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Pêches et Océans Canada

Innovation & Emerging Technologies:

A Major Pillar of the National Aquaculture Strategic Action Plan Initiative (NASAPI)

Aquaculture Innovation Workshop
National Conservation Training Center
Shepherdstown, WV
January 18, 2011

Outline

1. NASAPI : The overall framework
2. Aquaculture Emerging Technology Priorities in Canada
3. DFO's Preliminary Assessment of Closed-Containment Technologies
4. DFO's investments in Recirculation Aquaculture Systems
5. Development of a Comprehensive Methodology to Assess the Environmental Impact of Finfish Aquaculture Technologies

1. NASAPI : The Overall Framework

PURPOSE OF NASAPI

- Under the leadership of the Canadian Council of Fisheries & Aquaculture Ministers (CCFAM), NASAPI is a national, collaborative exercise to outline a road map for economically, environmentally and socially sustainable aquaculture development throughout Canada

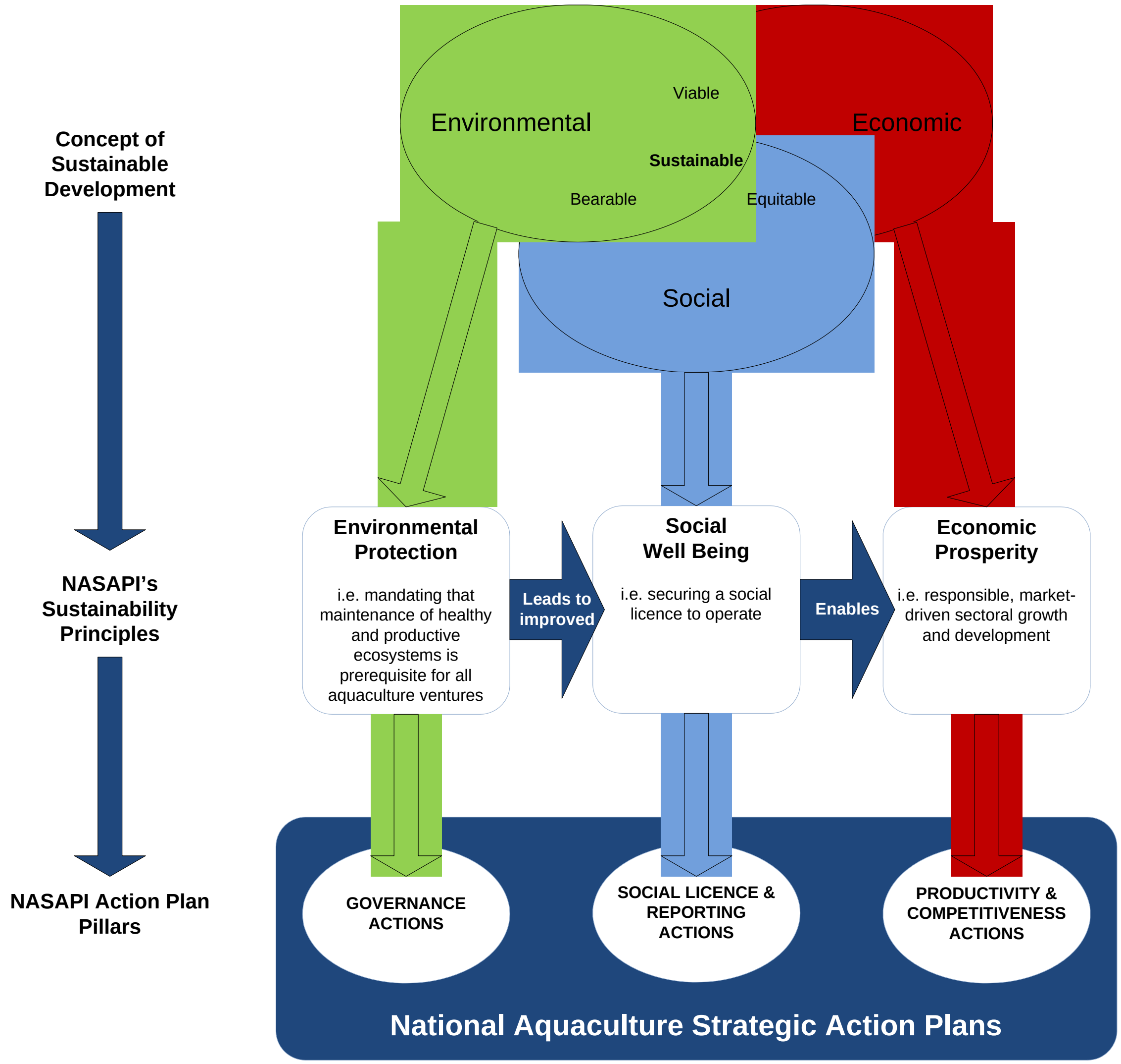
What is NASAPI?

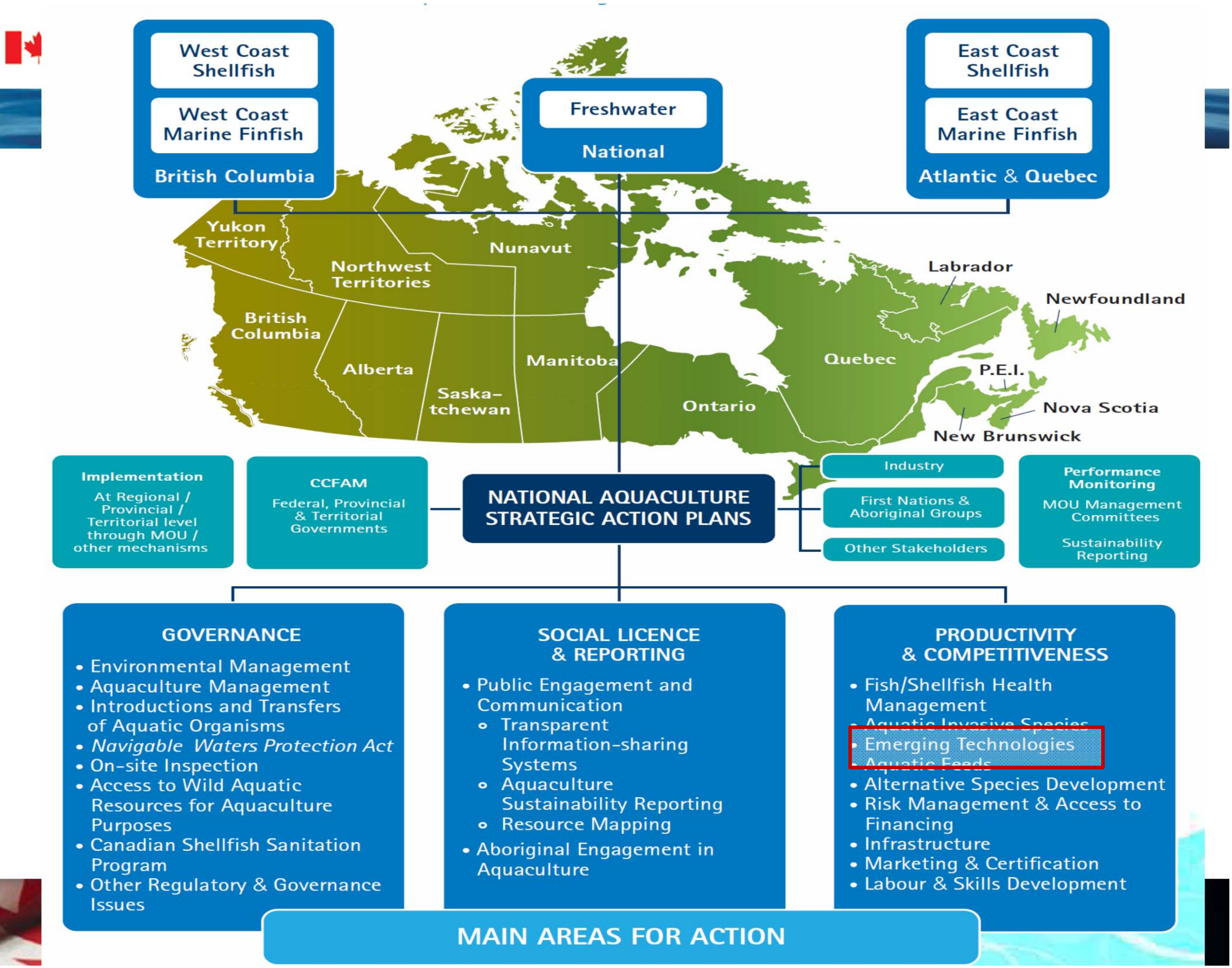
- Overarching Document
  - Framework encompassing purpose, vision, objectives and guiding principles for NASAPI
- 5-Year Strategic Action Plans to help each sub-sector of the industry reach its full potential
  - East Coast Marine Finfish
  - West Coast Marine Finfish
  - East Coast Shellfish
  - West Coast Shellfish
  - Freshwater
- A process bringing together federal, provincial and territorial government mandates, along with FN/Aboriginal groups, industry, academia and ENGOs to develop the first ever national aquaculture plan for Canada

