Research issues	Research Subtopics & Action Points	Status & Observations	Timeframe & Funding	Group Rank	General Rank
	1 = high; 2 = medium; 3 = low, but still necessary; 4 = low, disagreement on need				
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DISEASE					
1. Develop methods identify of diseases that emerge on farms that may pose a threat to wild fish populations.	Develop mathematical models of the dynamics of fish farm epidemics.		3 y; $250k; *	1	
	Use models to determine if and how disease persists and spreads in wild populations.		3 y; $250k; +		
2. Identify ways to determine the population impacts of sea lice on wild salmonids.	Use models and experimental approaches to address the difficulties of assessing impacts of lice on wild fish at the population level.	Scottish scientists are currently discussing research proposals	4 y; $600k; o	1	
	Develop methods to determine target levels for sea lice on farms that threaten wild fish. These may vary by location and time of the year.		2 y; $150k; +	1	
3. Develop methods for early detection/identification of diseases.	Develop on-farm surveillance methodologies to identify disease issues at an early stage.		1 y; $80k; *	2	
	Develop surveillance methodologies for wild fish populations.		1 y; $80k; o		
4. Develop on-farm health management systems to prevent or minimize the emergence of disease.	Conduct research to determine the impact of vaccination programmes, involving inreasing numbers of vaccines, on the immunocompetence of small fish.		2 y; $150k; *	2	
ESCAPES					
5. Complete a global assessment of the data on escapes.	Identify causes of escapes, geographic and temporal differences and the use of Better Management Practices to reduce them.	Good data on escapes from Norway; some from Scotland, North America; little from Chile. Data on BMPs/Codes of Practice from Norway, Maine, Scotland.	0.5 y; $40k; possibly recurrent; *	2	
6. Develop HACCP-like procedures to reduce escapes through cost-effective management procedures.	Incorporate information into BMPs.	Initatives being developed in Maine and possibly eslewhere.	0.5y; $50k; *	1	

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7. Identify and rank the impact of escapes on wild fish populations.	Analyze the behavior and survival of farmed Atlantic salmon escapes, focusing on coastal areas and in the ocean in Pacific North America, Chile, and also in the Atlantic.	Norway co-coordinating pilot European study. There is a high level of disagreement on the behaviour, survival, and impacts.	3 y; $800k; +	1	
	Identify and analyze the fitness of salmon escapes.	Detailed, long-term studies on lifetime reproductive success and fitness of Atlantic salmon escapes on wild Atlantic salmon exist, complemented by modelling work.	3 y; $800k; +	2	
	Undertake detailed studies of impacts of Atlantic escapes on Pacific salmon in North America and on non-salmonids in Chile.	Research is needed to end disagreement on this issue.	5 y; $1.5 million; +	1 / 2	
	Develop reporting procedures for escapes.	UK, Ireland and Norway conform with NASCO reporting procedures for escapes.	0.3 y; $25k; +	3	
8. Identify and analyze economic, regulatory and social impacts of escapes.	Evaluate the economic and social impacts of farmed salmon escapes.		0.5 y; $40k; */+	3	
9. Recommend and rank methods to mitigate impacts of escapes.	Identify farm siting criteria to reduce impacts of escapes (knowledge of oceanic and coastal migratory patterns in order to reduce straying into wild salmon rivers).		2 y; $350k; *	1	
	Identify/develop containment BMP procedures.		*		
	Increase understanding of genetic background of farmed salmon relative to native stocks.	SALGEN project, to be completed in 2004, should provide much relevant information.	+		
	Research potential use of highly domesticated or sterile fish (including both technical and marketing issues).	Requires detailed review.	0.3 y; $40k; *		
	Develop recapture protocols.	Recapture protocols in Scotland and, possibly, elsewhere.	0.3 y; $40k; *		

