Securing our future: the role of aquaculture

Geoff Allan

NSW Department of Primary Industries, AUSTRALIA
In 2009, seafood supplied 16.6% of world population intake of animal protein & 6.5% of all protein

FAO Status of World Fisheries and Aquaculture 2012
Health benefits

- Heart disease & stroke - reduces triglycerides, optimises blood pressure, improves blood flow, minimises irregular heart beat
- Rheumatoid arthritis & other auto-immune diseases
- Obesity
- Diabetes
- Asthma
- Some cancers
- Neural development
- Cognitive decline
- Maculopathy
- Depression
- Particularly important for pregnant women and the elderly
Demand

♦ In 2010, the world consumed 128 Mt of fish, 60 Mt from aquaculture*

♦ Increasing demand in China & rest of Asia – rising middle class!

♦ Predict 3 billion middle class people in Asia within 10 years

♦ Increased protein consumption with increased income & seafood is a preferred protein source

♦ China may already be a net importer of seafood

*FAO Status of World Fisheries and Aquaculture 2012
Plan

• Global seafood supply & future demand

• Challenges & priorities to secure future seafood supply
  – Hatchery production
  – Genetic improvement
  – Nutrition and feeds
  – Health management
  – Production systems
Capture fisheries & aquaculture

*FAO Status of World Fisheries and Aquaculture 2012
Supply & consumption*

*FAO Status of World Fisheries and Aquaculture 2012
Global Seafood Requirements (million tonnes)

- Additional demand if consumption increases at same rate as during 2000-2010
- Additional demand if consumption stable at 2010 level 18.6 kg/capita whole fish
- Aquaculture production less plants (assumes stable production past 2010)
- Capture production less non-food (assumes stable production past 2010)
Global Seafood Requirements (million tonnes)

If capture prod & consumption stable at 2010 level:
♦ Need 80 Mt from aqua (20 Mt above current) by 2025
♦ Need 99 Mt (39 Mt above current) by 2050

If capture stable & consumption increases at 10 yr rate:
♦ Need 111 Mt from (51 Mt above current) by 2025
♦ Need 189 Mt (128 Mt above current) by 2050

- Additional demand if consumption increases at same rate as during 2000-2010
- Additional demand if consumption stable at 2010 level 18.6 kg/capita whole fish
- Aquaculture production less plants (assumes stable production past 2010)
- Capture production less non-food (assumes stable production past 2010)
What do consumers think of seafood?

Community perceptions of the sustainability of the fishing industry in Australia

April 2011

Community perceptions of the sustainability of the sectors of the Australian fishing industry

<table>
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<td>Traditional fishing</td>
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<td>Recreational fishing</td>
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<tr>
<td>Commercial fishing</td>
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Base: All respondents; n=1025

Prepared for: Peter Horvat
Communications Manager
Fisheries Research and Development Corporation

Prepared by: Michael Sparks
Director
Intuitive Solutions
Reality for capture fisheries

• Most species are fished sustainably
• Most are resilient
• High quality products
• Important in coastal communities
• Growing demand for fresh, locally caught seafood
• Reality that global increases in production unlikely

Need 111 Mt from (51 Mt above current) by 2025
Need 189 Mt (129 Mt above current) by 2050
Food security for seafood – can we produce enough to meet demand?

• *Yes but* ....

• For capture fisheries need to:
  – Maintain stock & ecosystem
  – Secure access to fishing areas

• For aquaculture:
  – Hatchery production
  – Genetic improvement
  – Nutrition and feeds
  – Health
  – Production platforms

• For both wild catch & aquaculture:
  – Correct community perceptions
  – Improve post-harvest & supply chain management
Food security for seafood – can we produce enough to meet demand?

- Yes but ....
- For wild catch need to:
  - Maintain stock & ecosystem
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Hatchery production

Essential for all successful, sustainable aquaculture

• Transfer and spawning of broodstock
• Domestication
• Controlled spawning
• Larval rearing
• Nutrition – live feed/ formulated diets/ weaning
• Health – microbial management/ parasites/ treatments
• Biosecurity
• Transport
Variable hatchery success has driven production of many spp

- Freshwater species
  - carps, tilapia, catfishes, salmonids
- Technology for freshwater species advanced, not a barrier to development

Priorities: improvement in survival & growth, health management; improved biosecurity SPF & reduced costs

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<td>Transport</td>
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Y achieved; P partially achieved; N not achieved
Hatchery success – key driver for production

- Tra or striped catfish *Pangasianodon hypophthalmus*
- “Princess of Vietnamese Aquaculture”
- Mass seed production has led to the outstanding production success with production of 1.2 Mt in 2011
Growth of striped catfish larvae and fingerlings in Viet Nam*

Priorities for future include:

• Increased survival at each phase
• Better hormone management
• Genetic improvement

*Larvae & fingerlings increased 18 & 26 fold in last decade (Phuong, 2011)
Variable hatchery success has limited production for some marine species

- Marine species
  - Red drum, cobia, Asian sea bass, sparids, sea bream, shrimp, oysters, mussels, abalone, etc
- Technology still developing, problems with low survival & deformities barrier to development