Objectives of NASAPI

- To modernize industry and government management of the sector in a manner that is more responsible, sustainable and transparent
- To generate enhanced public and investor confidence in aquaculture

NASAPI Sustainable Development from Principle to Practice





West Coast Shellfish
West Coast Marine Finfish
British Columbia
Freshwater
National
East Coast Shellfish
East Coast Marine Finfish
Atlantic & Quebec
Yukon Territory
Northwest Territories
Nunavut
British Columbia
Alberta
Saska-tchewan
Manitoba
Ontario
Quebec
Labrador
Newfoundland
P.E.I.
Nova Scotia
New Brunswick
Implementation
At Regional / Provincial / Territorial level through MOU / other mechanisms
CCFAM
Federal, Provincial & Territorial Governments
NATIONAL AQUACULTURE STRATEGIC ACTION PLANS
Industry
First Nations & Aboriginal Groups
Other Stakeholders
Performance Monitoring
MOU Management Committees
Sustainability Reporting
GOVERNANCE
• Environmental Management
• Aquaculture Management
• Introductions and Transfers of Aquatic Organisms
• Navigable Waters Protection Act
• On-site Inspection
• Access to Wild Aquatic Resources for Aquaculture Purposes
• Canadian Shellfish Sanitation Program
• Other Regulatory & Governance Issues
SOCIAL LICENCE & REPORTING
• Public Engagement and Communication
o Transparent Information-sharing Systems
o Aquaculture Sustainability Reporting
o Resource Mapping
• Aboriginal Engagement in Aquaculture
PRODUCTIVITY & COMPETITIVENESS
• Fish/Shellfish Health Management
• Aquatic Invasive Species
• Emerging Technologies
• Aquatic Feeds
• Alternative Species Development
• Risk Management & Access to Financing
• Infrastructure
• Marketing & Certification
• Labour & Skills Development
MAIN AREAS FOR ACTION

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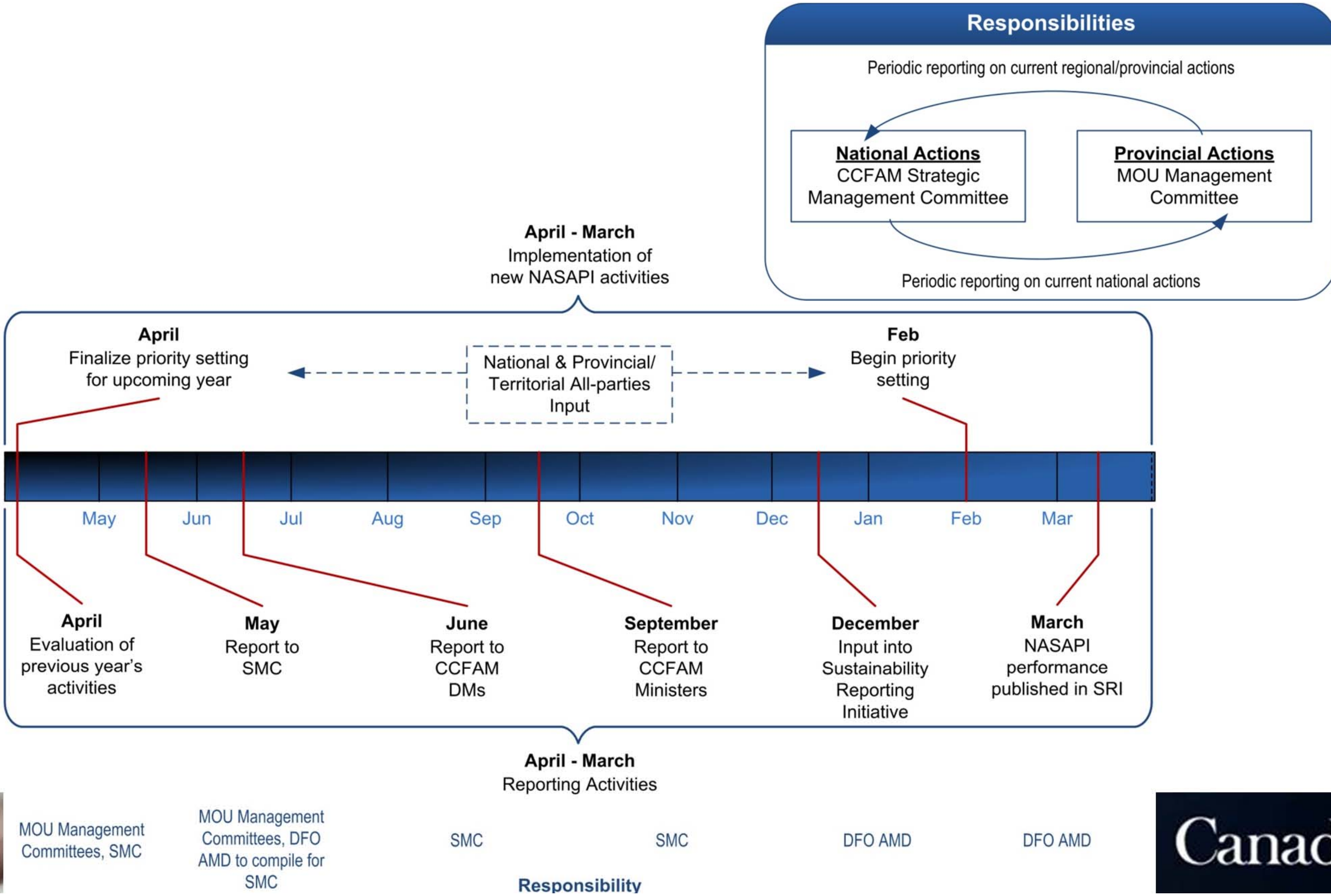
National Aquaculture Strategic Action Plan Initiative

Priority Setting & Reporting Process



Canada

2. Aquaculture Emerging Technology Priorities in Canada

NASAPI - Emerging Technologies

- ET–1 Improve the quality and traits of broodstocks for Atlantic salmon, steelhead and rainbow trout aquaculture
  - Selection of genetic traits to enhance productivity and sustainability
- ET–2 Quantify the environmental footprint, (e.g. carbon footprint, water quality impacts, sediments, chemicals, antibiotics, pesticides, nutrient loading, escapes, disease, etc.) of aquaculture subsectors and identify areas where investment into green technologies is most pertinent

