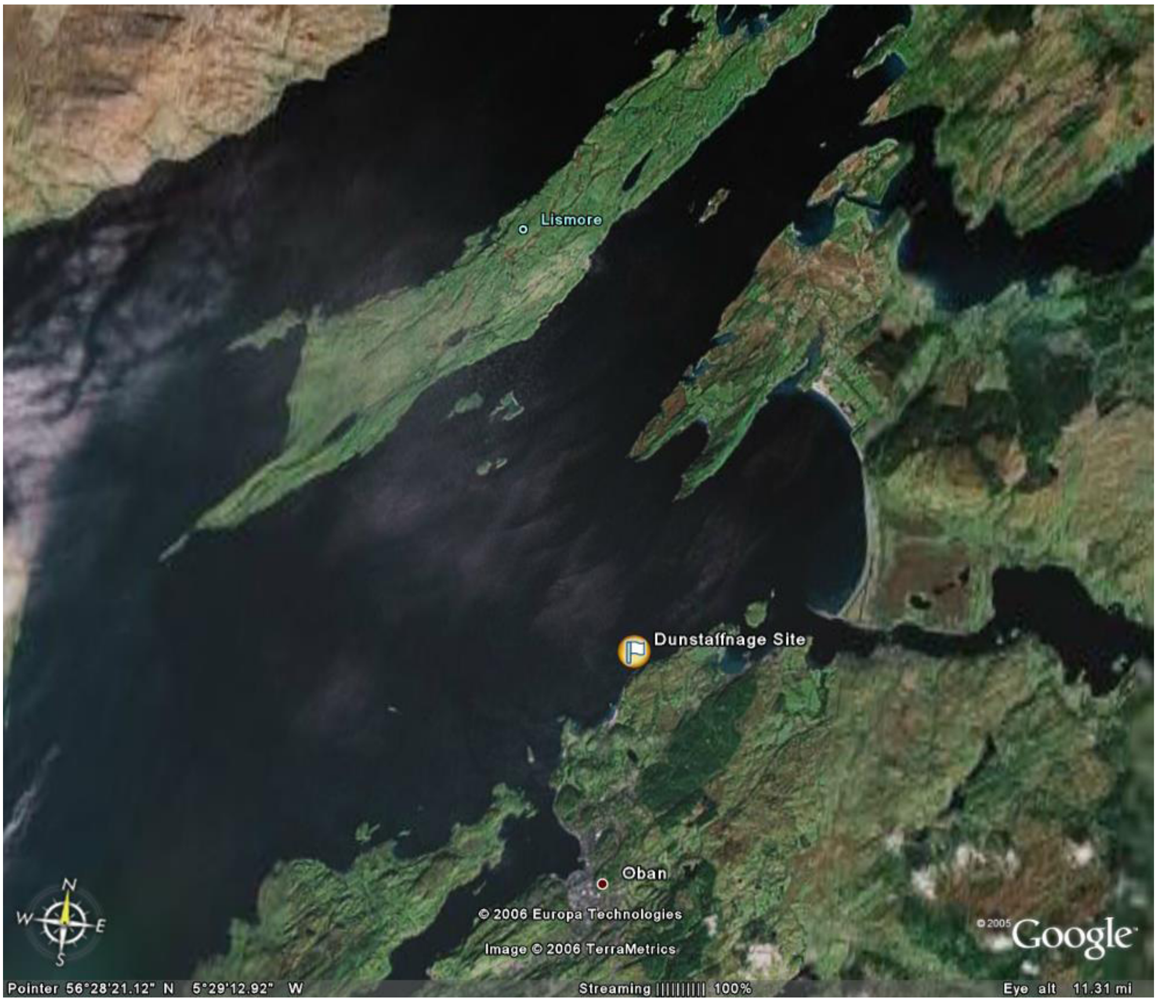


Figure 6.1.2 : The Dunstaffnage site, Oban and the mouth of Loch Etive to the East. (Google Earth)

Table 6.1.II : Summary Statistics, Benthic macrofauna (from Scottish Sea Farms, Biological Seabed Survey at Dunstaffnage, 30th June 2005, report by Hunter Biological)

	South West			North East				
				CAGE				
Distance	REF2[1]	50m	25m	EDGE	25	50	150	REF1[1]
No of Species[1]	58	33	26	8	14	13	27	17
Abundance m^{-2}	1852	1867	830	18126	9200	407	637	378
Evenness[2]	0.8	0.62	0.75	0.19	0.25	0.8	0.86	0.86
Shannon-Weiner[3]	4.7	3.1	3.5	0.6	1	2.8	4.1	3.6
ITI[4]	64	63	57	0	0	28	59	52