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FEED					
10. Assess the current dependence and recent trends of aquaculture (including salmon farming) on fish meal and fish oil.	Analyze current use of fish meal and oil in compound aquafeeds and animal feeds, including current and future trends/use issues.	Existing papers may have bias– need independent analysis.	0.5 yr; $20k; *	1	
	Analyze current status of development and use of dietary fish meal and fish oil replacers within farmed aquatic species, including salmonids.				
11. Evaluate new farm-level feed management technologies to increase efficiency.	Assess opportunities for globally recognized BMPs to improve FCRs at farm level	Will require data on the nutritional requirements of salmon. Disagreement as to whether we should work on reducing FCRs at farm levels since this has been (and is being) done by industry already.	Funding could be from industry and government. 0.5 yr; $25k; *	4	
	Define BMP potential to reduce nutrient loads through improved diet formulations.	Recent trends demonstrate that this is possible. Feed industry?	$20k; *		
	Identify opportunities to develop the next generation of better technologies, including identifying key research partners and donors.	Feed industry responsibility?	$25k; *		
12. Identify and recommend ways the salmon industry could utilize reduction/feedgrade fisheries more sustainably.	Prepare discussion paper on the use of fisheries resources in fish feed to discuss criteria and standards for assessing "sustainable fishery" as a feed ingredient.	Will require good data on species used in fishmeal and fish oil, to better understand trophic impacts. Lack of science, so management decisions might need to be taken based on incomplete data. If reduction fisheries are properly regulated and managed, market forces will regulate whether salmon industry uses fishmeal or switch to vegetable protein.	0.25 yr; $10k; o	2	
	Prepare discussion paper on the traceability of the feed supply chain from fishery to feed processor.		0.4 yr; $15k; o/+	2	
	Identify threats to fishery resources in order to establish what steps might be taken to protect/sustain the reduction/feedgrade fishery.		$20k; +/o	1 / 2	
	Identify biomass of species used for fish meal/oilsthat should be left to sustain the marine ecosystem.	Who would do this? FAO? ICES?	o	4	
	Undertake peer reviewed stock assessment status of the individual stocks of fish meal/oil species.	Who would do this? FAO? ICES?	o	3	
	Conduct extended feeding trials within selected salmon producing countries (Chile, Norway, UK, Canada, USA) using different feed formulations and different selected fishmeal and fish oil replacers.	Trials should be supervised in a collaborative manner between the farmer, feed manufacturer, and other interested parties.	3 yr; $300k; *	1	

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13. Identify and evaluate the use and limitations of terrestrial vegetable and animal proteins as alternative dietary protein and lipid sources to reduction fisheries.	Experiment with supplemental molecules (omega 3's, sulfur-containing amino acids, etc.) in vegetable meal/oil feed formulations as complete aquaculture feeds for carnivorous fish species.	Feed industry issue	*	1	
	Analyze impact of various antinutritional factors (ANFs) on feed utilization and fish health, and how to remove / destroy these in various vegetable protein sources so that more use of vegetable proteins is economically viable.	Feed industry issue	*	2 / 3	
	Evaluate new sources for long chain n-3 oils (EPA/DHA).	This is a human nutrition challenge in the long term.	*	3	
	Bring other free amino acids to the market (development/registration) to balance the vegetable protein in fish's nutritional needs.	Long term R & D issue. This group could influence legislation and public opinion.	*	2?	
	Bring animal proteins back to the (European) market in a safe way--LAPs are a bigger resource than all global fish meal production, and the European situation is a great spill of resources.	This is both a regulatory and an image issue. This group could influence legislation and public opinion.	*	2?	
	Identify potential and problems of GM-plants and microorganisms for salmon feed.		+	4	
	Analyze potential for micro algal production (with or without genetic modification) as a feed grade resource	Prestudies show that without GM, it is not yet economically acceptable.	*		
14. Identify obstacles for use of fishery by-products and waste,and fish offal in fish feeds.		Feed industry issue	0.25 yr; $10k; +	1	
15. Evaluate fishing of lower trophic level species (Krill/Calanus) to meet salmon feed needs.		Feed industry issue	Overview for $10k; +	1	
16. Conduct research to improve understanding of salmonids nutritional needs	Define amino acids- and EPA/DHA needs in various environments (mainly determined by water temperature).	Important, but a long term costly research process.	*	2 (basic study)	