NASAPI - Emerging Technologies

- ET–3 Invest in R&D to advance commercial closed-containment aquaculture (CCA) systems and recirculating aquaculture systems (RAS)
  - Identify opportunities for commercial-scale evaluation
  - Identify principal areas of risk and appropriate mitigation strategies
  - Promote benchmarking

- ET–4/5 Invest in R&D to advance cage (ET4) and suspension (ET5) aquaculture in high-energy/off-shore areas
  - Identify opportunities for commercial-scale evaluation of new technologies and equipment

NASAPI - Emerging Technologies

- ET–6 Advance Integrated Multi-Trophic Aquaculture (IMTA)
  - Conduct a comprehensive assessment of markets, biophysical resources, production technologies and financial viability for cultivation of marine plants
  - Evaluate overall environmental performance of IMTA
  - Conduct economic modelling with various primary (e.g. finfish), secondary (e.g. shellfish) and tertiary (e.g. marine plants) species

- ET–7 Improve market access for shellfish producers
  - Enhance shellfish depuration
  - Improve access to relaying and depuration facilities

NASAPI - Emerging Technologies

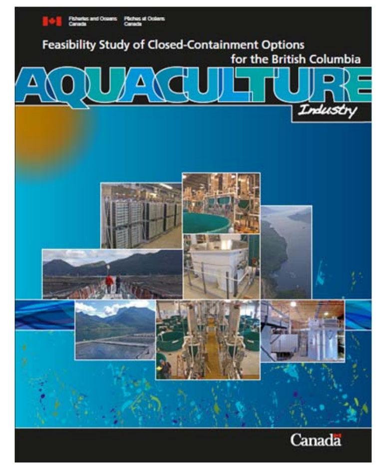
- ET–8 Improve mechanization for shellfish handling and harvesting
  - Enhance mechanical handling (i.e. grading, resetting stock post-overwintering, etc.), harvesting and processing technologies

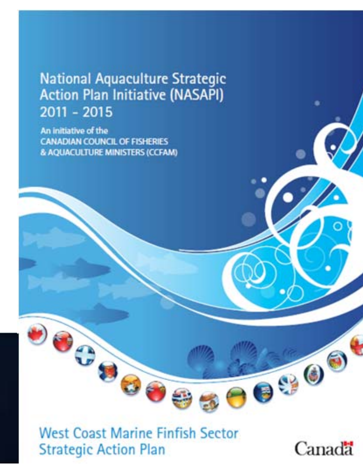
- ET–9 Improve productivity and efficiency through enhanced net pen technologies and practices
  - Develop improved technologies to manage toxic algae blooms
  - Develop efficient means to oxygenate waters in net pens
  - Enhance technologies for biofouling control and predator control
  - Develop methods to improve mort utilization / disposal

3. DFO's Preliminary Assessment of Closed-Containment Technologies

Closed Containment Aquaculture

- Canadian Science Advisory Secretariat (CSAS)
  - *Evaluation of Closed-Containment Technologies for Saltwater Salmon Aquaculture (2008 – 2010)*
- DFO Aquaculture Management Directorate
  - *Feasibility Study of Closed-Containment Options for the British Columbia Aquaculture Industry (2010)*
- NASAPI Strategic Objective ET-3 Closed-Containment and Recirculating Aquaculture
  - Support for pilot-scale project(s) to validate technologies and practices (2011-2015)





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CSAS Outcome

A) Six scientific peer reviewed papers:

1. Review of past experiences.
2. An engineering evaluation of the design and operation of closed-co systems.
3. A comparative analysis of the biological requirements for salmonid production at a range of densities in closed-containment systems.
4. Assessment and review of the potential transmission of pathogens and parasites between closed-containment systems and the external environment.
5. An engineering evaluation of the unit process technologies to maintain water quality for optimal fish growth and fish health.
6. Using results of the five papers above, a conceptualized series of integrated systems that could be considered in the development of a pilot project or model farm.

B) R&D research priorities

C) Economic analysis recommendations

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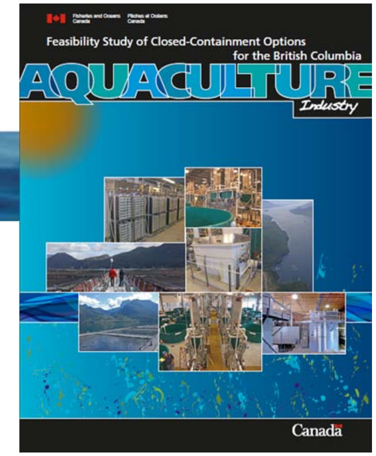
CSAS Economic Recommendations

1. Research existing successful RAS technologies for raising fish other than salmon and determine if they can be applied economically and practically in BC to commercial scale salmon production.

2. Identify methods for assigning values to environmental service costs so that comparison can be made between different aquaculture systems and different forms of animal food production (e.g. Life Cycle Analysis).

3. Conduct a sensitivity analysis to clarify the effects of changes in key assumptions of growth rate, mortality and feed conversion rate in conceptual models for close-containment systems.

Feasibility Study of Closed-Containment Options for BC



- *The goal of this study is to respond to the CSAS economic recommendations.*

- The goal of this analysis is not to provide potential investors with data that could be used to support future investment decisions.

- All scenarios have been developed and analyzed within operating environment of the British Columbia industry.

- Several subject matter expert committees were formed to validate the assumptions and inputs used by the model, in addition to identifying possible areas of uncertainty

9 Systems under evaluation

- Net Pen
- Floating Rigid Wall
  - With aeration & pure oxygen
- Floating Flexible Wall -- pure oxygen
- Land-Based / Flow Through
  - Grade, below grade, liquid oxygen injection & mechanical filtration
- Land-Based / Recirculation