Priorities:
- Manage broodstock for controlled spawning,
- Nutrition for larval rearing
- Systems & abiotic factors
- Health & microbial management
Hatchery success – Biosecurity 

*L. vannamei*

- Shrimp one of most successful aquaculture industries
- Major diseases decimated production, especially for *Penaeus monodon*
- Program of Specific Pathogen Free *Litopenaeus vannamei* successful
- Required multi-generational hatchery, strict biosecurity
- New mortality problem in Asia – unknown cause
Snapper growth to 33 dah in commercial-scale hatchery

\[ y = 0.0005x^{3.3206} \]
\[ R^2 = 0.9975 \]

\[ y = 0.0014x^{2.6834} \]
\[ R^2 = 0.9984 \]

- **21°C, 35‰, 14:10 L:D**
- **24°C, 20-35‰,** 12:12 and 18:6 L:D

Mean wet weight (mg)

Time (days after hatch)
Lack of hatchery success has prevented production of some spp

- Difficult species
  - Tunas, spiny lobsters, eels
  - High value industries restricted by supply of wild juveniles
  - No mass production
  - Exciting research advances

Priorities:
- Manage broodstock for controlled spawning,
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Southern Bluefin Tuna – research

- Broodstock transfer - helicopter
- Hormone treatment developed
- > 50 million eggs; ~ 74% of eggs collected successfully; fertilisation ranged from 55% to 85%
- Larval rearing – still massive mortality
Day 9, 6mm

Day 22, 12mm
Day 90, 19cm, 250g
Genetic improvement

- Hatchery technology precursor to genetic improvement
- Production increases from fish still well behind other terrestrial livestock
- Enormous, still largely untapped potential for production increases
Genetic improvement

• In Europe 37 genetic improvement programs for 14 selected species (AquaBreeding survey 2009)

• Differ in selection strategy, traits selected, numbers of generations

• Most run by private companies

• Genetic improvement maintains and improves the stock, avoiding inbreeding

• Control of reproduction essential to capitalise on advances in genetic improvement
Critical issues

• Organism characteristics:
  • Fecundity, potential for stripping gametes
  • Timing, opportunities for ploidy manipulation,
  • Gamete conservation.

• Choice of traits:
  • Growth, feeding efficiency, product quality (fillet yield, fish shape), disease resistance

• Type of breeding program:
  • Family based, marker assisted, individual selection

• Needs effective population size to restrict inbreeding & maintain genetic variability

• Substantial improvement possible e.g. 5-20%/generation
Priorities for genetic improvement

• Improved understanding & control of sex determination
• Better understanding and control of gamete quality
• Improved understanding of puberty
• Improved sterilisation methods (inc. ploidy & other technologies)
• Improved knowledge of interaction between traits
• Improved tools - particularly genomic tools to improve genetic improvement programs
Nutrition & feeds

- Basis for increases in sustainable production
- Better understanding of ingredients (excellence of fishmeal & fish oil)
- Improvements in transport & global trade
- Increased understanding of nutritional requirements
- Much better processing – esp extrusion technology
Nutrition & feeds

- Increases in use of formulated feeds
  4 Mt 1994 – 27 Mt 2007

- FAO 2012 estimates 67% aquaculture production “fed”

- Exceptions are filter feeders, fish fed on natural production, etc

Feeding continuum:

- Primary productivity only ➔ single ingredients
  farm-made feeds ➔ formulated pellets

- Farm made feed use will reduce but will still provide essential nutrition for many species for many farms
Primary challenge: supply & cost of ingredients

- Fishmeal & fish oil – will there be enough?
- What other protein & energy sources are available?
- Competition with ingredients for other feeds:
  - Other animal feeds (e.g. poultry, pigs)
  - Pet feeds
- Competition with biofuels
- Competition with humans
Fishmeal & fish oil use in aquafeeds

- Aquafeeds used 58.8% FM & ~80% FO in 2008
- Particularly in Europe, Northern America and Australia, concerns persist about sustainability of fishmeal & fish oil
- Not helped by alarmist documentaries like “the end of the line” and some NGO certification programs
But the reality is a bit different

- Use in aquafeeds does NOT threaten sustainability of resource
- Major FM/FO fishery judged to be among best managed fisheries in world + IFFO certification
- FM & FO sustainable - 5 Mt FM & 1 Mt FO achievable
- More from offal - 36% of source product in 2010 (FAO 2012)
- Not enough to meet demand at current use
- Reduced use of FM & FO in aquafeeds (driven by economics & made possible by research)

**Fishmeal & fish oil will remain key ingredients for aquafeeds - will increasingly be used for speciality & finisher feeds**
Alternative protein meals

Global production

USDA oilseeds: world markets & trade 2010; DDGS - ethanol producer mag, 2/9/2010

DDGS – Increased from >5 Mt/yr to 30 Mt/yr in 2009
Alternatives to fish oil

- Fish oil used for energy and EFA
- For some spp, energy can be sourced from CHO
- Energy from lipid can be sourced from:
  - vegetable oils (soya & canola high w3)
  - animal fats, especially poultry oil
- EFA
  - oil from fish offal (excellent source omega-3)
- Other alternative lipid sources
  - SCP (algae, yeast, bacteria) with high HUFA content. $$$$
  - Genetically modified oilseeds with high omega-3 content
Single Cell Oils

