Review of the Environmental Impacts Related to the Mechanical Harvest of Cultured Shellfish

Prepared for: Cashin Associates
for the Suffolk County Shellfish Aquaculture Environmental Impact Study

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What follows is a review of the literature pertaining to the impacts of mechanical harvest, or "dredges" as they pertain to shellfish aquaculture to help identify which of these concerns might be considered significant impacts that would warrant further study in the preparation of the EIS.

Several publications that are central to the issues are also attached;
An Annotated Bibliography prepared by NOAA
review articles by Tarnowsky, Godcharles and Coen.

Robert B. Rheault, Ph.D.
Moonstone Oysters
1121 Mooresfield Rd
Wakefield RI 02879
401 783 3360
bob@moonstoneoysters.com

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The topic of the impacts of fishing activity in general is quite inflammatory and a great deal has been published on the matter. The impacts have been compared to clear-cutting (Baulch 1999) "trawling gear devastates the world's continental shelves". Others describe "Watery Wastelands" devastated by trawling (Levy 1998). The reality of the situation is more nuanced and requires an understanding of the environments and the gear and how they interact. It is important to understand that reports which describe huge heavy trawls operated in deep waters to capture wild fish or shellfish do not apply to the operation of small dredges used inshore to harvest culture shellfish on leased bottom.

I have examined hundreds of articles on the subject of the impacts of fishing gear. The vast majority of the studies describe impacts to deep water environments from sea scallop dredges or bottom trawls (otter trawls or beam trawls – large fishing nets). Where the results of these studies are applicable I have included them, however most of these studies describe activities far different from hydraulic clam harvesting or oyster "dry dredges" on cultured bottom

In many cases, the "potential impacts" described in the DEIS comments have not been studied and there is no data to permit one to make a rational recommendation one way or the other. In many cases, the research reports were unpublished or published in the grey literature and I have not been able to review them personally. In several cases the agenda of the authors appear to have clouded their science, and the assumptions of the authors have led to predetermined conclusions.

There are many reports and reviews that claim little or no significant impact while others report devastation and destruction. While some consider trawling to be physically disruptive to the bottom and potentially harmful to the benthic community due to gear damage, sedimentation, predation exposure, and reduction in benthic primary production (Auster and Langton 1998, Bradstock and Gordon 1983, Brown 1989, Collie et al. 1997, and Engel and Kvitek 1998), others feel that trawling may mimic natural disturbances and stimulate benthic production, enhancing fish production (DeAlteris 2000, MacKenzie 1982, Van Dolah et al. 1991, and Currie and Parry 1996).
A few review articles are worthy of special mention. The 1995 Review of the Potential Impacts of Mechanical Harvesting on Subtidal and Intertidal Shellfish Resources by Coen is a 46 page unpublished review of the impacts of hydraulic escalator dredges in South Carolina. A similar review was done by Tarnowsky in 1991 for Maryland. Both of these reviews are attached as appendices to this report. They both provide and objective and thorough review of the literature as it pertains to this issue.

The DEIS concludes that the proposed aquaculture activities are not likely to have a significant environmental impact. The very nature of the question demands a subjective response that must balance a host of issues. Since no activity can be done without an impact, the important questions become: What is a <u>significant</u> impact? What can be considered a positive or beneficial impact? (Langan 1998). Are the impacts significant if the effects are not detectable after a few weeks or months or if the impacts pale in comparison to frequent natural disturbances such as storms (DeAlteris et al 1999). Are the impacts significant if the impacts are restricted to a small area or if the impacts are mitigated by other positive ecosystem benefits? Another important question is: If the impacts are indistinguishable from those of other common and approved harvest activities should we be regulating them differently simply because this is aquaculture instead of a wild harvest fishery? The answers to these questions are subjective and rarely are the issues black and white.

