



A REVIEW OF THE STATUS OF SALMON SEA LOUSE RESEARCH

REPORT PREPARED FOR MARINE SCOTLAND



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BIBLIOGRAPHIC POLICY

The Sponsor has agreed that references in this document may be cited as web links as appropriate.

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EXECUTIVE SUMMARY

This short paper has been commissioned by Marine Scotland, which requested an overview of current international research on the salmon sea louse *Lepeophtheirus salmonis*. Its purpose is to help guide discussions at a proposed sea louse experts workshop to be held in May 2011, and to introduce the concept of developing and co-ordinating a Scottish Sea Louse Research Framework. Marine Scotland proposes to host an international symposium on sea louse research in the autumn of 2011, and has asked SARF to organise and facilitate the event. The present paper therefore also serves as an updated review of the entire subject area for the SARF Board, which will have an important decision-making role in any such work.

Sea louse research is multi-disciplinary, but it is also multi-national. This international aspect has been brought to the fore through the two multi-national workshops held in 2010, in Bergen and in Aberdeen. These workshops highlighted three overarching points:

- There has been, and still is, an enormous amount of research into various aspects of understanding and managing the salmon sea louse
- The key interest-groups in each country, including industry and various public sector bodies, already have their own firm and experienced views on 'research priorities and strategies'. These are summarised in Section 1.3 of this paper
- There is a significant amount of commonality amongst all the groups, and an effort is now underway to establish an agreed 'international' sea louse research strategy. Section 1.4 of this paper outlines the fundamental research themes, which are:
 - **Structural measures and dispersion modelling**
 - **Farming and use of wrasse**
 - **Biological measures and molecular knowledge building**
 - **Resistance challenges and use of medication**
 - **Surveillance (farmed and wild fish)**
 - **Novel technologies / Other**

Section 2 of the paper identifies a sample of the types of individual research projects that are currently underway or recently completed, brigaded under each of the agreed research theme headings.

Section 3 of the paper considers the role that SARF research has played so far in specific sea louse research, and indicates that SARF member organisation research priorities in 2011 are focusing increasingly on this topic.

Section 4 of the paper provides some conclusions, and observes that Scotland might benefit from a co-ordinated and managed 'national sea louse research framework', and that this might serve to provide Scotland's point of contact with the international efforts that are underway. The Healthier Fish and Shellfish Working Group and SARF are both identified as possible contributors of expertise to such an endeavour.

1 INTRODUCTION

1.1 Background

1. Marine Scotland, recognising the importance of the salmon sea louse *Lepeophtheirus salmonis* (and possibly *Caligus elongatus*) to the salmon industry and other stakeholders in Scotland, has expressed a desire to support further research in this area. It proposes to host a focused industry/research technical workshop in May 2011, and it proposes to use the outcomes from the workshop to help develop an international symposium on sea lice, to be held in Scotland in the autumn of 2011. Furthermore, Marine Scotland has indicated that it is willing to provide £100,000 additional funding for sea lice related research project to be commissioned by SARF during the year 2011/12.
2. In order to help advise these various activities, Marine Scotland has requested that SARF prepare a short review paper on all recent and current activities in the field of sea louse research. The intention would be to expand this paper into a 'Scottish Sea Louse Research Framework', following further input from the activities noted above.
3. This review paper is based upon a desk top assessment of published material in this field, and has also benefited from expert advice from Marine Scotland Science, Marine Scotland, and individual members of the SARF board.

1.2 The Sea Louse – Setting the Scene

4. The format of the paper is deliberately focused on tabular listings of research priorities or projects, brigaded under a number of 'theme' headings. It is not appropriate to enter into detailed discussion about the nature of the sea louse and its interactions with farmed and wild salmonids in this paper. The entire subject area has been covered very effectively in recent reviews, particularly Revie *et al* 2009¹ and Costello 2009². Other helpful general sources of information about relevant research are available from Scotland³, Canada⁴, Norway⁵, and globally⁶. References to individual projects will be noted where appropriate later in the paper.