[1] REF2 is located 900 m SW of the cage group, REF1 880m to the NE.
[2] Total number of species from 3 pooled 0.045m^2 grabs.
[3] Species Evenness - Pielou's evenness index, j (Pielou, 1966)
[4] Shannon Weiner Diversity - Shannon-Wiener information function, H(s) (Lloyd, Zar and Karr, 1968)
[5] Infaunal Trophic Index (ITI) – defined in section 3.3

Figure 6.1.3 : Current speed (mm.s⁻¹) and water depth (m) measurements for bin 1 (3m above the bed) during the survey period at the Dunstaffnage site. (Provost, SAMS, Current Speed and Meteorological Measurements at the Dunstaffnage Fish Cage Site, Firth of Lorne, Argyll. Data Report Prepared for Scottish Sea Farms Ltd February 2006)

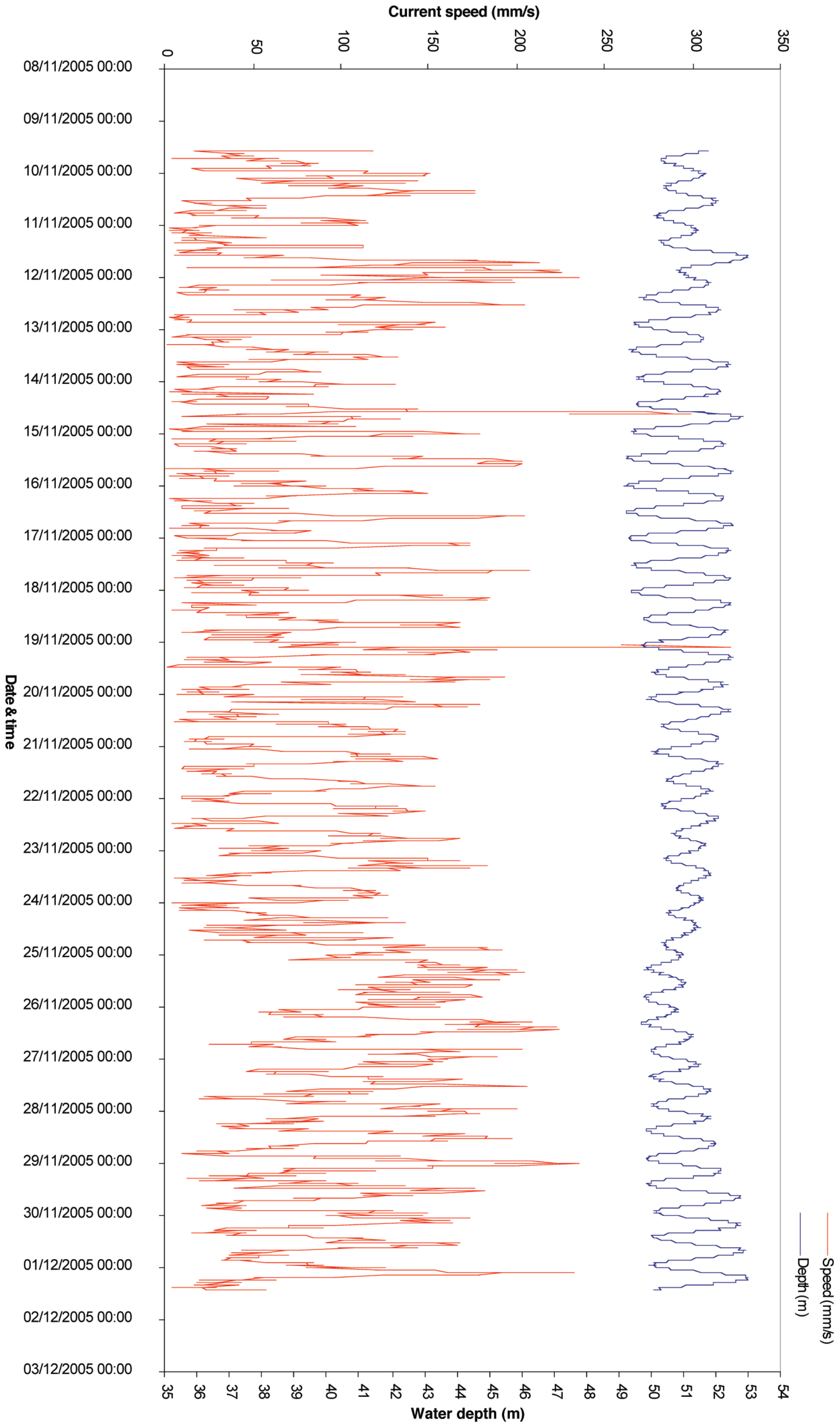


Figure 6.1.4 : Scatter plot of east and north vector components (mm.s^{-1}) measured 3 m above the bed at the Dunstaffnage site (22 day record, 10 minute averages). (Provost, SAMS, Current Speed and Meteorological Measurements at the Dunstaffnage Fish Cage Site, Firth of Lorne, Argyll. Data Report Prepared for Scottish Sea Farms Ltd February 2006)

