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The benthic impacts of a large cod farm — Are there indicators for environmental sustainability?

Thomas D. Nickell [a,*], Chris J. Cromey [a], Ángel Borja [b], Kenneth D. Black [a]

[a] Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, Dunbeg, Argyll, PA37 1QA, Scotland, UK
[b] AZTI-Tecnalia; Marine Research Division; Herrera Kaia, Portualdea s/n; 20110 Pasaia, Spain

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ABSTRACT

A cod farm in Vidlin Voe, Shetland was at the time of the study the largest cod farm in Europe, and was started in 2003. Run according to organic principles, the farm consisted of 17 * 32 m diameter cages in the 3 km long sea loch (locally known as voe), which though extremely exposed at the mouth, is sheltered near the cages. Benthic macrofauna and physical/chemical sediment parameters were measured in the summer months of 2004, 2005 and 2006 as biomass increased in the growing cycle. A range of biotic indices showed the benthic environment was enriched at peak biomass of the farm, but by contrast, surficial CHN levels and organic matter were low and uniform. The commonly used sediment indicators redox, total organic carbon and total organic nitrogen did not correlate well with biotic indicators at this site. Predictions from a near-field particle tracking and resuspension model (CODMOD) and a simple nutrient enhancement box model of the voe system (Equilibrium Concentration Enhancement (ECE) model), were used to assess the assimilative capacity of the system.

1. Introduction

Marine cod farming is a very recent development in Scotland. When No Catch Ltd (as Johnson Brothers) began their commercial cod farm in Vidlin Voe in 2003, there was only one other sea site in Scotland where a small tonnage was being trialled. It has since grown to a maximum consented harvest biomass of 1390 t. Still in its infancy in Europe, Norwegian cod farming has grown from 1500 t in 2003 (Rosenlund and Skretting, 2006), to 5500 t in 2005 (Standal and Utne, 2007). Production of farmed cod in Iceland is a combination of fully reared fish and ongrowing of wild juveniles, and ongrowing of wild adults; total Icelandic production was 595 t in 2004 (Gunnarsson and Björnsson, 2005).

Salmonid aquaculture has been practiced in Vidlin Voe for over 20 years and is one of the many aquaculture activities in the area (Fig. 1). The fish farm is economically important for the local economy, which is primarily agricultural/livestock grazing land.

The fjordic voe is open, with no definable sills or basins *sensu* Edwards and Sharples (1986) (low water area = 2.6 km^2), open to the northern North Sea and with a calculated flushing time of 5 days. Bathymetry at the site varies from 16–17 m in the south to ca 30 m at the northern edge of the cage group (Table 1). The substrate is muddy sand, becoming more coarse towards the mouth of the voe. To the northeast of the cage group within the voe is a wave dominated, sand/gravel biotope subjected to strong water movement (Howson, 1988; 1999).

For a water body subject to a variety of environmental pressures and impacts, zones can be defined on the basis of residence time, which can assist with management (CSTT, 1994). *Zone A* is local to the point source with water residence times of a few hours. In the present study *Zone A* is the sea bed near the farm impacted from the flux of waste feed and faeces. *Zone B* is the scale of the water body (in the present case Vidlin Voe), with water residence times of a few days to several weeks and sufficiently long for nutrient enrichment to lead to enhanced growth of phytoplankton. *Zone C* is a regional scale water body with residence times of weeks to months, sufficiently long for complex ecosystem processes to take place. In the present study, the northern North Sea is *Zone C* and measurements were not taken in this zone, and it was not modelled. Although the present study was primarily designed to examine *Zone A* effects, some observations in *Zone B* are discussed in relation to predictions of a simple, regulatory *Zone B* model.

At the time of writing, there are no published studies on the environmental impacts of cod farming, and thus there has been no investigation on the different scales of impact or modelling of benthic effects. Hence, the objectives of this investigation were: (i) to determine the usefulness of different benthic indicators in assessing environmental impacts from cod farming, from 2004–2006; (ii) to determine the extent of the spatial impact, by means of modelling; and (iii) to assess whether cod farming can be described as environmentally sustainable on the basis of accepted indicators.

* Corresponding author. Tel.: +44 1631 559261; fax: +44 1631 559001.
E-mail address: tdn@sams.ac.uk (T.D. Nickell).
URL: http://www.sams.ac.uk/research/sams-scientific-staff/Thom_Nickell (T.D. Nickell).

