Institution: University of the Highlands and Islands (UHI)

Unit of Assessment: 7 Earth Systems and Environmental Science

Title of case study: NewDEPOMOD: a predictive toolbox for predicting fishfarm waste to underpin national environmental regulations and the global aquaculture industry

Period when the underpinning research was undertaken: 2006 to ongoing

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr Thomas Adams	Research associate, modeller	2010-present
Dr Rebecca Weeks	DEPOMOD Project Manager	2018-present
Prof Kenny Black	PI marine ecology	2006-2017
Dr Thom Nickell	Benthic ecologist	2006-2015
Mr Trevor Carpenter	Physical/Ecological modeller	2013-2018

Period when the claimed impact occurred: 2013 to 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

The Scottish salmon industry is valued at over £1billion and has ambitions to double production by 2030. Waste from salmon farms can harm the sea-bed, so controlling waste is critical to minimize environmental damage. Researchers from the University of the Highlands & Islands have built an innovative waste-modelling software toolkit, NewDEPOMOD that underpins the industry and protects the environment. NewDEPOMOD is the only named software accepted by Scottish Environmental Protection Agency to predict – and minimize – sea-bed damage. All Scottish salmon companies use NewDEPOMOD in new or expansion license applications. Between 2017-2020, NewDEPOMOD has generated commercial and research income of £2.7M.

2. Underpinning research

NewDEPOMOD is a third-generation depositional modelling tool developed and commercialised by the Scottish Association for Marine Science (SAMS) research team at UHI. It has developed from DEPOMOD (1997), which was the first aquaculture discharge model to take into account site-specific hydrodynamic and site management conditions such as currents, water depth, fish biomass, and feed volume. It used these variables to predict waste amount and deposition footprint on the sea-bed. Since 2000, SAMS' research has increased the capabilities of the tool. AutoDEPOMOD (launched in 2005) incorporated site-specific bathymetry and introduced customisable parameters (e.g. biomass) to match modelled discharge levels with the environmental quality standards set by the SEPA. This enabled fish farmers to optimise production capacity within limits that prevent environmental harm [3.1]. The programme to update AutoDEPOMOD – which led to the development and commercialisation of NewDEPOMOD in 2017 – was initiated in 2012, funded by the Scottish Government.

NewDEPOMOD includes more complex physical ocean processes, an improved user-friendly interface, improved software compatibility, and site-specific model tuning [3.2]. It also allows for direct comparison of model outputs against up-to-date regulations from SEPA. Research and development of NewDEPOMOD enabled UHI-SAMS scientists to more accurately model how solid waste particles behave when they reach, and interact with, the ocean floor [3.3].

Experiments measured how particles hit the sea-bed and either become part of the sediment or are subsequently resuspended and dispersed further away by water currents over time. These experiments featured more sophisticated modelling of sediment consolidation and erosion physics [3.3].

Further research and development of NewDEPOMOD was carried out by UHI-SAMS through a NERC/Innovate UK project with Marine Harvest (now MOWI) – valued at £150,185 and running from 2016-2018 – which directly linked industry practice and management to SEPA regulatory requirements through matching regional hydrodynamic model outputs to SEPA regulations. This built confidence with SEPA that NewDEPOMOD was better able to predict environmental impact and hence approve applications for farming at higher tonnage production levels and in expanded locations [3.2]. Moreover, the enhanced flexibility of the NewDEPOMOD software in a modern computer language (Java) and compatibility with modern operating systems, allows application of the model to new species and environments, and development is ongoing to upgrade the AutoDEPOMOD-based spin-offs to the NewDEPOMOD platform. These include use in the Mediterranean (TROPOMOD, MERAMOD [3.4]), and for production of cod (CODMOD [3.5]).

Research continues at UHI-SAMS through projects designed to validate and integrate NewDEPOMOD with modern environmental and industry challenges. In collaboration with aquaculture companies and regulators and funded by the Scottish Aquaculture Innovation Centre, the ExPAND project (£475,762, 2018-2020) and ExPAND2 (£550,695.50, 2020-2023) is enabling NewDEPOMOD to produce model outputs that match new updates of SEPA regulations and requirements for aquaculture licensing. The INCREASE project (£231,902, 2017-2020) is validating model predictions against field data in highly dispersive Orkney sites. A further three research projects totalling £756,262 are extending NewDEPOMOD's near-field waste deposition predictions into a wider understanding of impacts of aquaculture installations on the UK marine environment.