1.3 Existing Sea Lice Research Priorities

5. It is important to recognise that the salmon farming industry itself, along with its many collaborators, suppliers and regulators, has a very good understanding of what the current issues are regarding the challenges of sea lice, and the research and development that is required. The following overviews (Tables 1 to 9) are summarised from the presentations given in Bergen in 2010⁷. They have been presented in a common format, and have hopefully captured the main overarching priorities or strategies presented in Bergen. Not all Bergen participants' presentations are included, since the purpose of this Section is to focus on wider strategy issues rather than single issues. There were also informative presentations from the pharmaceutical and feed company sectors at Bergen, and readers are recommended to consider these by viewing them on the referenced website.

¹ <http://www.lusedata.no/Dokumenter/Sea%20Lice%20Report%20-%20Final180509.pdf>

² <http://rspb.royalsocietypublishing.org/content/early/2009/07/02/rspb.2009.0771.long>

³ <http://www.scotland.gov.uk/Uploads/Documents/SeaLiceMulti.pdf>

⁴ <http://www.dfo-mpo.gc.ca/aquaculture/rd2009/toc-tdm-eng.htm>, and http://www.al.gov.bc.ca/ahc/fish_health/sealice_MS.htm

⁵ http://www.imr.no/nyhetsarkiv/2011/januar/lus_og_romming_odelegger/en and

<http://www.cermaq.com/portal/wps/wcm/connect/cermaqen/home/press/news/ei>

⁶ <http://www.worldwildlife.org/what/globalmarkets/aquaculture/WWFBinaryitem11790.pdf>

⁷ <http://www.lusedata.no/Sider/FaktaArtikkel.aspx?Tittel=Sea%20lice%20>

Table 1. Scottish Industry Priorities – J. Webster SSPO

Resistance monitoring –review of best practice (SSPO/loA). Support for the current review of the CoGP and the NTS.
Preserving efficacy –identification of best practice in rotation of treatments (SSPO/pharmaceutical companies).
Zoning -pilot project to assess hydrographic connections between Farm Management Areas. Assistance for farming companies involved in the development of Farm Management Agreements.
Identifying, screening and developing new products –support for pharmaceutical companies
Industry sea lice database –collection, analysis and presentation of sea lice data. Information to be shared by companies within and between Farm Management Areas. Publication of sea lice data by region on SSPO website.
Wrasse as a biological control –supporting for trials involving member companies and researchers on captive breeding and the use of wrasse (Corkwing, Cuckoo, Ballan).
Refinement of procedures for bath treatments in wellboats and pens
Modelling discharges from wellboats –FEPA compliance
Potential for improved retention of in-feeds in fish
Review of current position on EQSs for SLT actives.
Revisit conclusions of PAMP

Table 2. Norwegian Industry Priorities – P. Negaard

Mutual, binding agreements on cooperation
Cooperation with authorities
Exchange of, and coordinated and use of, information
Coordinated management and fallowing: Large areas Requires change sin site structure
Synchronized(medical) treatments: Systematic alternation/ rotation of chemicals
Technical quality on treatment
Methods that are medicine independent / not inducing resistance: Cleaner fish
Prevent the spread of lice(copepodids): Filtration
Prevent the lice from settling on the fish: Functional feeds Vaccine breeding,
Knowledge
Regional surveillance and emergency plans
R&D

Table 3. Norwegian Veterinary Priorities – Grontved, NVI

Preventive measures: Ring-fence areas Synchronised production cycle of 1-year class of fish Fallowing Vaccines Breeding Health feed Other measurements
Biological control: Use of cleaner fish, wrasse Future coming biological control measurements?
Monitoring and surveillance: Counting, sensitivity testing, population development
Use of chemotherapeutants
Surveillance of wild salmonids

Table 4. Norwegian FSA Legislative Tools Under Consideration – R. Thorarinsson, FSA