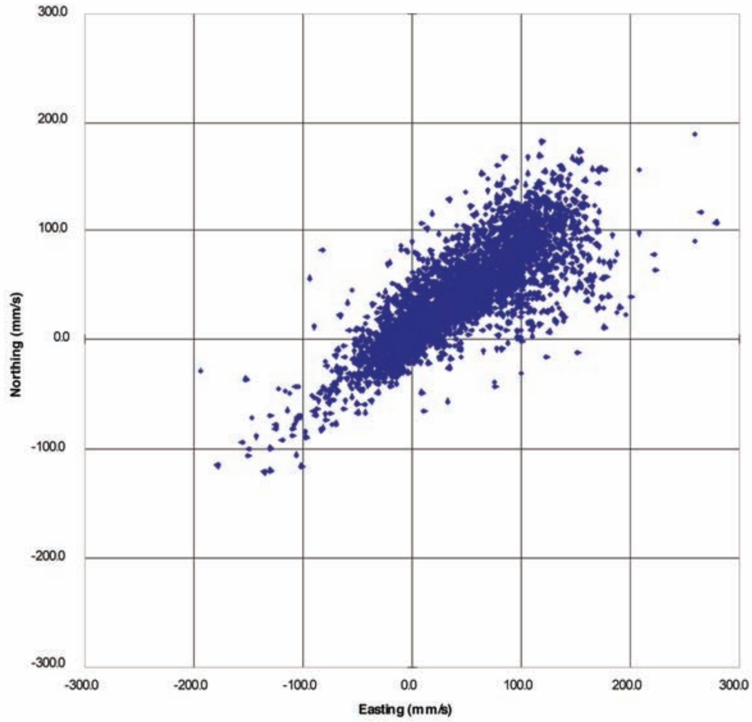
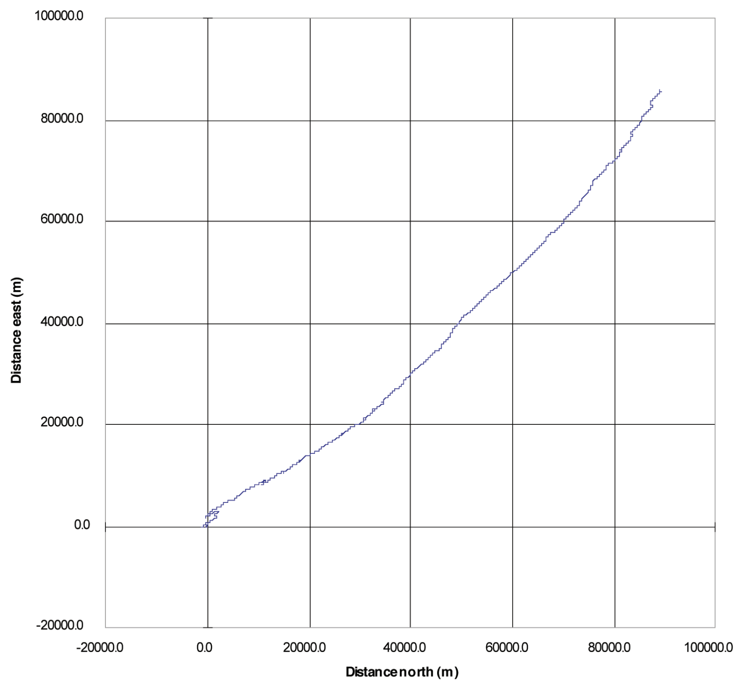


Figure 6.1.5 : Cumulative vector plot (m) for currents measured 3 m above the seabed at the Dunstaffnage site (22 day record, 10 minute averages). (Provost, SAMS, Current Speed and Meteorological Measurements at the Dunstaffnage Fish Cage Site, Firth of Lorne, Argyll. Data Report Prepared for Scottish Sea Farms Ltd February 2006)



operations such as net changing and fish transfers. Slaughtering is done by transferring live fish to a well boat and transporting them to the company's fish processing plant at South Shian on the shore of nearby Loch Creran. There the fish are pumped ashore and slaughtered under controlled conditions with full treatment of blood wastes. Thus, no blood-water is discharged either at the Dunstaffnage site or elsewhere.