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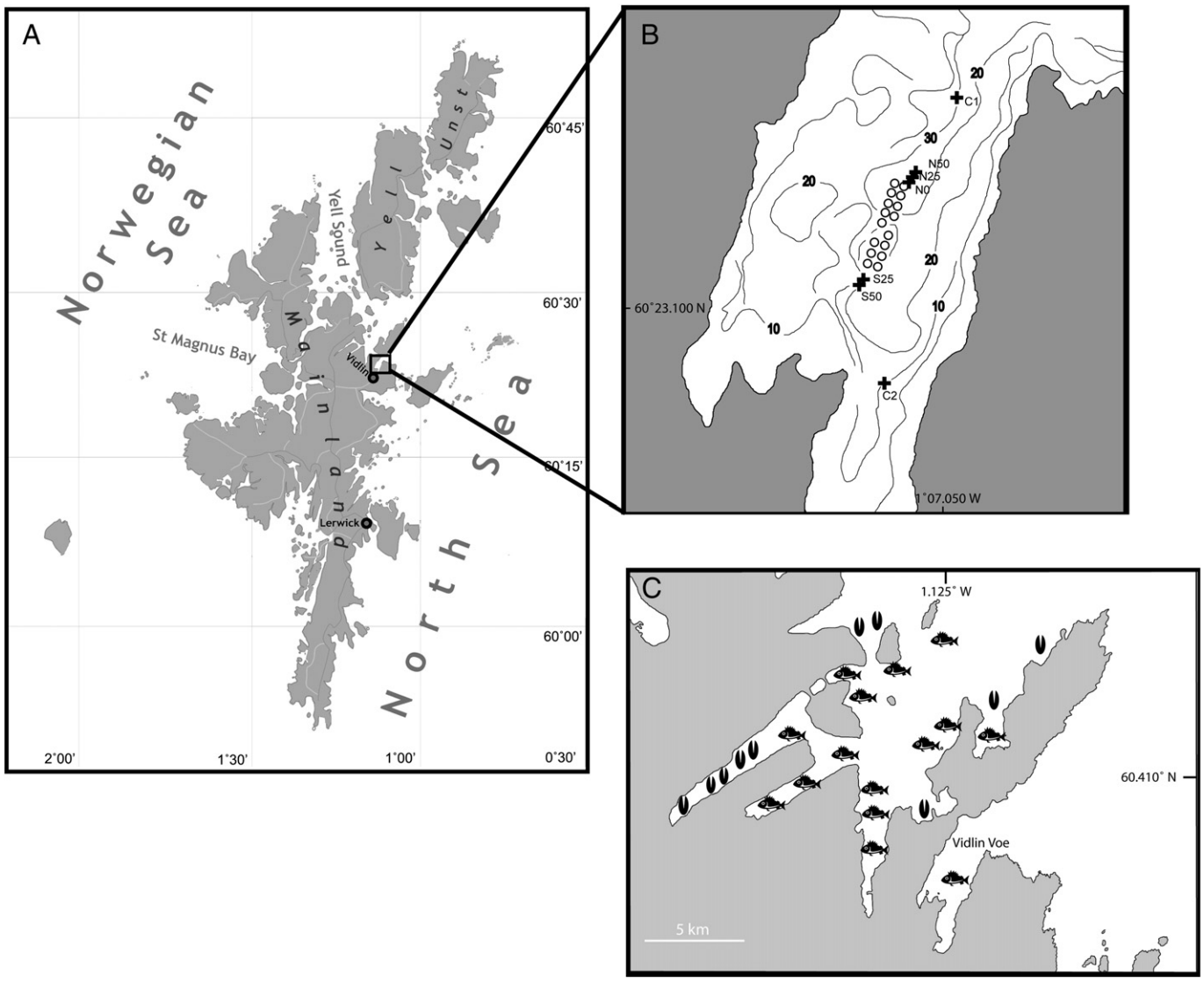

Fig. 1. Shetland (A) with Vidlin Voe study area (B) showing cage (○) layout, sample station (+) positions and bathymetry (in m). (C) Aquaculture sites in the Vidlin Voe area. = fish farms, = mussel farms. The cod farm in Vidlin Voe was the only cod farm in Shetland at time of writing.

2. Materials and methods

2.1. Sampling strategy

Two benthic surveys of the Vidlin Voe cod farm were carried out in the present study; 2–3/08/2005 and 25–26/07/2006, with one historic dataset available (Williamson, 2004). Sampling stations used in the surveys (Table 1, Fig. 1) were the same as the 2004 regulatory benthic monitoring stations (Williamson, 2004), located according to Scottish Environment Protection Agency guidelines (SEPA, 2005). At some stations, differences between GPS positions between surveys were apparent when using a measured line to mark out distance from the cage group, most likely attributable to cage movement by the site operator. In these cases, a relative distance approach was adopted (e.g. 0, 25 m, 50 m, etc. from the outermost cage edge).

Sediment sampling was *via* 0.1 m^2 van Veen grab (Stubbs et al., 1987) deployed from a fish farm vessel. Redox measurements (Zobell, 1946; Pearson and Stanley, 1979) were taken from core sub-samples ($\phi = 0.057$ m; depth = 0.14 m) from the grabs (duplicates at each station; 1 core per grab to avoid pseudo-replication), at 0.5 cm depth intervals to 4 cm, after which 1 cm intervals were used. A Palmer stand (Hodgkin, 1938) was used to accurately measure probe depth within the sediment, and the probe was recalibrated in Zobell's solution between cores. Redox values were corrected for reference electrode (SEPA, 2005).

Macrofauna were collected from duplicate 0.1 m^2 grabs per station, sieved on board over 1 mm mesh using round mesh sieves and sieve table, and the residue preserved in ca. 10% buffered (with excess borax) formal-saline with rose Bengal as vital stain.

Table 1
Vidlin station locations. N = north, S = south, C = reference, and the number following N or S refers to distance (m) from cage edge.

Station	2005 and 2006 surveys		Depth (m)	2004 survey		
	Lat.	Lon.		Lat.	Lon.	Depth (m)
N0	60°23.385N	1°07.205W	29	60°23.313N	1°07.247W	30
N25	60°23.398N	1°07.182W	28	60°23.316N	1°07.219W	29
N50	60°23.408N	1°07.165W	25	60°23.322N	1°07.201W	26
S25	60°23.152N	1°07.420W	17	60°23.179N	1°07.535W	18
S50	60°23.123N	1°07.456W	16	60°23.168N	1°07.551W	16
C1	60°23.578N	1°06.917W	32	60°23.577N	1°06.914W	33
C2	60°22.881N	1°07.463W	17	60°22.882N	1°07.462W	17