Clearly there are significant impacts to be avoided. These include wholesale changes in ecosystem structure or trophic energy flow; long-term changes that are not recoverable within a reasonable time frame after the practice ceases (such as introductions of diseases or non-native species); and negative impacts on threatened or endangered species. These are all clear examples of significant impacts. Beyond these clear examples are areas of subjective interpretation. The impact is significant if you are the worm who just got cut in half, but perhaps not so if you are the flounder who gets to eat the worm exposed by the dredge.

Descriptions of dredges, hydraulic dredges and otter trawls

Most dredges are rake-like devices that use bags to collect the catch. They typically remove molluscan shellfish from the seabed, but are also used to harvest crustacea, finfish, and echinoderms. Dredges take either epifauna or infauna; the design details of the gear vary greatly and are specific to the target species and the substrate.

In estuarine waters, dredges are used to collect clams, oysters, conch, and crabs. The oyster dredge consists of a steel frame, 0.3–2.0 m wide, with a blade with teeth. The tow chain or wire and a bag for the catch are attached to the frame. The dredge is towed slowly (<1 m/s) in circles, from vessels that are 7–15 m long. Similar dredges are used to catch blue crabs in the mid-Atlantic region during the winter. These dredges can have teeth as long as 8cm that penetrate soft bottoms to capture partially buried epifauna.

To capture shellfish that bury deeper than a few centimeters fishermen fit dredges or rakes with longer teeth or occasionally use water jets to loosen the sediment and bring the shellfish to the surface. This is commonly called a “hydraulic dredge”. Large hydraulic clam dredges are used offshore to collect surf clams and ocean quahogs while smaller (1-2m) dredges are used inshore to collect soft and hardshell clams.

In the soft clam fishery, which occurs in shallow estuarine waters, the dredge head (manifold and blade) is attached to a conveyor or “escalator” that carries the materials retained on the blade to the working deck of the vessel.

Offshore, large, heavy dredges are used catch sea scallops, which inhabit a sand–gravel–cobble bottom and live on the surface of the seabed. The scallop dredge has a steel frame with a tongue with an eye, a blade with no teeth, and a bag. The width or mouth opening of the dredge ranges from 3.0 to 4.5 m, and dredge weight varies from 500 kg to 1000 kg.

Differences between wild harvest fishing and the harvest of cultured shellfish

An important consequence of sea scallop dredging and otter trawling is the reduction in habitat complexity (architecture) that accompanies the removal of sessile epifauna and the alteration of physical structure, such as rocks and cobble (Bradstock and Gordon 1983). Emergent epifauna and other vertical structures provide critical habitat for juvenile fish and the destruction of this structure can increase predation risk. It is important to remember that on cultured grounds the grower replaces the shell and replants with live shellfish, repairing the damage to vertical structure and productivity so the significant impacts of fishing gear on structure are limited to wild harvest fishing activities and are not relevant to the harvest activities on cultured grounds.

Frequency and scale are also important in the quantification of impact (Collie et al. 2000, and Kaiser and Spencer, 1996). Since a grower will typically leave his grounds untouched for several years while the shellfish are given the opportunity to grow, wild harvest fishermen will typically tow over the same grounds many times a year. They will drag longer tows over much wider areas. And spend hours dragging unproductive bottom searching for fish or shellfish.

In the case of the planed leasing in Suffolk County, small leases will largely preclude hydraulic or even dry-dredge harvesting because a 10 acre lease will need to be subdivided into sections for different year classes, meaning growers are trying to turn over plots as small as 3-5 acres. And the proposed scale of leasing in the system is very small so you don't really need to worry about system-wide impacts from a large number of boats.