Zonal regulations(areas with biggest resistance problems); South Hordaland county and Hardangerfjord. North Trøndelag county (possibly S. Nordland county). “Ryfylke” basin in Rogaland county.
Specifically: Synchronized following of extended geographical areas Large geographical areas treating against sea lice in a synchronized manner only requires a maximum area sea lice threshold levels. Filtering out and destruction of sea lice from well boats and transfer/effluent water from slaughter houses

Table 5. Irish Government Priorities – D. Jackson, Marine Institute

Optimising Hydrogen Peroxide treatments
Modelling of suitable scales for strategic treatments
Development of improved treatment delivery strategies
Optimisation of IPM approach
Optimise SBM and fallowing
Standardisation of sensitivity bioassays

Table 6. Canadian Priority Topics – C.Bridger, AEG. Note: more detailed description of projects available in the presentation.

Regulatory Research
Management Practices
Environmental Management
Novel Treatments/Green Technology
Modelling

Table 7. Faroes Priority Topics – P. Ostergard, DVM

We are planning a project to give us information on how the salmon lice are spread in the Faroes. “Who infects who” and how is the infection maintained Real - time PCR on water samples – nauplius and copepodids “Ocean” samples Fjord samples Farm samples Compare to lice count - numbers Collaboration with the Faroese current - modelling project
Alternative measures to control... Cleaner fish None of the well known cleaner fish are found in the Faroes We really want to try this way, but import of a new species which will find its way to freedom..... Import allowance for wrasse has been applied for.... The Veterinary authorities seem to be the right address, but... What about “all - female” or triploids wrasse? What about lumpfish? Native fish species in the Faroes Biological – infections etc

Table 8. Institute of Aquaculture Sea Lice Topics/Work. Also incorporates the activities of the Minister’s sub-group on fish health.

Screening and development of new treatments Experimental models to test pharmaceuticals, vaccines & immunostimulants GLP/GCP efficacy, safety, residue depletion, environmental risk assessment Assessment of the use of alternative lice stages & other model organisms for in vitro bioassay screening (HIE/UoS)

<p>Resistance</p> <p>Lab cultures of lice with varying sensitivities to existing treatments at MERL In vitro & in vivo techniques for monitoring of resistance developed& compared (publication in preparation) Stability of resistance in multiple generations underway (SARF/IntervetSP) Commercial studies to optimise existing treatment regimes in less sensitive lice populations e.g. combination treatments</p>
<p>Microsporidian infections of Sea Lice and Salmon</p>
<p>Factors affecting susceptibility of Salmon to Sea Lice</p>
<p>Fresh Start: The Renewed Strategic Framework For Scottish Aquaculture</p> <p>Immediate Priorities</p> <p>Creation of a national system for the collection of sea-lice and mortality data(by end of December 2009). Development of an improved strategy for control of sea-lice taking account of integrated sea-lice management approaches including effective sampling protocols and appropriate treatment interventions.(by end of March 2010). Delineation of appropriate scale management areas for all of Scotland to allow single year class stocking, simultaneous fallowing and area treatments.(by end of March 2010).</p> <p>Sea-Lice Control Strategies</p> <p>ISSUES</p> <ul style="list-style-type: none"> •Limited armoury of treatment products •Lack of discharge consents may prevent alternation of treatment products •Resistance development has led to major mortalities and welfare problems in some areas <p>WAY AHEAD</p> <ul style="list-style-type: none"> •Reinforcement of ISLM approach. •Possible re-siting of Aquaculture installations. •Sharing of knowledge on effective treatment protocols

Table 9. Integrated Pest Management Priority Issues – G. Ritchie, Marine Harvest

<p>Objectives of IPM</p> <p>Combine good husbandry/management practices & biological control Optimise the effectiveness of available medicines Avoid resistance development Prolong the market life of medicines Minimise environmental inputs With focus on ;</p> <ul style="list-style-type: none"> Preventative measures Strategic and coordinated measures
<p>The Way Forward?</p> <p>We all know what an IPM strategy for sea lice should consist of Is there a need to update an IPM strategy, based on new knowledge, and tailor it to today's production systems and approaches, and make it sustainable? Do we need to start at Step 1 (well defined and implemented SOPs/BPs)? What improvements can be made at Step 2 (identification and monitoring)? What new knowledge exists to strengthen Step 3-5?</p>