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CHEMICAL INPUTS					
17. Assess approval processes for licensed/registered antibiotics and parasitics	Identify research priorities for issues that are not already being addressed. E.g., products should have been tested against specific species that are frequently found near areas of use.	Short-term toxicity studies have been done. May be gap in terms of long term effects research. In EU this is well documented.	$25k?; *	2	
	Collect data on use of antibiotics and parasitics to generate future studies on potential overuse, and an understanding of regional variation in needs and use.	While data exists for many countries, it needs to be compiled and compared.	$25k; *	2	
18. Assess the ecological effects of chemical use and highlight areas where regulations need to be modified.	Conduct field studies of hatcheries and farms that use key products. Field studies should follow assessment of the approval process to best focus research on needs.	Regulations are often made using a precautionary approach. Need to follow up on products over a long period of time.	*	1	
19. Assess evidence for (or against) antibiotic resistance	Identify any incidence of antibiotic resistance in aquatic species	All animal production industries are facing this issue.	*	2	
20. Evaluate the current use and ecological impact of Bronopol (Pyces)		Bronopol has recently been approved in several countries.	*	4	
21. Consolidate and distribute information on existing BMPs for use of antifoulants and softer alternatives.	Identify site and regionally specific levels of BMPs related to total Cu use and accumulation, accumulation in fish, and impact of Cu on flora/fauna in freshwater & saltwater.	Kenny Black may have student working on this.	*	1	
	Assess and identify alternatives for antifoulants.	Industry initiative.	*	1	

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NUTRIENT LOADING & CARRYING CAPACITY					
22. Improve mathematical models of the benthic impacts of nutrients from aquaculture, coupling inputs with biological and chemical responses within their environmental context (e.g. oxygen supply, temperature).	Conduct a literature review and create a white paper--done by generalists--synthesizing the literature and adding to existing models will require a multi-disciplinary team of benthic ecologists, feed nutritionists, fish physiologists, geochemists, and sanitary engineers who deal with aerobic and anaerobic digestion of organic carbon.	Some reviews exist so should be relatively easy. Available models predict TVS loadings, but these need to be expanded. More complex models of nutrient effects exist to assess the impact of sewage discharges, where biological uptake of nutrients and remineralisation of organic materials have been incorporated. More complex models, which explicitly include vertical stratification and mixing, have not been applied to assessing assimilative capacity issues relating to fin-fish farming. Experimental callibration and validation will also be needed.	Current proposal to EU to fund this, but also need non-EU experts.; +	1	
	Use a synthesis of the existing literature to develop specific modules (to add to existing models) that describe the diagenesis of labile organic carbon in sediments and use the resulting physicochemical changes to predict biological responses in both spatial and temporal frames. to develop these modules.		+		
	Need agreement on selection and development of process modules and their integration into operational computer models after full calibration and field validation.		Some work ongoing, but more $ needed. Current proposal to EU; o		
23. Increase understanding of the impacts of dissolved organic and inorganic nutrients to improve assimiltive capactiy estimates.		Models exist that can tackle these questions at a range of levels from simple equilibrium concentration enhancement box models, through biogeochemical models incorporating biological processes and simplified physics, to shelf-scale, multi-trophic ecosystem models driven by complex hydrodynamic models. Such ecosystem models are unwieldy and expensive for coastal basin scale work but can provide important boundary conditions.	$300k to start; c	1	

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24. Analyze the effects of dissolved nutrients from aquaculture on the water column.		This will depend on the scale and exchange rates of the receiving system, the scale and form of other nutrient sources, constraints on the system, (e.g. light), and the degree to which these nutrients are buffered within the system (e.g. by macro-algal production), or otherwise lost from the system (e.g. by denitrification).	o	1	
25. Integrate relatively simple biogeochemical-physical models at the basin scale and extend them to more open waters.		Models need to incorporate those factors that increase the potential for stratification (lack of wind and significant freshwater input) and those that disrupt stratification (wind and fetch plus geological features). In addition, dinoflagellates appear to gain an advantage over diatoms when silicon (silicate) is depleted. Therefore, the supply of silicate and perhaps other micronutrients is important to understanding the potential for noxious phytoplankton blooms.	EU may fund some of this but we need non-EU experts also. o	1	
26. Investigate the potential of integrated finfish aquaculture to recycle a proportion of its wastes into useful secondary products, such as bivalves and seaweeds.	Identify how impacts will vary with the trophic status of the receiving water body, co-culture species and environmental conditions (e.g. light availability).	A comprehensive study of the sceintific, regulatory, and commercial/socioeconomic issues is required.	+		
	Model ratios of species to optimize integrated aquaculture.		+		
	Identify regulatory and policy changes that could encourage integrated aquaculture.		+		
	Undertake financial analyses on integrated aquaculture to better understand the implications.		+		