The following is exerpted from a review **Effects of Trawling and Dredging on Seafloor Habitat (2002) Ocean Studies Board (OSB)** (E. M. Dorsey and J. Pederson 1998)

> Many experimental studies have documented the acute, gear-specific effects of trawling and dredging on various types of habitat. The results confirm predictions based on the ecological principle that stable communities of low mobility, long-lived species will be more vulnerable to acute and chronic physical disturbance than will short-lived species in changeable environments. Trawling and dredging can reduce habitat complexity by removing or damaging the biological and physical structures of the seafloor. The extent of the initial effects and the rate of recovery depend on the habitat stability. The more stable biogenic (i.e., of biological origin), gravel, and mud habitats experience the greatest changes and have the slowest recovery rates. In contrast, less consolidated coarse sediments in areas of high natural disturbance show fewer initial effects. Because those habitats tend to be populated by opportunistic species that recolonize more rapidly, recovery is faster as well.

The direct effects of fishing gear are the most obvious and the vast majority of the literature addresses these effects. They include:

- *reduction of complexity and diversity* or *shifts in community structure* following large scale removal of target species as well as by-catch or capture of non-target species.
- *loss of vertical structure* which provides critical habitat and refuge for juvenile fish and crustaceans
- and *reduction in productivity or biomass* following harvest.

Potential Indirect Effects (from E. M. Dorsey and J. Pederson 1998)

- *Nutrient cycling*. Seafloor trawling and dredging could increase or decrease the exchange rate of nutrients between the sediment and water column and introduce pulses of productivity in addition to pulses from the natural seasonal cycle.
- *Hypoxia*. Resuspension and oxidation of sulfides can scavenge oxygen and cause local areas of low oxygen or hypoxia.
- *Increased susceptibility to other stressors*. Loss of physical structure in a habitat can expose organisms to other stressors, such as predation.
- *Turbidity*. Resuspension of sediments can limit visibility and decrease light penetration. This might impact feeding behavior, impair respiration or slow the growth of algae or SAV.

Impacts on Species Richness, Diversity and Productivity

Many studies document the reduction of complexity following disturbance by fishing gear, and the subsequent loss of diversity. In the marine environment the addition of any firm substrate or vertical relief will stimulate diversity. The removal of shells, bivalves and other structures by harvest gear of any type will have the opposite effect. In oyster aquaculture, unlike the wild fishery, the shell and juvenile shellfish are replanted after harvest and so the vertical structure is replaced. In clam aquaculture grounds, there is typically little structure to begin with, so the disturbance is short term and recovery is rapid. Seed clams are replanted following harvest so productivity and biomass are retained.

From Coen 1995:

> Most studies agree that dredging causes some mortality to small and large infaunal and epifaunal organisms in the direct path of the device (Godcharles 1971, Kyte et al. 1975, Kyte and Chew 1975, Vining 1978, Meyer et al. 1981, Mackenzie 1982, Peterson et al. 1987, Barnes et al. 1991). However, since many of these small benthic organisms (crustaceans, polychaetes, molluscs) have rapid generation times, high fecundities and excellent recolonization capacities, it is generally accepted that this community effect is only short-term (e.g., Godcharles 1971, Peterson et al. 1987, Bennett et al. 1990, Hall et al. 1990). Hall et al. (1990) suggest that the effects will be apparent and protracted only if the fauna are primarily immobile or if the affected area is large relative to remainder of the habitat.

In addition to the removal of the target species, and some non-target species, diversity is temporarily impacted by the attraction of several predatory species known to aggregate in the dredge tracks to eat uncovered or damaged prey. Manning (1957) reported crabs and several fish species attracted to areas of active dredging. Within one hour of dredging Caddy (1973) directly observed predators at densities up to 30 times those outside the tracks, especially winter flounder but also sculpin and rock crabs, were attracted to scallop dredge tracks. Similarly, Eleftheriou and Robertson (1992) noted congregations of fish (primarily pleuronectids, gadoids, and gobies) feeding in scallop dredge tracks, as well as seastars and a large variety of crustaceans.