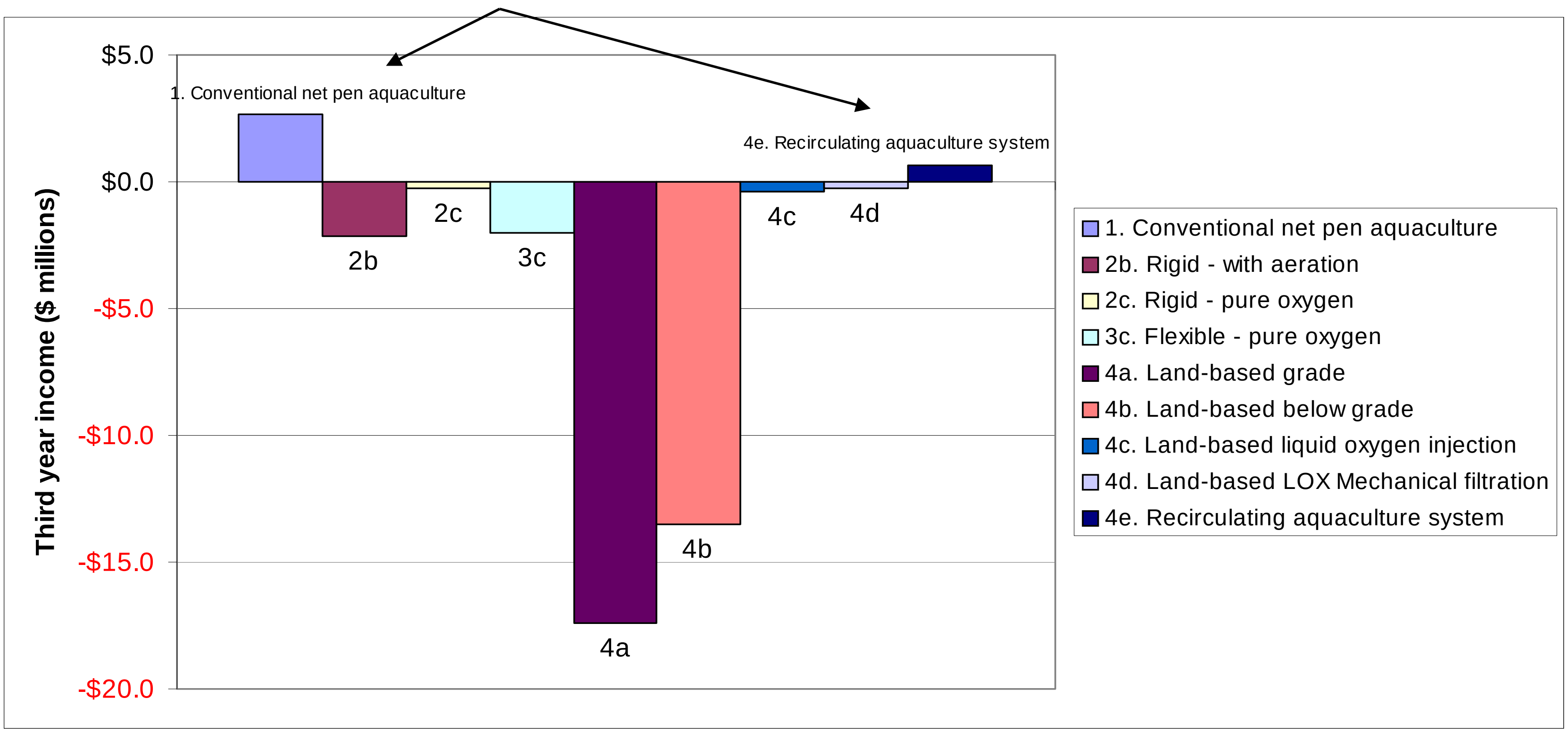
Key Assumptions

Item	Unit	Net pen	RAS
Biological			
Biologicl feed conversion ratio (FCR_b)	-	1.27	1.05
Thermal growth constant (TGc)	-	2.7	2.7
Mortality over cycle	%	~10	7.0
Technical			
Temperature	ºC	7.74 - 10.41	15
Average biomass density	kg/m^3	15	50
Water turnover rate	Minutes/Exchange	-	24

Item	Unit	Value
Total production weight	mt	2,500
Initial smolt weight	g	75
Target fish weight	kg	5.65
Project length / amortization period	Years	19
Loan/equity ratio	-	2 : 1

Initial Analysis of All Production Systems

Only those two technologies showed economic potential



Production Scenarios for DFO's Economic Model

Net Pen

- 2 sites for bay management protocol
  - Twelve 30m X 30m steel cages per site
- Offshore sites serviced by boats
  - Staff, feed, smolts, supplies, etc.
- On-site feeding system and storage
- Fish harvested in a single batch
- Site lies fallow until the subsequent introduction of smolts

Recirculating Aquaculture System

- Production plan requires regular stocking of smolt
  - ~40,000 per month
- Steady monthly harvests
  - Upon attaining steady-state operations
  - Initial harvest ~12 months after smolt transfer at 15ºC

Net present value and internal rate of return

TABLE 6 Net present value

Technology	Initial investment	Total equity*	Operating shortfall	Line of credit	NPV (7%)	IRR
Net pen	$5,000,716	$5,041,353	$9,800,218	$6,459,108	$19,225,055	40.3%
RAS	$21,920,637	$9,300,703	$5,534,958	$3,687,271	-$1,985,136	5.1%

*Includes private investment for capital and a one-third commitment on line of credit

The cost of capital and related financing are the main cause of difference for the total cash flows of the projects.

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Sensitivity Analysis - Summary

Item	Unit	Third-year income /Profit margin					
			Net pen				
Exchange rate	USD/CAD		0.85		0.95		1.05
		$4,077,996	*39%*	*$2,641,147*	*25%*	*$1,458,043*	*14%*
Market price FOB	USD/lb		3		2.6		2.2
		$4,517,310	*43%*	*$2,641,147*	*25%*	*$725,904*	*6.9%*
FCR b	-		1.2		1.27		1.3
		$2,882,333	*28%*	*$2,641,147*	*25%*	*$2,537,781*	*24%*
Feed price	$/mt		1200		1350		1500
		$2,641,147	*25%*	*$2,091,428*	*20%*	*$1,537,097*	*15%*
Smolt price	$ per fish		1.8		2		2.2
		$2,748,978	*26%*	*$2,641,147*	*25%*	*$2,533,140*	*24%*
Contigency on capital cost	%		5		10		15
		$2,667,771	*25%*	*$2,641,147*	*25%*	*$2,614,522*	*25%*
			RAS				
Exchange rate	USD/CAD		0.85		0.95		1.05
		$1,946,961	*19%*	*$381,467*	*3.6%*	*-$920,024*	*-8.8%*
Market price FOB	USD/lb		3		2.6		2.2
		$2,391,694	*23%*	*$381,467*	*3.6%*	*-$1,720,942*	*-16%*
FCR b	-		1		1.05		1.1
		$727,960	*6.9%*	*$381,467*	*3.6%*	*$34,973*	0.3%
Feed price	$/mt		1400		1500		1600
		$693,775	*6.6%*	*$381,467*	*3.6%*	*$69,158*	*0.7%*
Smolt price	$ per fish		1.8		2		2.2
		$499,975	*4.8%*	*$381,467*	*3.6%*	*$262,958*	*2.5%*
Loan interest rate	%		7		8		9
		$381,467	3.6%	$207,199	2.0%	$31,115	0.3%
Average biomass density	kg/m3		50		40		30
		$381,467	*3.6%*	*$137,542*	*1.3%*	*-$106,871*	*-1.0%*
Water temperature	ºC		15		13		11
		$381,467	*3.6%*	*$86,754*	*0.8%*	*-$209,847*	*-2.0%*
Contigency on capital cost	%		10		20		30
		$493,285	*4.7%*	*$381,467*	*3.6%*	*$269,648*	*2.6%*
Total FTEs	-		16		18		20
		$521,351	*5.0%*	*$381,467*	*3.6%*	*$241,583*	*2.3%*
Mortality over cycle	%		4		7		10
		$478,482	*4.6%*	*$381,467*	*3.6%*	*$277,988*	*2.7%*

Profit margin:
- **Higher than 10%** (green)
- **Between 2.5% and 10%** (yellow)
- **Lower than 2.5%** (red)

Canada

Conclusion

- The results of this analysis have shown that while both technologies are profitable on a pro-forma basis, with returns significantly higher for net pen, RAS technologies are:
  - Considerably more sensitive to market forces beyond the control of the operator;
  - Have the ability to become non-profitable within a range of variability that has been experienced by the Canadian salmon aquaculture industry in the past.
- *In summary, RAS shows some economic potential but with a high level of uncertainty for all major assumptions and therefore a high risk associated to it.*
  - Potential has to be assessed and all assumptions verified in real-life scenario (pilot scale) before any final policy decision/direction.