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27. Analyze environmental impacts of and potential for open ocean aquaculture.	Conduct preliminary environmental impact assessment for generic cases in several likely environments e.g. the North Sea, Hawaii, the Eastern Seaboard of USA.	Some of this work may have already been attempted and could input into a global analysis that might highlight environmentally risky areas for such activities. Not yet urgent.	o	3	
	Assess simple ecosystem models and develop/use more complicated shelf-scale ecosystem models if they are needed.		o		
28. Conduct environmental cost-benefit analyses of the environmental impacts and benefits of closed systems. (see below)	Analyze the adaptability and efficiency of closed systems for freshwater culture, where solid waste could be collected, pumped ashore, and composted for use in terrestrial agriculture.		+		
	Analyze the adaptability and efficiency of closed systems for marine culture with potentially high salt and sulphate concentrations.	Economic analysis of a BC closed-system salmon operation is being done.	+		
BENTHIC IMPACTS & SITING					
29. Evaluate and recommend methods for benthic remediation.	Compare impacts of natural sediment recovery with mechanical benthic remediation methods such as dredging, with biological benthic remediation methods such as seeding with pollution-tolerant macrofauna, which may accelerate remineralisation where there is a paucity of larval supply.	Benthic remediation has been little studied and even less published. However, it might be far metter to manage sites within their limits and focus less on remediation.	o		
	Define better engineering practices/standards to improve nutrient-enriched bottoms as rapidly as possible		+ / o		
30. Investigate differences of impacts for different feeds and/or species.	Improve understanding of the interrelationship of feed management, the quality of wastes under different feeding regimes, and associated benthic impacts.		*	2	
31. Study potential of closed containment systems. (See above)	Research the potential of new/future containment systems to eliminate escapes, benthic and visual impacts, and associated ecological,social, and financial costs.		*	1	
32. Develop methods and measure impacts of salmon aquaculture on hard bottoms.		This is an issue in Scotland and likely to become more important as industry attempts to move offshore.	o	2	

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33. Prioritize the issues of proper siting.	Initiate collaborative social science, multistakeholder process (e.g. industry, researchers, NGOs, and agencies) to identify and prioritize siting issues.	Processes that do not include all of these partners have little credibility or track record. ICZM needs to be more widely adopted and decision making devolved as far as possible to the local level.	+	1	
34. Use GIS models and other technical tools in the siting of salmon aquaculture operations and to develop siting criteria.	Develop GIS models that reflect the environmental and physiological aspects of location combined with social aspects for use in siting.	Models are being developed in Chile, Canada and Scotland. The work is not all well structured and some are unaware of the capacity of modern GIS tools. See http://www.aquaculture.stir.ac.uk/gisap/	+		
	Relate aquaculture impact to potential/existing impacts from other economic activities.	Capacity of GIS to model and analyze interactions and trade-off of activities is well developed but poorly implemented.	o		
	Incorporate many factors into models and siting criteria, including interactions with wild fish, conservation or cultural features, other marine uses and local and basin scale impacts of nutrients and chemicals.	Models allow the sensitivity of cage location to be examined against predicted environmental responseat the basin scale.	+		
35. Determine acceptable levels of impact on benthos.	Define the likely parameters of an "acceptable level of impact" of salmon cages from a societal perspective.	Much work done on standards, etc., but more work needed.	EU may support this.		
36. Design assessment methods for cumulative farm impact vs. the impact of a single farm.			* / +	1 / 2	
CROSS-CUTTING ISSUES					
37. Define BMPs for the major environmental impacts.			*		
38. Disseminate information on environmental impacts of salmon aquaculture.	Disseminate BMPs related to all environmental impacts of salmon aquaculture.		*		
	Create a website and listserve to increase information sharing on environmental impacts of and BMPs for salmon aquaculture.		*		
39. Create register of projects addressing the issues.	Build on and/or compile existing registers.	See UK registry at http://www.defra.gov.uk/science/areas/aquatic/default.asp.htm	*		
40. Identify good legislation in salmon farming nations.		Group could put pressure on governments/authorities to implement good legislation.			

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