Species richness and density of three polychaete species were significantly reduced in areas where hoes were used for commercial digging for soft-shell clams in Maine (Brown and Wilson 1997). Dolmer et al. (2001) noted reduced densities of small polychaetes found after dredging for bottom cultures mussels while infaunal abundance and diversity decreased immediately following suction dredge harvesting of Manila clams from an area of muddy-sand bottom in Northern Europe (Spencer et al. 1998). High mortality of non-target benthic fauna resulting from cockle (Cerastostema edule) harvesting by suction and tractor dredges was quickly and naturally alleviated with study sites becoming indistinguishable from controls within 56 days (Hall and Harding 1997). While significant effects are often observed immediately following bottom culture harvesting in unvegetated, soft-sediment habitat, quick recovery of invertebrate communities appears quite common (Kaiser et al. 1998).

Perhaps one of the most complete studies on faunal impact was done in Florida by Godcharles (1971) who discovered no lasting impacts on the benthic populations. Using three gear types (benthic corer, trynet trawl, hydraulic escalator dredge) to sample both infauna and epifauna they reported little difference between control and experimental dredging sites. Recovery was slowest in some of the vegetated areas, which were completely stripped of plants by the dredge with a maximum of thirteen months possible. Godcharles reported no significant faunal differences between control and experimental plots, (including the vegetated stations), in the trynet samples.

Tarnowsky 2001 reviewed recovery times from various sources of man-made impacts and found that with few exceptions recovery was rapid, in most cases on the order of months. This resiliency of the benthos is characteristic of shallow-water coastal and estuarine systems, which are subjected to continual disturbances (Turner et al., 1995). These communities are characterized by their resilience and persistence in the face of disturbance. There are dozens of anecdotal reports of massive sets of clams (*Mya*, *Mercenaria* or *Spisula*) following dredging, significant storms or oilspills. These species are adapted to rapidly colonize empty niches (Visel pers comm.).

See also:

Conner, W.G. & J.L. Simon (1979) The effects of oyster shell dredging on an estuarine

benthic community. *Estuarine and Coastal Marine Science* 9: 749-758.
Abstract: This paper describes the extent and nature of the effects on the benthos of physical disruptions associated with dredging fossil oyster shell. Two dredged areas and one undisturbed control area in Tampa Bay, Florida, were quantitatively sampled before dredging and for one year after dredging. The immediate effects of dredging on the soft-bottom community were reductions in numbers of species (40% loss), densities of macroinfauna (65% loss), and total biomass of invertebrates (90% loss). During months 6-12 after dredging, the analysis used (Mann-Whitney U Test, alpha = 0.05) **showed no difference between dredged and control areas in number of species, densities, or biomass (except E_1). Community overlap (Czechanowski's coefficient) between dredged and control areas was reduced directly after dredging, but after 6 months the pre-dredging level of similarity was regained.**

De Alteris, J., Skrobe, L., and Lipsky, C. 1999. The significance of seabed disturbance by mobile fishing gear relative to natural processes: a case study in Narragansett Bay, Rhode Island. Pages 224-237 *in* L. R. Benaka (ed.). Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22. Bethesda, Maryland.
Abstract: Seabed disturbance by mobile bottom-fishing gear has emerged as a major concern related to the conservation of essential fish habitat. **Unquestionably, dredges and trawls disturb the seabed. However, the seabed is also disturbed by natural physical and biological processes. The biological communities that utilize a particular habitat have adapted to that environment through natural selection, and, therefore, the impact of mobile fishing gear on the habitat structure and biological community must be scaled against the magnitude and frequency of seabed disturbance due to natural causes.**

Fonds, M. 1994. Mortality of fish and invertebrates in beam trawl catches and the survival chances of discards. I*n:* deGroot, S.J. and Lindeboom, H.J. (eds.) Environmental impact of bottom gear on benthic fauna in relation to natural resources management and protection of the North Sea. NIOZ Rapport 1994-11, Texel, Netherlands.
summary: Survival experiments were carried out with fish and invertebrates collected from the by-catch of commercial beam trawls for sole fishing. **Mortality was lower for discards from 4-m beam trawls as compared to the much heavier 12-m beam trawls. Mortality of small animals that pass through the 8cm meshes of the nets during trawling ranges from less than 5% for starfish, 10-20% for small fish, 20-30% for crustaceans**, to 40-80% for the more vulnerable shellfish.