1.4 International Agreement on Sea Lice Research Themes

6. Research into sea lice is a broad topic, covering many different research theme areas. Section 1.2 provides an overview of these areas as presented at the Bergen meeting in February 2010. This meeting was followed by a multi-national workshop held in Aberdeen⁸ in October 2010. This meeting proposed an overarching internationally-agreed set of sea lice research themes, whilst recognising

⁸ <http://www.lusedata.no/Sider/FaktaTema.aspx?Tema=Sea%20lice%20multination>

the multi-disciplinary nature of sea lice research. The following themes (and sub-themes for information) are suggested, based upon the Aberdeen meeting:

1. Structural measures and dispersion modelling

- a. Data provision and data requirements
 - i. Oceanographic and hydrographic data
 - ii. Sea lice biology
 - iii. Standardised sea lice counts: wild; farmed
- b. Hydrographic modelling
- c. Sea lice dispersion modelling
- d. Best practice in area / bay management protocols

2. Farming and use of wrasse

- a. Intensive production of wrasse
- b. Sustainable wild harvest of wrasse
- c. Best practice in use of wrasse, including re-use
- d. Fish health & welfare issues

3. Biological measures and molecular knowledge building

- a. Experimental protocols for investigating sea lice
- b. Host/parasite interactions
- c. The genetics of the salmon sea louse
- d. The biology of the salmon sea louse
- e. Resistance and selective breeding
- f. Functional feeds

4. Resistance challenges and use of medication

- a. Understanding/improving the IPM approach
- b. Consistency with use of current medication – regulation, etc
- c. Best practice in use of medications
- d. Development of resistance – treatment efficacy
- e. Sensitivity testing
- f. New developments in medication

5. Surveillance (farmed and wild fish)

- a. Standardised techniques for surveillance and monitoring
- b. Movements of wild salmonids
- c. Fate and behaviour of escaped salmonids

6. Novel technologies / Other

- a. Other biological techniques
- b. The role of other finfish species – challenges or opportunities
- c. Closed containment aquaculture
- d. Other

- 7. It is important to stress the distinction between a consideration of **aspirations** for future sea lice research (or rather, the need for new knowledge that can come from research) and the analysis of **recent** and **current** research that is presented in Section 2 of this paper. One key task during 2011 will be to identify where there are gaps between current activity and future aspirations, but it will also be important to **prioritise** these gaps in terms of available resources for undertaking research.
- 8. There is a degree of overlap between the main themes. For example, 1 a ii refers to standardisation of sea lice counting techniques, and is clearly necessary as a tool within the broad theme of structural measures. However, it also overlaps with techniques that are/will be utilised in theme 5, surveillance. Such overlaps are inevitable, and the paper will try to identify other examples of these on a project by project basis, where appropriate.

2 RECENT AND CURRENT SEA LICE RESEARCH

9. The following list of recent or current research is not intended to be in any way 'complete', but rather to give an indication of the types of sea lice related research that are prevalent.

2.1 Theme 1: Structural Measures and Dispersal Models

10. The overarching goal of Theme 1 is to develop scenario testing and decision support tools for a strategic approach to integrated pest management. This suggests optimising the use of assets in management decision for sea lice control, by building modelling tools to predict the best salmon production plans with deployment of cages and treatment/control strategies. Such work forms the basis of a best practice approach to geographic management/production strategies.
11. *Note that the tables in this Section present projects according to the overarching 'theme', rather than dividing them into sub-themes. Where there is an important point to note in this regard, it is inserted in the Status/Comments column of the tables. References for Section 2 are presented as end-notes rather footnotes.*