6.1.3.2 Release Assessment

Fish farms release particulate organic material from three main sources:

a) wasted (for example, uneaten) feed
b) faecal material
c) detached fouling biomass

Feed wastage occurs in pulses associated with feeding events, and increases towards the end of a meal as the fish approach satiation. Several feedback systems are typically operated to limit feed wastage at modern salmon farms, including video cameras under the cages, and sediment traps with particle sensors. These systems reduce feed input during meals on the detection of feed particles passing to the bottom of the cage. Thus, early estimates of feed wastage (Gowen and Bradbury 1987) of up to 20% have been superseded and current estimates are of the order of 5%. Although this value is difficult to verify, farmers have a strong interest in keeping this to a minimum, as feed is costly and farmers are often judged on the food conversion ratios (FCR) of their crop, which is dependent on low feed wastage: 5% has become an accepted estimate in Scotland. At some point in the future, farms in Scotland may be consented on the basis of total feed input over the farming cycle as is common in Norway, rather than maximum allowable on-site biomass as at present – this would exert an additional pressure to reduce feed wastage. The settling velocities of a large range of different feed sizes, types and brands have been measured (Chen, Beveridge and Telfer 1999).

Faecal material is produced in post-prandial pulses. Its amount is related to the digestibility of the feed: modern diets are highly digestible (>85%). The settling velocity spectrum of salmon faeces from a range of fish sizes is well characterised (Magill, Thetmeyer and Cromey 2006). This is not the case for detached biomass: this occurs when encrusting, fouling organisms are dislodged from cage structures and settle to the bottom. In the Scottish setting, this is likely to be a minor component of the particulate flux from farms, but the subject has received no research attention.

The maximum biomass proposed for the site is 1,300 tonnes. This will probably be attained early in the second year of each two year production cycle, and maintained at that level for the remainder of each cycle by cropping. Thus the total production from the site over a two year period will be much greater than the maximum biomass, probably of order 2,000 tonnes. If a food conversion ratio of 1.2 is assumed, then the total feed input will be 24,00 tonnes. If 5% of this is wasted and 85% of the remainder is assimilated by the fish (thus 15% are lost as faeces), then the total losses of feed and faecal material are 120 tonnes and 342 tonnes respectively.

Wild fish and scavenging epibenthos may intercept particulate material in the water column or on the seabed. This process has been shown to be important in reducing the flux of organic matter to the seabed in fish farms in the oligotrophic Mediterranean Sea (Dempster *et al*. 2004; Dempster *et al*. 2002; Machias *et al*. 2004; Tuya *et al*. 2006) but there has been no attempt to quantify this aspect in Scotland, although it is known to occur (Carss 1990). In the absence of hard evidence, we assume that this is a less important process in mesotrophic Scottish waters.

6.1.3.3 Exposure Assessment

Organic particulate material settling from fish cages intersects the seabed. It either stays where it lands and degrades, or it is resuspended and is advected, possibly outside the farm area. The critical resuspension velocity has been estimated at about 9 cms^{-1} and verified in a specifically designed resuspension tracer study in fish farm sediments (Cromey *et al.* 2002b). At the site considered here, near-bed currents are regularly higher than this and it is likely that considerable amounts of the vertical flux will be transported away from the farm. This is in accord with estimates by Strain and Hargrave (Strain and Hargrave 2005) where, at a more dynamic site, these authors found that the majority of the carbon flux could not be accounted for in terms of the benthic oxygen demand. Such processes are amendable to modelling (Cromey *et al*. 2002b) and a DEPOMOD output for the present site (Figure 6.1.6) shows that significant sedimentation rates will be confined to a relatively small area around the farm.

The duration of effect is an important aspect of risk analysis. There have been several previous UK investigations into the recovery of the benthos after the cessation of fish farming. The first, a three year study completed in November 1995 (Nickell *et al*. 1995; 1998), considered benthic recovery at three sites and concluded that a numerical model which could be used to manage rotation of fish farm sites was not possible from the data obtained. A descriptive model, based on indicator species and numbers of species, appeared to hold broadly for all three sites giving recovery to 'normal' communities in around two years, even at the most heavily impacted. There was no obvious relationship between recovery times and ambient hydrography, and it was shown that recovery was a complex process where dominant associated environmental drivers changed with different sites and seasons.