Goodwin, L. and Shaul, W. 1978. Studies of the mechanical escalator harvester on a subtidal clam bed in Puget Sound, Washington. Progress Report No. 53. State of Washington Department of Fisheries. 23 p.
Abstract: The hydraulic harvest of clams in the small experimental plot produced some changes which were evident to divers shortly after harvest was completed. The abundance of attached kelp was reduced in the treatment plot compared to the control plot. The harvest left large amounts of old clamshell and sand at the substrate surface. The harvest greatly reduced the standing crops of commercial size clams within the treatment plot. Butter and littleneck seed clam abundance was as high within the

treatment plot as the control plot, and a new crop of these clams was expected to develop from these small clams. **The harvest had little, if any, effect on the number of benthic animal species, but did reduce the number of individuals and the weight per unit area of some organisms. These reductions are probably a short-term situation. Most species had recovered to the control plot levels** in 1978. No effects on the percentage of fines in the substrate of the treatment plot were observed. Some vertical changes in substrate distribution were evident since clam shell and sand was more abundant in the substrate surface after harvest in the treatment plot compared to the control plot. **Chemical parameters of the substrate were slightly reduced or unchanged in the treatment plot compared to the control plot**.

Hall, S. J., Basford, D. J., and Robertson, M. R. 1990. The impact of hydraulic dredging for razor clams *Ensis* sp. on an infaunal community . Netherlands Journal of Sea Research. 27(1) : 119-125.
Abstract: The impact of fishing for razor clams (*Ensis* sp.) by hydraulic dredging on the associated infaunal community has been examined in a manipulative field experiment executed in autumn in a Scottish sea loch at 7 m depth. Infaunal samples from replicate fished and unfished plots were examined after 1 and 40 days. Major effects on the total number of individuals were observed immediately after fishing and sign test revealed a reduction in the abundance of a significant proportion of species in fished areas. **However, after 40 days no effects of fishing could be detected and no visible signs of fishing remained on the sea bed**. We hypothesized that active migration into the water column and passive suspension during wind-and tide-induced sediment transport dilute localized effects and conclude that, given the restricted depth at which fishing is possible at present, **hydraulic dredging is unlikely to have persistent effects on most of the infaunal community in most habitats**.

Hall, S. J. and Harding, M. J. C. 1997. Physical disturbance and marine benthic communities: The effects of mechanical harvesting of cockles on non-target benthic infauna. Journal of Applied Ecology. 34(2) : 497-517.
Abstract: This paper describes the results of manipulative field experiments which examine the effects of disturbance by two mechanical cockle harvesting methods, hydraulic suction dredging and tractor dredging. Although the **suction dredge experiment revealed some statistically significant effects, taken as a whole the results indicated that the faunal structure in disturbed plots recovered (i.e. approached that of the un-disturbed controls) by 56 days**. From the available evidence the most likely mechanism of recovery was through the immigration of adults into disturbed areas.
We conclude that mechanical harvesting methods impose high levels of mortality on nontarget benthic fauna, but that **recovery of disturbed sites is rapid and the overall effects on populations is probably low**.

Kaiser, M. J. 1998. Significance of bottom-fishing disturbance. Conservation Biology. 12(6) : 1230-1235.
Abstract: Since the early 1970s there has been increasing interest in the ecological effects of bottom-fishing activities on the benthic ecology of the seas of northern Europe. The

majority of studies have examined the short-term effects of disturbance on benthic fauna. I highlight the **importance of evaluating the ecological relevance of fishing disturbance versus natural perturbations**, which varies among different habitats. Most experimental studies have shown that it is possible to detect short-term changes in community structure in response to fishing disturbance. Evidence suggests that long-term changes are probably restricted to long-lived fragile species or communities found in environments that are infrequently disturbed by natural phenomena. Understanding the relative ecological importance of physical disturbance by fishing versus natural events would provide a basis for predicting the outcome of fishing activities in different marine habitats.