4. DFO's investments in Recirculation Aquaculture Systems

Aquaculture Innovation & Market Access Program

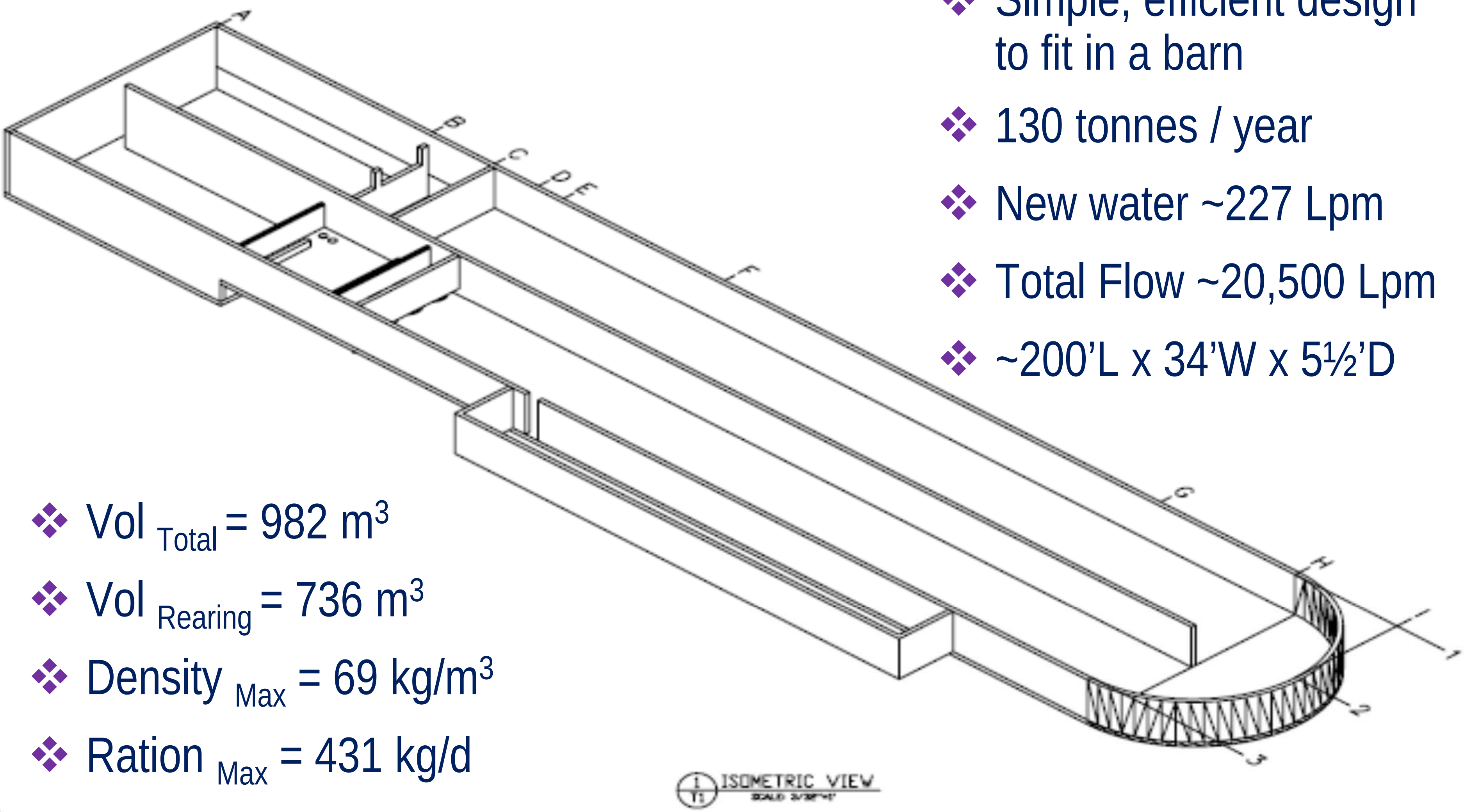
- Objectives
  - Supporting the development and adoption of new technologies and management techniques
  - Focus on the development / pre-commercialization end of the RDC spectrum
  - Industry-focused projects with implementable results within 3 years max. (ideally 1 year)
    - Applied research (industry-driven)
    - Development
    - Early commercialization
    - Early industry adoption of innovative technology or results

AIMAP CCA & RAS Initiatives

- Proposals submitted in the current round of applications
  - 'Namgis Land-Based Atlantic Salmon Recirculating Aquaculture System Pilot Project ('Namgis First Nation)
  - Land-based Atlantic Salmon Grow-out Employing Recirculating Aquaculture System (RAS) Technology - Pilot Project (Marine Harvest)
  - Twin Rivers: Commercial Application of a Recirculating Water Aquaculture System to Grow Coho Salmon in Toquaht, BC (Grieg Seafood BC, Ltd. & Toquaht Aquaculture Enterprises, LP)
- Project supported in earlier round of funding:
  - Canadian Model Aqua-Farm, Warren MB
    - Constructed in 2010
    - Intensive monitoring program (2011-2013)

Model Farm Layout

- Simple, efficient design to fit in a barn
- 130 tonnes / year
- New water ~227 Lpm
- Total Flow ~20,500 Lpm
- ~200'L x 34'W x 5½'D



- Vol $_{Total}$ = 982 m^3
- Vol $_{Rearing}$ = 736 m^3
- Density $_{Max}$ = 69 kg/m^3
- Ration $_{Max}$ = 431 kg/d

Model Farm Photos

Empty Barn Pre-Construction

Pouring Concrete

Construction & Installations Complete

Feeding First Batch of Fish

5. Development of a Comprehensive Methodology to Assess the Environmental Impact of Finfish Aquaculture Technologies

ET–2 Quantify the environmental footprint

- Environmental concerns associated with salmon aquaculture are diverse and range
  - from highly localized ecological impacts associated with farm sites and practices (e.g., disruption and replacement of benthic communities, degradation of local water quality, mortality/displacement of proximate marine fauna, etc.)
  - to regional and longer temporal scale impacts (e.g. impacts on wild salmonids, etc.)
  - through to contributions to global-scale concerns (e.g., contributions to global climate change, impacts on pelagic fish stocks, etc.) that arise from supply chain activities

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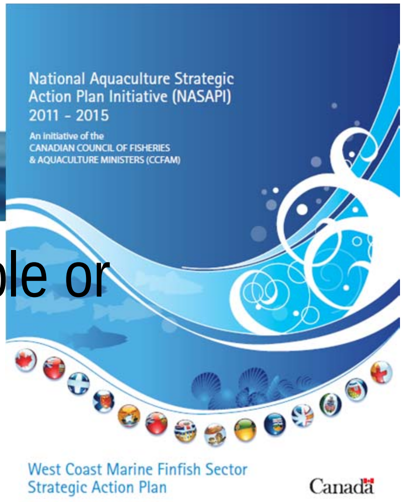
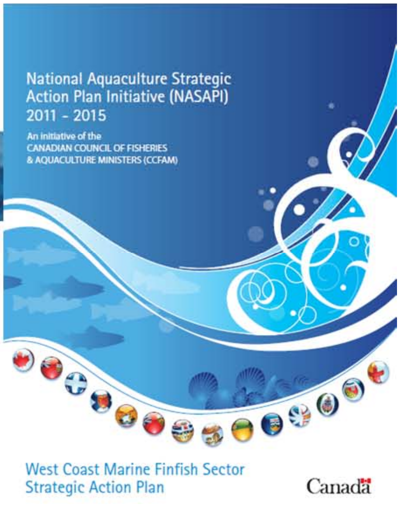
ET–2 Quantify the environmental footprint



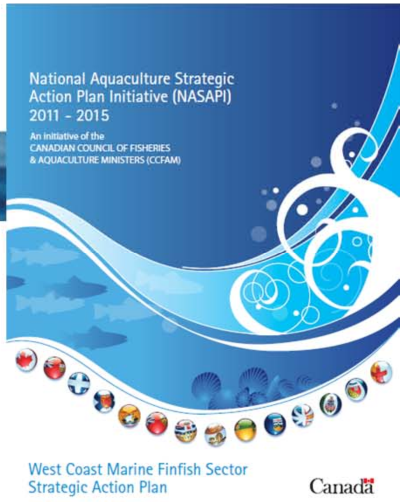
- Few methodologies and/or frameworks are currently available or under development.
  - Life Cycle Assessment (LCA)
  - Environmental Impact Assessment (EIA)
  - Strategic Environmental Assessment (SEA)
  - Ecological Footprint Analysis
  - Global Aquaculture Performance Index (GAPI)
  - Others (?)
- Even where well established and broadly accepted, these methods are generally limited to:
  - quantifying single environmental impacts and do not allow for the integration and assessment of multiple concerns simultaneously;
  - part of the full suite of potential/perceived environmental effects that may characterize the environmental performance of salmon aquaculture
  - do not allow for the integration of local and global impacts.