PROJECT	COUNTRY	REF	STATUS/COMMENTS
SAMS. Gillibrand & Willis 2007. Dispersal of sea louse larvae from salmon farms: modelling the influence of environmental conditions and larval behaviour	Scotland	i	<i>"The dispersal and distribution of sea louse larvae was strongly influenced by environmental conditions and larval behaviour."</i>
SAMS Project. Modelling Sea lice dispersal in the Clyde Sea System	Scotland	ii	Goal to optimise fish farm sites locations.
Understanding the dispersal of, and risk from sea lice, within Scottish coastal systems. (MSS presentation in Bergen. R. Reynard).	Scotland	iii	Multi-partner, 5 year project. Focus on Loch Linnhe system. (Background on long Torridon monitoring experience).
Modelling in support of Coordinated Area Management Production Plan	Canada P	DFO	Foreman / Stucci, 2008-9

2.2 Theme 2: Farming and Use of Wrasse

12. The overarching goal of Theme 2 is to ensure that wrasse can be safely, sustainably and economically obtained; that they can be used and managed effectively on salmon farms; that their disposal or recycling at the end of the salmon crop cycle is safely based on good evidence. Assessment of the effectiveness of the use of wrasse, including species choice, is a key feature of such work. Regulatory and fish health and welfare issues are important. Cultivation of wrasse in hatcheries/nurseries is effectively the rearing of a 'new' marine species (perhaps more than one species), and therefore carries the same fundamental research requirements as were evident in the development of techniques for farming species such as seabass, turbot or Atlantic cod.

PROJECT	COUNTRY	REF	STATUS/COMMENTS
Ben Forward, RPC. Potential cleaner fish in Bay of Fundy	Canada	iv	Early-stage assessment. Suggest further research.
Practical use of wrasse in salmon on-growing pens	Scotland	SARF068	SARF Project: Viking.
Wrasse research at Macrihanish	Scotland	v	Overview. Marine Harvest involved
Wrasse research at Otter Ferry	Scotland	vi	Overview
Wrasse research in Shetland	Scotland	vii	Overview

Wrasse: SSPO involvement in co-ordination	Scotland	viii	Summary
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Note: There are many other references to the possible use of wrasse as cleaner fish, but those indicated above give the clearest picture of current research from a Scottish perspective.

2.3 Theme 3: Biological measures and molecular knowledge building

13. The overarching goal of Theme 3 is to develop biological sea louse control that involves the use of measures which exploits aspects of the parasite or host's biology or environment. This biological control strategy could be based on use of in-feed supplements, vaccines and selective breeding of host fish, as well as many others.

PROJECT	COUNTRY	REF	STATUS/COMMENTS
Physiological, Biochemical, And Histological Approaches To Examining Sea Lice-Salmon Interactions	Canada	ix	Complete.
Effect of Sea Lice on Mucus Pattern Distribution	Canada	x	Sea lice infested fish have washed out mucus
INSTITUTE OF AQUACULTURE Projects	Scotland	xi	Many papers: see website reference.
IMR Report on Sea Lice genetics	Norway	xii	Overview paper.
Evaluation of light traps as a monitoring and control tool for planktonic-stage sea lice	Canada P	DFO	Mackas, 2008-2009
A Review Of The Biology And Genetics Of Sea Lice	Norway & global	xiii	Boxaspin; general review.
Reducing the impact of sea lice infection on fish health and welfare through selective breeding	Scotland	xiv	Landcatch EFF project.

2.4 Theme 4: Resistance challenges and use of medication

14. The overarching goal of Theme 4 is: to use existing medicines as effectively as possible, within the disciplines of an IMP approach; to ensure that environmental regulatory regime definition and use of medicines is as compatible as possible; to develop new medicines, or better ways to use existing medicines. Identifying and understanding resistance of sea lice to current medicines is an important sub-set of this theme, as is understanding how resistance can be 'bred out' of wild sea lice populations over time.