Kaiser, M. J., Broad, G., and Hall, S. J. 2001. Disturbance of intertidal soft-sediment benthic communities by cockle hand raking. Journal of Sea Research. 45(2) : 119-130.
Abstract: Recent awareness of the ecosystem effects of fishing activities on the marine environment means that there is a pressing need to evaluate the direct and indirect effects of those activities that may have negative effects on non-target species and habitats. The cockle, Cerastoderma edule (L.) is the target of a commercial and artisanal fishery that occurs in intertidal and estuarine habitats across Northern Europe. Cockles are harvested either mechanically using tractor dredges or suction dredges or by large numbers of individual fishers using hand rakes. This study examined the effects of hand raking on the non-target species and under-sized cockles associated with intertidal cockle beds and the effects of size of the patch of sediment disturbed on subsequent recolonisation. Hand raking led to an initial three-fold increase in the damage rate of under-sized cockles compared with control plots. The communities in both small and large raked plots showed community changes relative to control plots 14 days after the initial disturbance. The **small raked plots had recovered 56 days** after the initial disturbance whereas the large raked plots remained in an altered state. Samples collected over a year later indicated that small-scale variations in habitat heterogeneity had been altered and suggest that while **effects of hand raking may be significant** within a year, they are unlikely to persist beyond this time-scale unless there are larger long-lived species present within the community.

Kaiser, M. J., Edwards, D. B., and Spencer, B. E. 1996. Infaunal community changes as a result of commercial clam cultivation and harvesting. Aquatic Living Resources. 9 : 57-63.
Abstract: Manila clams, *Tapes philippinarum* are cultivated beneath plastic netting, to protect them from excessive predation, and harvested after approximately two years in south-east England. Surveys were undertaken at the end of the growing stage immediately after harvesting by suction dredge and seven months later. **Infaunal abundance was greatest within a net covered clam lay** than in proximate and distant control areas, but the total number of species encountered was similar in all areas (20-22). Harvesting by suction dredge altered sediment composition by removing the larger sand fractions down to the underlying clay substratum, consequently there was a large reduction in the density of all individuals and the total number of species. **Seven months later, no significant difference was found between the infaunal community in the harvested clam lay or either of the control areas and sedimentation had nearly**

restored the sediment structure. These observations indicate that the practice of clam cultivation does not have long-term effects on the environment or benthic community at this site.

Kaiser, M. J., Laing, I., Utting, S. D., and Burnell, G. M. 1998. Environmental impacts of bivalve mariculture. Journal of Shellfish Research. 17(1) : 59-66.
Abstract: There is a pressing need to protect the ecology of nearshore marine habitats that are used for an ever increasing range of activities. In particular, fisheries managers need to consider both environmental and socioeconomic issues in coastal areas owing to the environmental changes that can occur as a result of cultivation and harvesting processes associated with mariculture. Bivalve cultivation can be broadly split into three main processes: (1) seed collection, (2) seed nursery and on-growing, (3) harvesting. The environmental impacts of each cultivation stage will vary depending on the species in question and the techniques used….
The final stage of cultivation involves harvesting. In many cases this involves little more than emptying the bivalves from poches or lifting ropes. However, in the case of species cultivated within sediment, or relayed on the seabed, the use of intrusive techniques is required. Both dredgers and suction devices cause disruption of the sediment and kill or directly remove non-target species. The time taken for communities affected by these processes to recover will vary depending on a number of factors, such as the cohesive qualities of the sediment and the aspect of the site and the longevity of the non-target fauna. As is the case with all anthropogenic activities that impinge on the marine environment, **the magnitude of the environmental changes that occur is linked to the scale of the cultivation processes. There are also positive aspects to coastal shellfish cultivation such as the provision of hard substrata and shelter in otherwise barren sites and the possibilities of using the cultured organisms as environmental sentinels**. Here, we review the potential environmental effects that occur throughout the cultivation cycle, from collection of the seed to harvesting. We suggest that careful consideration of the techniques used can effectively minimize environmental changes that might occur, and possibly ameliorate subsequent restoration of cultivated sites.