Also Syngenta, Dow Agrisciences

Lonza DHA Ulkenia
32% min DHA

Anthony P. Bimbo, 2010; Tacon, 2010

Martek’s Life’s DHA
40-50% DHA

Dupont’s NewHarvest Yeast yarrowia lipolytica
50% EPA

Alltech’s algal production facility at Winchester, KY-
products >30% DHA
Total compound animal feed production in 2009 was 708 million tonnes with production up 20% since 1995 & growing with an average APR of 1.3%/year.
## Resources for food production

<table>
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<th>Product</th>
<th>Water use (m³/kg)</th>
<th>FCR</th>
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<tbody>
<tr>
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<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Wheat¹</td>
<td>1.6</td>
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<tr>
<td>Corn¹</td>
<td>0.7</td>
<td></td>
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<tr>
<td>Soybeans¹</td>
<td>2.1</td>
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</tr>
<tr>
<td>Beef¹</td>
<td>17.1</td>
<td>8</td>
</tr>
<tr>
<td>Pork¹</td>
<td>5.9</td>
<td>4</td>
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<tr>
<td>Chicken¹</td>
<td>5.5</td>
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<tr>
<td>Salmon²</td>
<td>2.4</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Prawns²</td>
<td>3.6</td>
<td>1.5</td>
</tr>
<tr>
<td>S/W Barramundi²</td>
<td>3.6</td>
<td>1.5</td>
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¹Data from FAO  
²Estimate based on water for feed use
Priorities

- Nutritional requirements
- Ingredient processing
- Genetic selection/modification for nutrient composition EAA, EFA
- Fish oil alternatives
- Feed processing
- Genetic improvement for feed utilisation, FCR
Health

• Intensive livestock vulnerable to disease
• Atlantic salmon in Chile,
• Oysters in Europe
• Marine shrimp farming in Asia, South America and Africa
• Postlarval mortality in Asia
• Loss of production, sometimes catastrophic

• Production losses in China in 2010 estimated as 1.7 Mt - natural disasters, diseases and pollution (FAO 2012)
Health

• Control of pathogens is complex
  – detection, disease diagnosis, treatment, prevention & general health management

• Parasites – detection, understanding life stages & intermediate hosts

• Bacteria – detection, move away from antibiotics (legislation restricting use), vaccine developments and challenges

• Viruses – detection, vaccines, few effective therapies, genetic resistance

• Fungal – detection, few therapies
Health – advances in diagnosis

- Costly, need expensive equipment, facilities & training
- Traditional isolation & identification
- Amplifying specific sequences of DNA or RNA (added tests for live/dead)
- Immunodiagnostic methods e.g.
  - immunohistochemistry (IHC)
  - fluorescence antibody test (FAT)
  - indirect fluorescence antibody test (IFAT)
  - enzyme-linked immunosorbent assay, ELISA
  - Western blot
- Loop-mediated isothermal amplification (LAMP)
Health Priorities

• Diagnosis – molecular advances
• Vaccines – DNA vaccines (including delivery using non-infectious bacterial phages), parasite vaccines, adjuvanted multivalent oral vaccines, GMO

Treatments
• Integrated health management
  – Microbial management – culture system
  – Microbial management - organism
  – Immunity modulation
  – Role of nutrition, particularly micro-nutrients play
  – Other environmental factors
  – Genetic improvement – specific pathogen resistant
  – Biosecurity
Production platforms & environment

• In 2010, 44.6 Mt, nearly 70% food fish from inland
• Majority food aquaculture from pond culture
• Mollusc & plant culture using suspended or bottom technology
• Cage culture
• Tank culture

![Graph showing production of various aquatic species in metric tons (Mt)]
Pond culture
Pond culture

- Challenges: space, water, pollution from effluent
- Priorities: reduced water exchange, microbial management, biofloc, better feeds
• Challenges: inshore space, biofouling, disease

• Priorities: offshore zones, health management, technology to control biofouling, new technology for suspended culture
• Challenges: inshore space, offshore zones, storm damage for offshore, effective interaction with other infrastructure, scale, disease, feed delivery, biofouling, predation

• Priorities: cost-effective technology, effective interaction with other structures – “offshore economic zones”, health management, feed delivery systems, biofouling solutions, stock management
Intensive Tank Systems
Integration
• Challenges: cost – power, aeration, disease, scale, feeds

• Priorities: cost-effective technology, integration with horticulture – aquaponics, niche opportunities (close to market), health management, feed formulation for recirculation systems
Offshore economic zones

- Wind farming, wave turbines
  - 1,290 offshore wind farms in Europe generating 3,500 MW
  - Current slump in investment
- Future- Power generation with interspersed cage & longline culture (multitrophic aquaculture)
Conclusion

• Aquaculture is a major part of securing global protein supplies

• Production increases will continue to outstrip capture fisheries & agriculture

• Key challenges are to continue to improve technology for hatchery production, genetic improvement, nutrition & feeds, health management & production systems