ET–2 Quantify the environmental footprint



- DFO's objective under NASAPI is to outline a comprehensive approach or methodology that could in theory encompass as diverse a range of environmental impacts as is possible for the full range of salmon culture technologies (e.g. conventional net-pens, various forms of closed-containment, RAS, etc.)
  - The first step is to commissioned an expert study (Tyedmers & Ayer / Dalhousie University, Halifax) to generate discussion and to inform future planning

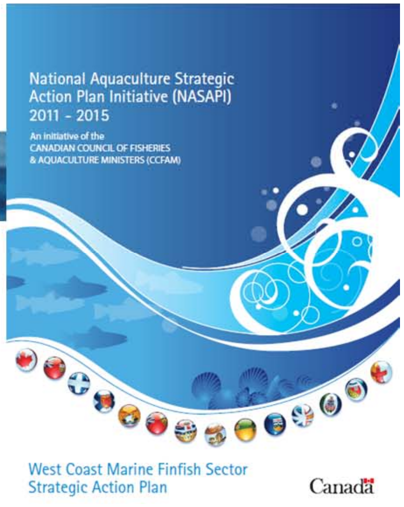
ET–2 Quantify the environmental footprint



The objectives of the study are to:

1. Identify and describe existing and emerging integrative scientific methods or frameworks.
2. Summarize the specific areas of potential environmental impact associated with aquaculture where gaps exist in the reviewed methodologies and provide an assessment of the potential for these gaps to be overcome in the short-term or long-term due to emerging research or data availability.
3. Provide a set of recommendations for discussion based on objectives 1 and 2 to develop a comprehensive approach that attempts to more fully quantify the environmental footprint of finfish aquaculture.

ET–2 Quantify the environmental footprint

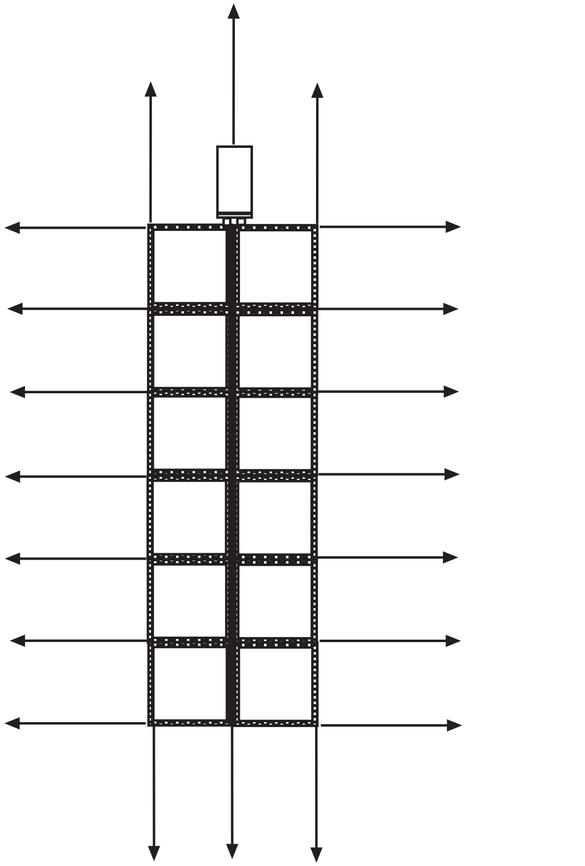


Next Steps

- Draft results and recommendations will be available is April 2011 and share with all interested parties for comments
- In Spring 2011, Task Group will be established to set up a workplan and oversee specific actions/projects
  - Timeframe to develop an agreed upon new methodology : 2 years
  - Timeframe to gather data and generate first preliminary results: 3 to 5 years