Langan, R. 1998. The effect of dredge harvesting on eastern oysters and the associated benthic community. in E. M. Dorsey and J. Pederson (eds.). Effects of fishing gear on the sea floor of New England. MIT Sea Grant Pub. 98-4, Boston, MA.
Summary: An oyster bed at the mouth of the Piscataqua River, divided nearly equally on either side of the New Hampshire and Maine jurisdictional lines, was studied to evaluate the oyster populations and benthic community. Differences in state regulations provided the researcher with an opportunity to compare the benthos where the differing regulations on commercial harvesting were employed. Suspended sediments due to dredging activity was also studied. **In Maine's jurisdiction (harvested), oysters showed a normal size distribution and good recent recruitment.** In New Hampshire's jurisdiction (non-harvested) oysters were large and recruitment was poor. **No significant differences (ANOVA) were found between the two areas in the number, species richness or diversity of epifaunal and infaunal invertebrates. Additionally, suspended sediments results indicated that the impact of the dredging activities in Maine were localized and not very large.**

Impacts on vertical structure

Numerous studies indicate that habitat complexity improves the survivorship of many fish species. Benthic organisms (plants, corals, and sponges) and sediment forms (mud burrows and gravel) add structure to the seafloor and increase habitat complexity (Kreiger 2001, Freese et al. 1999). Seafloor structures serve as nurseries for juvenile fish and provide refuge and food for adults. Even small structures, such as cobbles and clam shells, can form important habitat. Areas of the seafloor that lack these structures do not support the variety of fish populations observed in more complex regions (Collie et al., 1997; Kaiser et al., 1999).

With repeated trawling, the physical relief of the seafloor is reduced and juveniles of many fish species which are known to aggregate near seabed structure is depleted and there is an overall reduction in benthic production (Jennings et al., 2001). Also, removal of physical structure in a habitat can force some species into less optimal environments. For instance, the dredging of oyster reefs in North Carolina has lowered the reefs' vertical height relative to the seafloor. Thus, the only suitable substrate for the oysters is closer to the bottom in deeper areas that are more prone to anoxic events that result from nutrient overloading (Lenihan and Peterson, 1998). (Again – bear in mind that these impacts refer to wild harvest dredging, and that oysters in temperate waters do not form intertidal reefs as they do in the mid-Atlantic, and on cultured grounds oysters are replanted after harvest.)

Dealteris et al. (2004) compared replicated samples from randomly selected submerged aquaculture gear (cages of oyster-containing mesh bags placed directly on the seafloor), submerged aquatic vegetation sites (SAV; samples from *Zostera* beds), and non-vegetated seabed (NVSB). **Oyster cages displayed order of magnitude increases in abundances of fish, crustaceans, molluscs and had larger abundances of sessile organisms such as sponges, hydroids, bryozoans, and ascidians relative to SAV** and NVSB. Higher (but not statistically significant) diversity was observed in the oyster cages. Authors conclude that observed differences were due to differences in habitat composition, structure, and complexity which increased refuge areas and densities of fouling and forage organisms. Aquaculture structures can act as vital habitat and increase secondary productivity (Dealteris et al. 2004).

Freese, L., Auster, P. J., Heifetz, J., and Wing, B. L. 1999. Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska. Marine Ecology Progress Series. 182 : 119-126.
Boulders were displaced, and large epifaunal invertebrates were removed or damaged by a single trawl pass. These structural components of habitat were the dominant features on the seafloor. There was a significant decrease in density, and an increase in damage, to sponges and anthozoans in trawled versus reference transects. Changes in density, or damage to most motile invertebrates were not detected.