3. References to the research

Note: key UHI-SAMS researchers in **bold**. Authors in *italics* are also UHI-SAMS staff. C. Cromey was previously UHI staff and is now a freelance researcher conducting research under SAMS auspices.

3.1. *Wilding, T.A.*, Cromey, C.J., **Nickell, T.D.**, and *Hughes, D.J.* (2012). Salmon farm impacts on muddy-sediment megabenthic assemblages on the west coast of Scotland. Aquaculture Environment Interactions 2(2)145-156. DOI: 10.3354/aei00038

3.2. **Black, K.**, **Carpenter, T.**, Berkeley, A., and Amos, C. (2016). Refining sea-bed process models for aquaculture. NewDEPOMOD Final Report SAM/004/12.

3.3. **Adams, T.**, **Black, K.**, **Carpenter, T.**, *Hughes, A., Reinardy, H.C.*, and **Weeks, R.**, (*Accepted,* Aquaculture Environment Interactions). Parameterising resuspension in models of aquaculture waste deposition.

3.4. Cromey, C.J., Thetmeyer, H., Lampadariou, N., **Black, K.D.**, Kögeler, J., Karakassis, I. (2012). MERAMOD - predicting the deposition and benthic impact of aquaculture in the Eastern Mediterranean. Aquaculture Environment Interactions. 2, 157-176. DOI: 10.3354/aei00034

3.5. Cromey, C.J., **Nickell, T.D.**, Treasurer, J., **Black, K.D**., *Inall, M.* (2009). Modelling the impact of cod (*Gadus morhua* L) farming in the marine environment-CODMOD. Aquaculture 289, 42-53. DOI: 10.1016/j.aquaculture.2008.12.02

4. Details of the impact (indicative maximum 750 words)

Underpinning regulation of aquaculture industry – Scotland

The UK aquaculture industry is undergoing rapid expansion whilst adhering to strict environmental regulators to avoid environmental harm. Every salmon farm requires a license from the regulator, SEPA, to operate commercially; and SEPA specifies environmental quality standards for sea-floor sediments, enforced for all aquaculture sites [5.1]. SEPA provides guidance and support to enable businesses to estimate benthic impacts by site-specific modelling [5.2] and new regulations issued in 2019 made modelling near-field waste a compulsory part of the planning application process for new or expanding farms. NewDEPOMOD is the only named approved modelling tool [Section 7, 5.3]. Therefore, UK salmon production is currently underpinned by NewDEPOMOD. The Scottish Salmon Producers Organisation (SSPO) has identified NewDEPOMOD as a key tool to help unlock further capacity for the industry as it moves towards its 2030 target of doubling fish production [5.4]. NewDEPOMOD has been available through user licences since 2017; SSPO currently has seven members, which between them hold a total of 47 NewDEPOMOD licenses [5.5]. All SSPO operational salmon sites in Scotland are using NewDEPOMOD to match farm production to environmental capacity, allowing maximal farm production while ensuring environmental standards are maintained. Due to the enhanced capabilities of NewDEPOMOD, SEPA are now able to consent farms greater than the previous fixed limit of 2500 tonnes. NewDEPOMOD therefore directly creates value for industry. Industry commitment to NewDEPOMOD is evidenced through SSPO's considerable investment in ExPAND and ExPAND2 research projects.

MOWI Group is the largest global producer of farmed salmon and one of the top three largest salmon companies in Scotland. It has used NewDEPOMOD since its launch in 2017, calculating that the model directly enabled an increase in production by 5,600 tonnes every 2 years, with estimated additional annual profit of £3.36m [5.6]. Dr Philip Gillibrand, MOWI Oceanography and Modelling Manager, states: "the application of the [NewDEPOMOD] model has contributed to the company's growth over the past two years and is a vital part of the company's future growth and development plans" [5.6].

Underpinning international planning of aquaculture

Alongside and directly inspired by the UHI-SAMS development of NewDEPOMOD, there has been independent development of specialised applications for alternative aquaculture systems, locations, and species. TROPOMOD has been developed for aquaculture in Asia [5.7] and has provided the integral impact modelling in the AQUAPARK project, a scheme for planning and management of aquaculture parks in the Philippines [5.8]; TROPOMOD is currently being used in all planning, regulations, and licensing of aquaculture in Philippines. MACAROMOD has been developed for offshore aquaculture industry in Macaronesia [5.9] and is being integrated into their industrial practise and regulation. These initiatives have been developed from AutoDEPOMOD but due to third party software redundancies are in the process of being updated to the NewDEPOMOD platform, which is essential to their continued use. Ongoing developments to integrate country-specific and species-specific applications into the NewDEPOMOD package have led to salmon-producing countries such as Canada, Chile and

