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"Measurement of the Benthic Loading and the Benthic Impact
from an Open-Ocean Fish Farm in Tropical Waters"

Benthic loading of organic material at a depth of 90 feet, coming from a fully-loaded fish cage (2700 $m^3$) has been measured over a complete grow-out cycle for cobia (*Rachycentron canadum*). This investigation was carried out at the Snapperfarm site, two miles west of Culebra, PR. The organic loading was measured independently in the benthic water, using sediment traps, and in the sediment, using core samples. Samples were taken at four stations located along a transect aligned with the major tidal axis. The first station was directly under the cage, at R = 8 m and the last station was at R = 100 m. The tidal amplitude is approximately 44 cm/sec. Duplicate samples were taken at all stations for 15 consecutive months, ending in November 2005. At this time (January 2006) we report two significant although still preliminary results concerning organic loading in the benthos.

1) Organic loading in the benthic water.
No loading was observed for the first seven months. For the last eight months the organic loading in the benthic water showed a Gaussian distribution, a 'normal,' 'bell-shaped' curve, with the maximum at R = 0 (the cage spar). The onset of loading in the benthic water occurred simultaneously with a change in the manufacturer of the fish feed. Burris was bought out by Cargill, and the composition and physical integrity of the feed pellets changed dramatically. In particular, the feed became noticeably more dusty. The observed distribution in the benthic water falls to half-maximum at $R \sim 22$ m $\sim 1.75\ R_{cage}$. The extent of the "footprint in the water" is very stable from month to month, independently of the amount of organic loading. It depends on the sinking velocity of the powder grains and the current velocity of the water.

The absolute amount of the total organic loading in the water varies considerably from month to month, probably depending on the 'dustiness' of the feed pellets. Because we sampled only 'forward,' we cannot quantify organic loading transverse to the current, or 'backward.' Even assuming the loading in those three directions is one-half of the loading forward, the total amount of organic material reaching the benthic water can be 5% or more of the total amount of organic material being put into the cage. No loading was observed with the Burris feed, with leading ingredients: Animal protein products, grain products, fish oil. The Cargill feed lists leading ingredients: Grain products, plant protein products, processed grain by-products, animal protein products. The last two items on the Cargill ingredient list are mineral oil, fish oil.

2) Organic loading in the sediment.
No increase in the organic content of the sediment was observed over the 15 months of data-taking. As this result seemed at odds with the organic loading observed in the benthic water, we conducted 2 independent experiments to investigate the sediment:

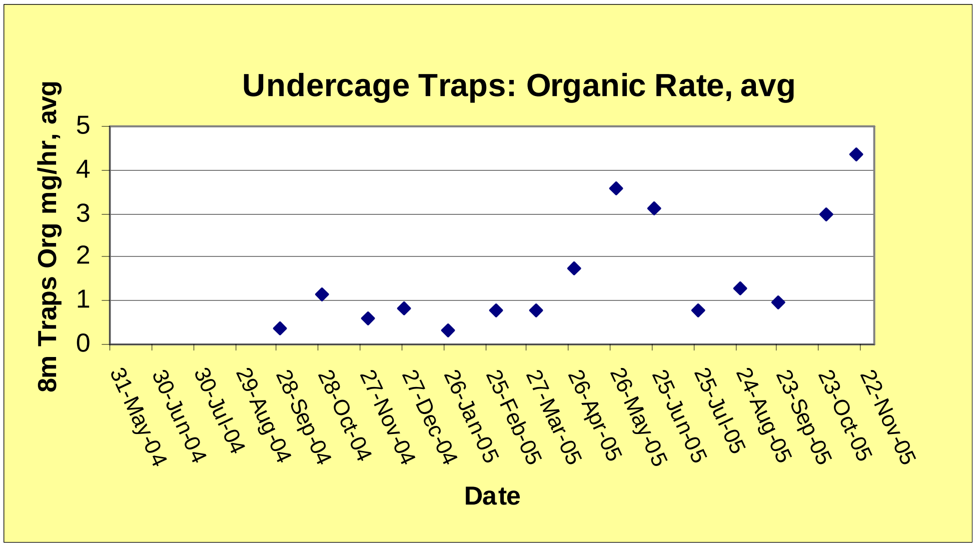
A) Two times we deliberately planted substantial quantities ( ~ 13 lbs), of soaked and mashed fish feed into the sediment, burying a layer of feed under a centimeter or so of sediment. Both times we returned to take core samples after 24 hours. Both times, there was no significant increase in the organic content of the sediment. The first time we did it, the null result was so unexpected that we feared a mistake somewhere. We repeated the experiment in a different site, very carefully. The result was the same: the planted feed disappeared within 24 hours.