The second study (Pereira *et al*. 2004) of benthic recovery at a Scottish salmon farm was of a shorter (15 month) duration and, at the most impacted

Figure 6.1.6 : A DEPOMOD output showing predicted solids accumulation rate on the seabed at the increased tonnage (1300 mt) for the Dunstaffnage site (g m-2 yr-1) AMSL (2006)

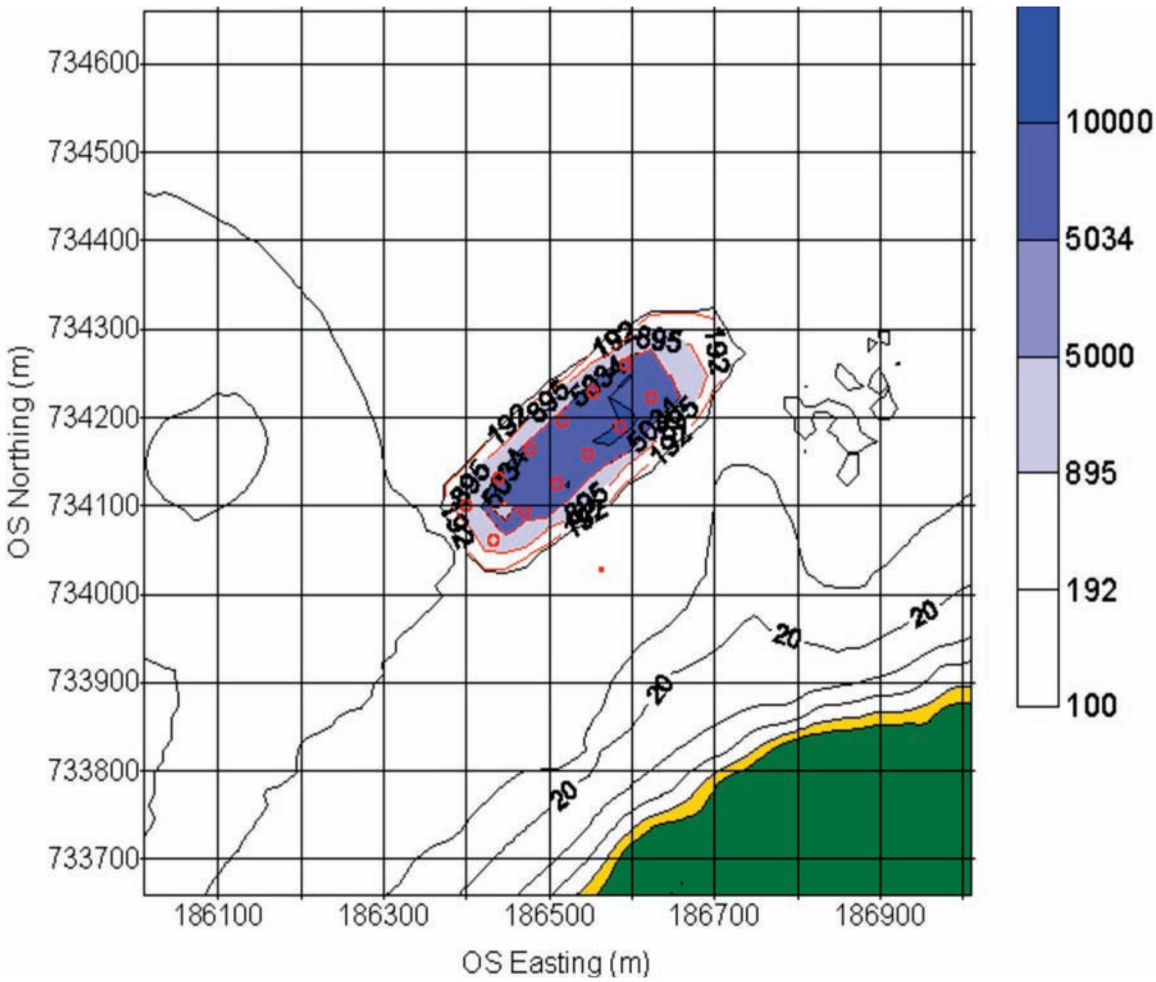


Figure 6.1.7 : Infaunal succession on an organic enrichment gradient (Pearson and Rosenberg, 1978)