Norway also trialling the tool. UHI-SAMS Research Services Ltd (SRSL) delivered in-person training for four people from four consultancy firms in Chile in late 2019, with training for a further 23 delegates booked for the first quarter of 2021. Since the start of 2020, there have been thirteen enquiries from Chile alone about NewDEPOMOD, and a research collaboration forged with Norwegian companies Aqua Kompetense and Akvaplan-niva. NewDEPOMOD currently has 62 international licenses active, and a further 12 ongoing licence enquiries. UHI-SAMS is receiving increasing numbers of enquiries for research projects, training, license sales, and regulatory management from countries including Australia, Canada, USA, France, and within the Aquaculture Stewardship Council (ASC) [5.5].

Commercialisation

The research, development, and improved workability of NewDEPOMOD over the past five years have turned the tool into a powerful commercial asset, and SRSL has highlighted NewDEPOMOD as a key commercial product in its business plan [5.5 and 5.10]. UHI-SAMS has employed a project manager and two modellers, with additional input from a research-focused science lead (10% FTE) and up to ten researchers. DEPOMOD and AutoDEPOMOD were free to download, and now NewDEPOMOD annual licenses are sold for £3,250 (academic), £2,500 (developer), or £6,500 (commercial) per license. Many licences are renewed annually to generate reliable and repeatable income. The total commercial income for 2017-2020 was £207,840.83, contributed by licence sales, training, and commercial modelling projects. With the inclusion of research funding totalling £2,164,806.50 for the same period, NewDEPOMOD has generated a combined commercial and research total income of £2,372,647.33.

5. Sources to corroborate the impact

5.1. Finfish Aquaculture Sector Plan
https://sectors.sepa.org.uk https://consultation.sepa.org.uk/sector-plan/finfishaquaculture/supporting_documents/Finfish%20Aquaculture%20Sector%20Plan%20Single%20Pages.pdf p.37

5.2. Scottish Environment Protection Agency, Marine aquaculture modelling
https://www.sepa.org.uk/regulations/water/aquaculture/pre-june-2019-guidance/aquaculture-environment/modelling/#Data_analysis

5.3. Scottish Environment Protection Agency, June 2019 – Version 1.1. Aquaculture Modelling: Regulatory Modelling Guidance For The Aquaculture Sector
https://www.sepa.org.uk/media/450278/regulatory-modelling-process-and-reporting-guidance-for-the-aquaculture-sector.pdf

5.4. Gatward I, Parker A, Billing S, Black K, et al. Scottish Aquaculture: a view towards 2030. Published 2017 by the Scottish Aquaculture Innovation Centre and Highlands and Islands Enterprise https://www.scottishaquaculture.com/media/1174/scottish-aquaculture-a-view-towards-2030.pdf

5.5. Testimonial from Dr Rebecca Weeks, DEPOMOD Project Manager at SAMS, controls licence distribution for NewDEPOMOD and provides support and training to licence holders.

5.6. Testimonial from Dr Philip Gillibrand, Oceanography and Modelling Manager, MOWI

5.7. White, P., Phillips, M., and Beveridge, MCM (2013). Environmental impact, site selection and carrying capacity estimation for small-scale aquaculture in Asia. In L.G. Ross, T.C. Telfer, L. Falconer, D. Soto & J. Aguilar-Manjarrez, eds. Site selection and carrying capacities for inland

and coastal aquaculture, pp. 231-251. FAO/Institute of Aquaculture, University of Stirling, Expert Workshop. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, RAO 282 pp.

5.8. AquaPark Project Final eReport, Akvaplan-niva, Bureau of Fisheries and Aquatic Resources, Map and Marine Scotland. https://www.academia.edu/38483177/AquaPark_Project_Final_eReport

5.9. Riera, R., Perez, O., Cromey, C., Rodriguez, M., Ramos, E., Alvarez, O., Domminguez, J., Monterroso, O., and Tuya, F. (2017). MACAROMOD: a tool to model particulate waste dispersion and benthic impact from offshore sea-cage aquaculture in the Macaronesian region. Ecological modelling 361 122-134. https://www.sciencedirect.com/science/article/pii/S0304380017303599

5.10. The Scottish Association for Marine Science, Annual Report 2019. https://www.sams.ac.uk/t4-media/sams/pdf/SAMS-Annual-Report-2019-Interactive.pdf