCR Fish Culture List Serve
(http://www.ncrac.org/node/406)

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