THANK YOU

Net Pen Scenario



Shaded Area = 13,200 m2

Impacted Area = 17 ha

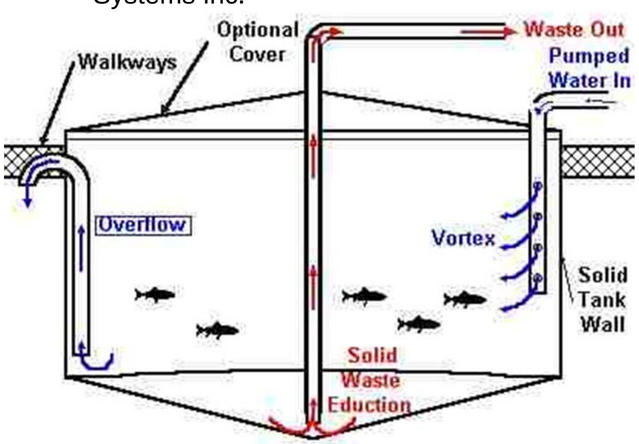
Land Area = 0 ha

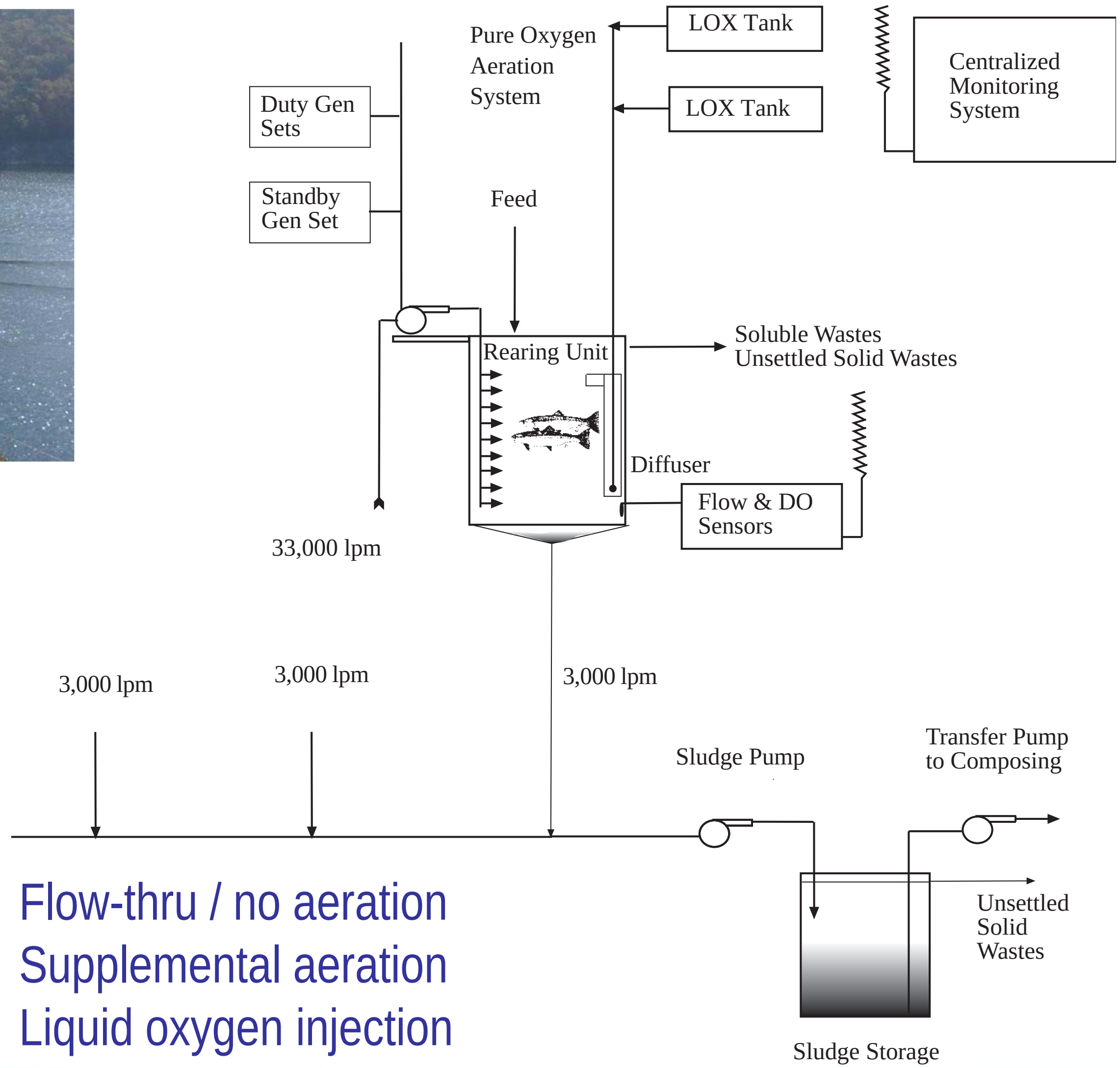
Photo: BCSFA

Floating Rigid-Wall Tank System

Photos: AgriMarine

Illustration: Mariculture Systems Inc.





- ✓ Flow-thru / no aeration
- ✓ Supplemental aeration
- ✓ Liquid oxygen injection

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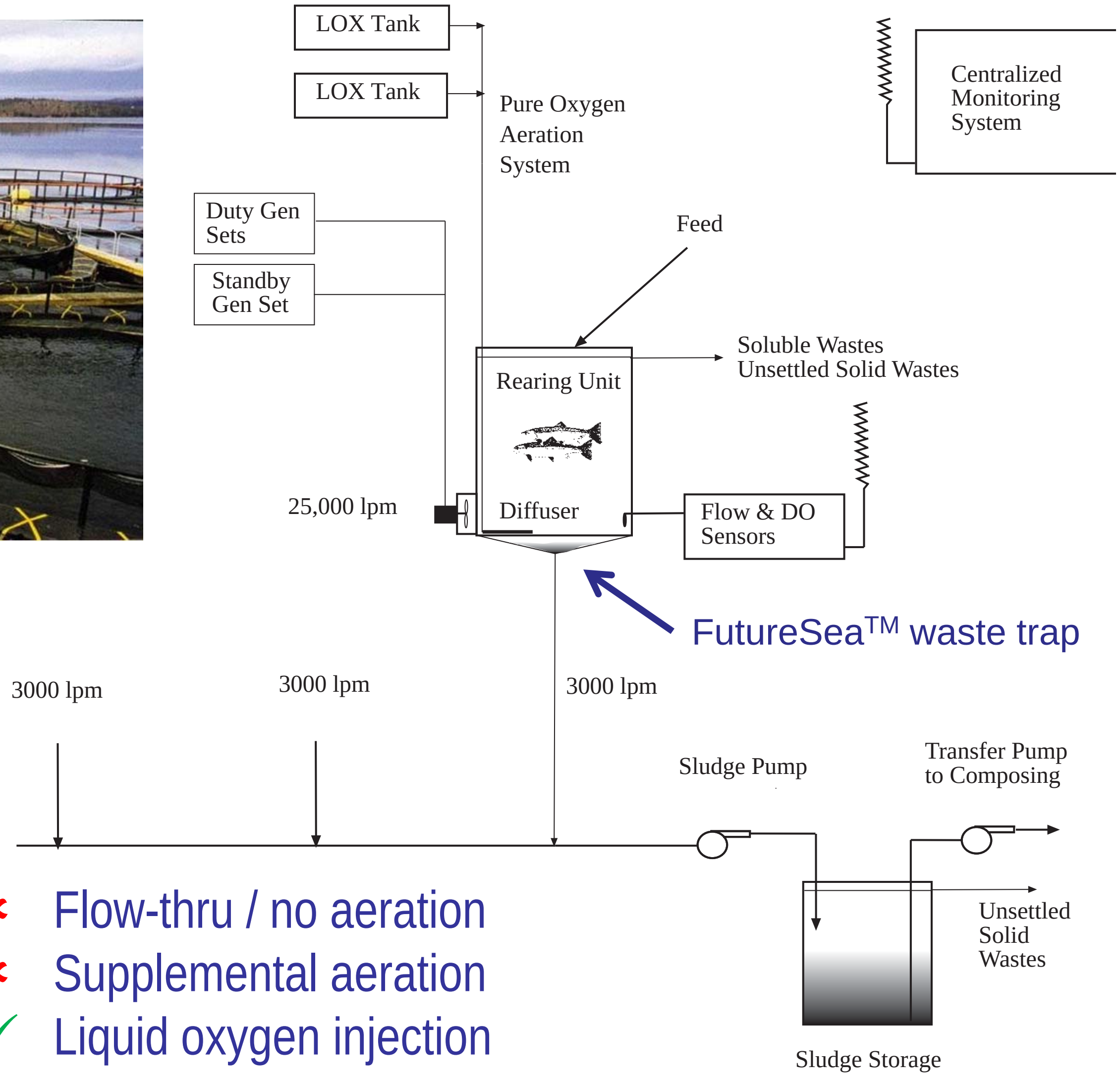
Floating Flexible Tank System


Photos: FutureSea



- ✘ Flow-thru / no aeration
- ✘ Supplemental aeration
- ✓ Liquid oxygen injection