PROJECT	COUNTRY	REF	STATUS/COMMENTS
IMR Report on bath treatment techniques 2009	Norway	xv	Identifies challenges with skirts; proposes solutions.
SAMS Project 2005. Effects of Sea Lice Treatments at a Salmon Farm on Zooplankton Communities	Scotland	xvi	<i>"Predicted concentrations that environmental concentrations of Excis and Slice do not adversely impact zooplankton communities."</i>
PAMP Project: The Ecological Effects of Sea Lice Medicines in Scottish Sea Lochs	Scotland	xvii	Important for assurance on regulation.
Page 2010. DFO. Dye studies on cage bath treatments.	Canada	xviii	A report on work-in-progress; more analysis required.
Burridge 2010. Ecotoxicology work on	Canada	As above	Good review

various medicines			
Hammell 2010. Resistance monitoring; training	Canada	As above	Good review
Beattie 2010. Treatment methods	Canada	As above	Good review
Armstrong 2010. An Introduction to Wellboat Treatment Technology	Canada	As above	Good overview of recent experience and emerging good practice
Steine 2010. Alphamax updates – focus on treatment in closed units.	Global	As above	Good review.
Mackinnon and McHenry 2010. Excis – Safety for the Fish and the Environment	Global	As above	Good review of 'fate and behaviour' studies. Concludes: <i>"Data from several sentinel species studies conducted in Scotland and North America concluded that cypermethrin as Excis does not kill crustaceans outside the treated cages unless held for extended periods and that it does not persist in the environment."</i>
McNeillie 2010. Interox® Paramove® 5 0 For Salmon Lice Control – Regulatory requirements	Canada	As above	Overview.
McEwen 2010. Practical Experience Of Sea Lice Assays in Scotland	Scotland	As above	Progress with on-site sensitivity assessment.
Evaluation of the Environmental Fate and Biological Effects of the Anti-Sealice Chemotherapeutant SLICE®	Canada P	DFO	Ikonomou, 2008-2011
Potential effects of bath treatments on sensitive non-target organisms in southwest New Brunswick	Canada M	DFO	Burridge, 2010-2011
Dye Dispersion Study to characterize how sea lice bath treatment therapeutants will disperse from salmon farm cage sites in southwest New Brunswick.	Canada M	DFO	Page, 2010-2011
Review of sea lice bath treatment model	Scotland	SARF023	SARF Project
Coastal assimilative capacity for amalgamated fish farm chemicals/organic pollutants	Scotland	SARF009	SARF Project

2.5 Theme 5: Surveillance (farmed and wild fish)

15. The overarching goal of Theme 5 is to standardize and further develop efficient and robust sea lice surveillance methods regarding counting (wild and farmed fish) and assessment of treatment efficacy (bioassays and sea lice counting pre/post treatment), and to better understand the sea lice implications of escapes of farmed fish.

PROJECT	COUNTRY	REF	STATUS/COMMENTS
IMR Report: Sea Lice surveillance, Hardengafjord 2008	Norway	^{xix}	Use of sentinel cages
<i>Example:</i> 2011, February – Price M.H.H., Proboszcz S.L., Routledge R.D., Gottesfeld A.S., Orr C., et al. Sea louse Infection of juvenile sockeye salmon in relation to marine salmon farms on	Canada (some global)	^{xx}	NOTE: There are 26 publications listed at this reference location. Most are concerned with monitoring what is taking place and

Canada's West Coast.			demonstrating linkage between farmed salmon, sea lice and wild salmonids. Main focus is Canada.
Modelling 2009 sea lice dispersion from salmon farms in the Broughton Archipelago	Canada P	DFO	Foreman / Stucci, 2009-2010
Spatial distribution of planktonic sea lice in the Broughton Archipelago, and cross-validation inputs to numeric model	Canada P	DFO	Mackas / Galbraith, 2009-2010
The effects of single and repeat <i>Lepeophtheirus salmonis</i> infections on the health of juvenile Pacific salmon.	Canada P	DFO	Johnston, 2010-2011
Sea lice infection levels on juvenile salmon during early seawater residency and migration out of the Strait of Georgia.	Canada P	DFO	Johnston, 2010-2011
Wild-farmed interactions, sea lice management, and characterization of the susceptibility of wild Pacific salmon populations to sea lice infection.	Canada P	DFO	Foreman, 2010-2011
Health of juvenile salmon during early seawater residency and migration past salmon farms	Canada P	DFO	Johnston, 2010-2011