B) Two times near the end of the grow-out cycle we sampled the iron content of the sediment, along the transect, from under the cage out to 100 meters. The fish food is "triply packed" with iron. Iron seems like an ideal tracer, sinking rapidly and integrating into the sediment. The elemental analysis for iron was done by NEMI method 236.2, Graphite Furnace Atomic Absorption. There is no statistically significant difference along the transect, from under the cage out to 100 meters. There is no build up of iron resulting from the cage operation.

## CONCLUSIONS / DISCUSSION

When the feed pellets have good structural integrity, i.e., are not dusty, no organic loading is observed in the benthic water. When the feed pellets are loosely packed grains, without sufficient "glue," then some fraction of the pellet will disperse into powdery grains. The grains are very small, with no air trapped inside them, and they sink rapidly, to load the benthic water. However, at the Snapperfarm site at least, any organic loading in the water will not integrate into the sediment.

Close observation of the "skin" of the sediment shows it to be remarkably kinetic. Except for brief periods during slack tide, the top few millimeters of sediment is racing along the surface. The direction of movement is not easy to predict. It is generally more-or-less in the tidal direction, but it can also go transverse to the tide, or even in giant whirlpool patterns. Many times, as we were working on the bottom, taking samples, we would put some tool down on the sediment, only to find a few minutes later that it was 10 feet away. We had to learn to contain all equipment in mesh bags. Food grains may land on the bottom, but they cannot remain in place. The bottom at the Snapperfarm site is flat and featureless except for occasional beds of rhodoliths. The sediment is essentially pure $CaCO_3$. There is no purchase for the feed grains, nothing to give them protection from the current.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8m Traps Org mg/hr, avg
0
1
2
3
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5
31-May-04
30-Jun-04
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29-Aug-04
28-Sep-04
28-Oct-04
27-Nov-04
27-Dec-04
26-Jan-05
25-Feb-05
27-Mar-05
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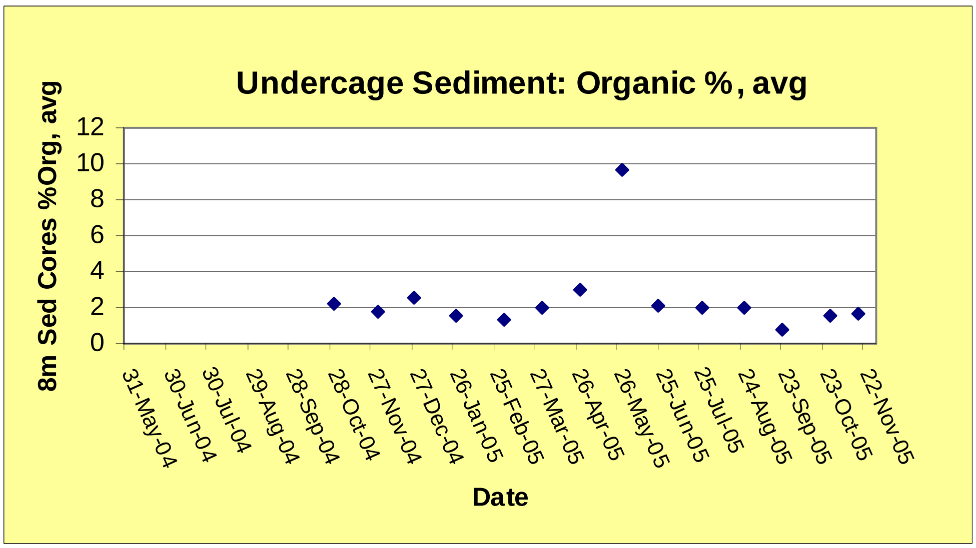
22-Nov-05
Date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27-Dec-04
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25-Feb-05
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22-Nov-05
Date