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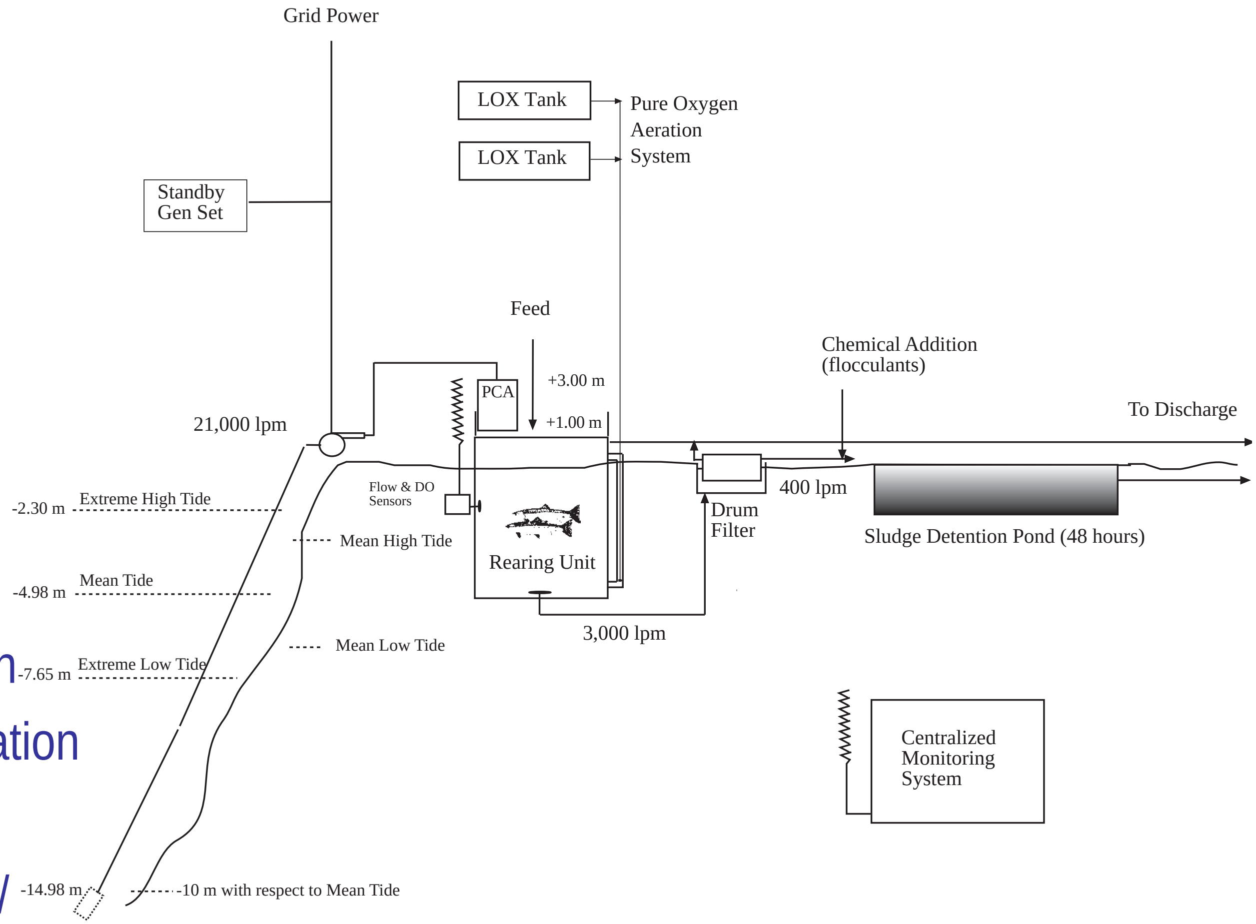
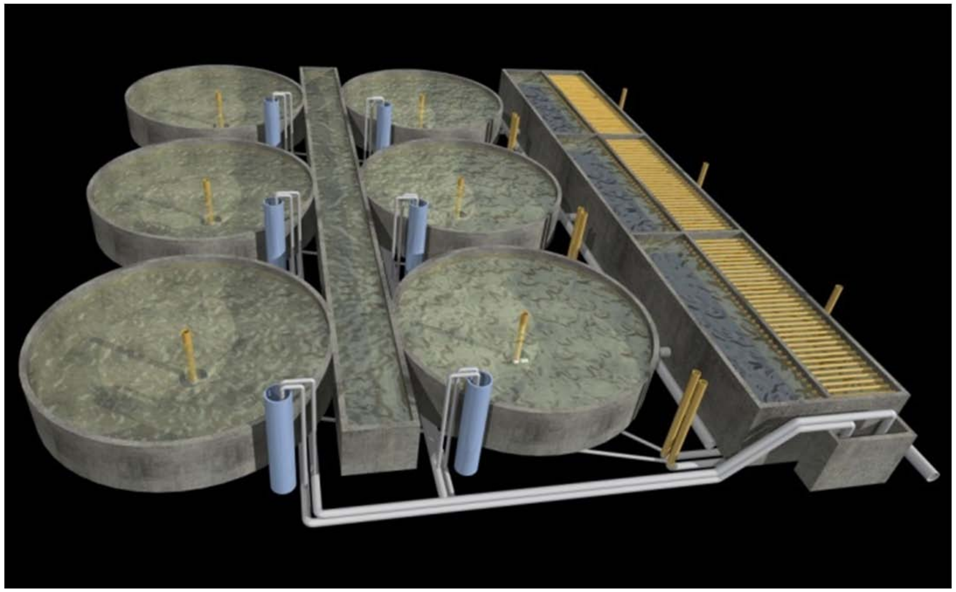
Land-Based Systems



- Flow-thru / on-grade / aeration
- Flow-thru / below grade / aeration
- Flow-thru / dual drains / LOX
- Flow-thru / dual drains / LOX / solids concentration

Recirculating Aquaculture System



- Five 6-tank modules
- Technologies:
  - Circular tanks with dual-drain solids management
    - Intermittent flushing to waste
  - Solids settling chamber with settle deck
  - Trickling biological filter / CO2 stripper
    - BioBlok media
    - 10:1 air : water ratio
  - Mechanical filtration
  - UV irradiation
  - Ozone injection
  - Low-head vertical propeller pumps
  - On-site oxygen generation (PSA)

CSAS Recommendations

- Technology

1. Conduct additional research in the field of floating, flow-through bag systems to see if past mechanical, material and structural failures can be overcome.
2. The energy efficiency of floating flow-through systems is sensitive to pumping head and pump efficiency. An engineering analysis should be done on how to design for and maintain optimum performance and reliability. The performance of existing low-head high-volume pumps for marine use should be documented.
3. Document the performance of diffused aeration and pure oxygen systems for large-scale marine applications.
4. Document the performance of dual drain and solids collection and removal systems for large-diameter, closed containment.
5. The need for, and application of pathogen reducing technologies (e.g., UV, ozone and filtration) in closed-containment facilities needs further investigation. However, effective deployment of any [expensive] pathogen disinfection technology needs to first identify Critical Control Points that includes identifying where pathogen movement is occurring (i.e., influent or effluent stream) and a risk assessment of what pathogen or diseases actually require mitigation.

CSAS Recommendations

- Fish Culture, Health and Welfare

1. Determine safe pH, un-ionized ammonia and CO2 criteria: determine cumulative oxygen consumption criteria for marine applications of diffused aeration and pure oxygen systems.
2. Document impacts of low dissolved oxygen on growth, mortality and food conversion ration (FCR).
3. Develop stocking density criteria for closed containment and impacts on growth rate, variation in size, mortality and FCR. More research is required to investigate responses to higher densities in closed-containment systems.
4. Develop a paper to discuss the key production parameters required for rearing salmon from the perspective of aquaculture veterinarians.
5. Explore opportunities for alternative management/control that are provided with closed containment systems. For example, drawing influent water from greater depth may help to reduce the movement of sea lice and harmful plankton into the containers; biosecurity measures may have greater impact than with net-pens.

CSAS Recommendations

- Fish Culture, Health and Welfare

6. Investigate the frequency of diseases associated with opportunistic pathogens (production diseases) that may be related to the intensive farming practices of closed containment.
7. More research is needed on the effect of CO_2, nitrate, ammonia and suspended solids on fish growth and the technologies required to address these issues.
8. Conduct research on optimization of swimming velocity to improve growth rate and feed conversion. This aspect may be confounded by a density effect, water clarity and other conditions and requires more research.
9. Assess the animal welfare aspects of density; however, this debate needs to be balanced by the potential benefits of culturing fish at lower densities. The EU guidelines for density are lower than 80 kg/m3.
10. Strain selection for Atlantic salmon is an accepted preventive strategy to reduce disease and stress and should be further investigated.

CSAS Recommendations

- Waste and Other Environmental Effects/Outputs/Inputs

1. Establish the specific environmental impacts from net pen systems and various closedcontainment technologies to clarify what issues closed-containment could be addressing.
2. Develop an economic technology for treatment and recovery or disposal of saline fish waste.
3. Conduct research into the potential for fish waste recovery, including mortalities, through biogas production.