2.6 Theme 6: Novel technologies / Other

16. Theme 6 is the general category that covers research into areas not addressed within themes 1 to 5.

PROJECT	COUNTRY	REF	STATUS/COMMENTS
Possible use of mussels as 'biofilters'	Canada	^{xxi}	Contained in current IMTA paper to SARF Board.
Robinson, DFO. Mussels. 2010	Canada	^{xxii}	Field trials will take place over the next 2 years.
Evaluation of the efficiency of non-chemical methods to reduce the impact of sea lice associated with salmon aquaculture sites using the principles of bio-filtration and traps.	Canada M	DFO	Robinson, 2010-2011 (Note: see above)

3 SARF AND SEA LICE RELATED RESEARCH

17. As Section 2 notes, there have been three SARF projects directly focused on sea lice research, with two further projects (SARF009 and SARF011) touching in small part on the release of sea lice treatment medicines to the environment. The three projects represent 5% of the total number of SARF projects commissioned to date, and 4% of the total cost of projects (SARF and non-SARF funds).
18. The current SARF research prioritisation exercise (Spring 2011) has highlighted a growing awareness of the importance of sea lice research amongst several SARF member organisations, and several possible research project concepts have been submitted for Board consideration. These include:
- **Post Authorisation Monitoring Project Refreshment Study**
 - Also noted as an industry priority (Table 1), this proposal to refresh the original so-called PAMP study is seen as an important contribution to SEPA's ability to continue authorising the use of sea lice medicines for salmon pen farming in Scotland.
 - **The Sensitivity of Cnidarians**
 - This proposed study would complement the original SARF011 work on environmental quality standards (EQS) with respect to the authorisation of sea lice medicines. This particular taxonomic group has not so far been properly included in such work, and whilst SEPA is confident that its regulatory regime protects this group adequately, concerns have been raised.
 - **Investigating the marine migration pathways of Adult and post smolt Atlantic salmon**
 - Provision of this data would greatly assist the spatial planning of aquaculture development in Scotland. It would also allow regulators and consultees to provide more informed and meaningful responses to proposals for new farms. It would help us judge the capacity for new development.
 - **Investigating the local coastal movements of sea trout in Wester Ross**
 - Sea trout may be particularly affected by sea lice from salmon farms because they do not migrate to the high seas to feed, but stay within coastal areas. A greater understanding of sea trout marine movement patterns is needed if we are to understand the interaction between aquaculture and sea trout.
 - **Modelling the behaviour of discharges from well boat sea louse treatments**
 - The use of well boats to treat large numbers of salmon is an important tool in the industry's armoury. It is subject to a consenting procedure, and the proposal is to investigate whether this consenting procedure could be optimised by provision of up to date information about fate and behaviour of treatment discharges.
19. In addition to the specific project concepts outlined above, several consultees in the prioritisation exercise stressed the importance of the current **sea lice dispersal modelling** work – see item 3 in Section 2.1. There is a general consensus that 'area management', in its broadest sense, is one of the key tools in managing sea lice. The definition of what an 'area' should be relies to some extent on an understanding of sea lice larval dispersion patterns. Consultees recognised that to extend the work beyond the Loch Linnhe system would be a long term and expensive undertaking, but a potentially important one. There has also been a request to consider **environmental impact minimisation** in general, and specifically **in relation to sea lice treatments**, and with a goal to improve overall productivity.
20. There are some key questions about the use of wrasse as cleaner fish:
- What are the fish health and regulatory implications of **moving** wild caught wrasse, or hatchery-reared wrasse, from one 'area' of Scotland to another
 - What should be done with wrasse at the **end of the salmon production cycle** – can they be re-used, or should they be destroyed?
 - **Sustainability** of wild-caught wrasse in the short and long term.

4 CONCLUSIONS

21. It is evident that managing sea lice requires a multi-disciplinary approach, and it is also evident that considerable research effort has been expended in the past, and continues to be expended. All the main salmon farming countries are investing in sea lice research, including Scotland. Efforts are underway to establish an internationally co-ordinated approach to sea lice research, so that duplication is avoided and information is shared speedily and cost effectively.
22. The recent establishment of the Sea Louse Research Centre at the University of Bergen⁹ followed directly from the two multi-national workshops referred to earlier, and it will serve as a focal point for all sea lice research efforts in Norway. One of its stated aims is to collaborate with other institutes in countries such as Canada, Chile and the UK. Our understanding is that the Bergen initiative is Norwegian, and not intended to be an 'international centre'. The key point is that each of the nations involved needs to have a central place for focusing sea louse research, and that these national 'centres' should work closely together.
23. The question for Scotland is whether there is an opportunity and need to develop a 'national sea louse research strategy/framework', and co-ordinate its implementation in some way. Establishment of a physical 'research centre' is possible, but potentially difficult and costly to undertake. The alternative is perhaps to develop, manage and constantly review a national sea louse research framework by way of a 'virtual centre', i.e. a stakeholder-led expert group supported by a professional secretariat.
24. The Healthier Fish and Shellfish Working Group¹⁰ was established in 2009, and took over and expanded on the activities of the long standing Aquaculture Health Joint Working Group¹¹. With its Ministerial support and its broad and inclusive membership, the current Group is well-placed to advise on the establishment of a specific national sea louse research framework and management programme. Similarly, with its broad membership and experience in secretariat-supported research prioritisation, commissioning, management and delivery, as well as its increasing advisory role, SARF would be well-placed to provide support to such an endeavour. Neither body is currently wholly focused on sea lice research, but a new entity arising as a sub-set of both bodies could be completely dedicated to the effective co-ordination of sea lice research in Scotland. It would also serve as Scotland's focal point for the international collaborative effort that is now gathering pace.

⁹ <http://www.cermaq.com/portal/wps/wcm/connect/cermaqen/home/press/news/ei>

¹⁰ <http://www.scotland.gov.uk/Topics/marine/Fish-Shellfish/18610>

¹¹ <http://www.scotland.gov.uk/Topics/marine/Fish-Shellfish/18610/previous/NewPage>

ANNEX 1. END-NOTE REFERENCES FOR SECTION 2

- ⁱ <http://www.int-res.com/abstracts/ab/v1/n1/p63-75/>
- ⁱⁱ <http://www.sams.ac.uk/research/departments/ecology/ecology-projects/researchproject.2011-02-24.6840123751>
- ⁱⁱⁱ http://www.lusedata.no/Dokumenter/5_-_scotland_-_sealice_marine_skotland_authorities_-_bergen_10-02-2010-22022010.pdf
- ^{iv} <http://www.scribd.com/doc/50375656/2010-Technical-Review-and-2011-Sea-Lice-Management-and-Program-Development-Workshop>
- ^v http://www.fishresearch.co.uk/news/73_wrasse_a_green_alternative_for_sea_lice_removal
- ^{vi} <http://bmfa.uk.com/pdf/2010/PATTERSON%20OFS%20Wrasse%20Presentation.pdf>
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- ^{viii} <http://www.thefishsite.com/articles/919/scottish-salmon-annual-report>
- ^{ix} http://www.upei.ca/~anatphys/Sea_Lice/research.htm
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- ^{xii} http://www.imr.no/publikasjoner/andre_publikasjoner/havforskningsnytt/2009/HI_News_9_engelsk.pdf/en
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