Kreiger, K. J. 2001. Coral impacted by fishing gear in the Gulf of Alaska. Pages 106-117 *in* Willison, J., Hall, J., Gass, S., Kenchington, E., Butler, M., and Doherty, P. (eds.), Proceedings of the first international symposium on deep-sea corals. Proceedings of a Symposium held at Dalhousie University, Halifax, Nova Scotia, Canada, July 30 – August 2, 2000.

Impacts on Submerged Aquatic Vegetation (SAV)

Eelgrass (*Zostera marina*), is an important component of estuarine areas from Nova Scotia to North Carolina, and is the primary habitat for the economically important bay scallop (*Argopecten irradians*). SAVs are important to numerous species and are protected under federal law as essential fish habitat (EFH). There is no doubt that repeated dredging in areas with SAV will damage the SAV. Tarnowski (2001) characterized the impact of hydraulic dredges to eelgrass as "catastrophic". However, in my opinion it is unlikely that SAV will be significantly impacted by shellfish aquaculture in Suffolk County since it is against policy to lease grounds with established eelgrass beds, and since harvesters prefer to avoid dredging in eelgrass beds because weeds fill the bag quickly and make sorting the catch more difficult.

Harvesting methods have been found to heavily influence macrophyte communities (Peterson et al. 1987, fonesca et al. 1984). Peterson compared various methods of clam harvesting (*Mercenaria mercenaria*). Harvesting with clam kicking boats (a practice that uses propellors aimed downward to blow sediment off wide areas to expose buried clams) caused a 65% reduction in seagrass biomass relative to controls and recovery was only partial after four years. Further, in areas harvested by hand-raking, which is perceived to have a relatively lower disturbance level, seagrass biomass decreased 25%. Oyster culture leases harvested by dredging displayed decreased eelgrass shoot density, shoot length, and biomass compared to reference plots. Biomass was reduced 30% after one year and 96% after 4 years with effects persisting up to two years post-treatment.

Dredging has the potential to cause substantial alterations to eelgrass in culture areas and these alterations can persist many years. This can be prevented by not allowing leases in areas with established eelgrass beds and by establishing a prohibition on dredge harvesting, hydraulic dredging and bull raking in eelgrass beds. This prohibition should apply to wild harvest fishermen using bullrakes. Some states have even barred or limited the use of scallop dredges in eelgrass beds (RI).

Sediment resuspension, turbidity impacts

Human-induced resuspension turbidity often results from large-scale dredging operations to remove or redistribute sediments, ship and boat traffic, and land runoff. The observed effects are typically site specific as a consequence of sediment grain size and type, hydrological conditions, etc. (Barnes et al. 1991). Harvest dredges (especially those that use water jets) will resuspend sediment in the water column. Most of the larger particles settle almost immediately, but fine silt can remain suspended for days. Most studies (including unpublished studies done on my farm) show that over 95% of the sediment sinks to the bottom within a few tens of meters of the source (reviewed in Coen 1995). Storms will also stir up sediments in shallow waters and most estuarine species are predictably tolerant of high suspended sediment loads.

DEC discusses worst case impacts of chronic and prolonged exposure to elevated sediment (suffocation, and other sub-lethal impacts (reviewed in Coen 1995). It is highly unlikely that harvest activities in Suffolk County will result in prolonged or chronic elevation of sediment levels because the leases are too small to support dredging or hydraulic dredging and because the activities are very limited in area. It is disingenuous to refer to studies describing the impacts of harbor and channel maintenance dredging and extrapolate these to fishing activities. The removal and dumping of tons of deeply buried sediments cannot be compared to the impacts of a few small dredges that mobilize a small area a few centimeters deep.

Turbidity reduces light levels, thereby generally decreasing predator feeding success and enhancing prey survival in some cases (Vinyard and O'Brien 1976). However, results are system- or species-dependent, being highly variable and often conflicting (Johnston and Wildish 1982, Boehlert and Morgan 1985). Turbidity can affect eggs, larval, juvenile and adult fishes and shellfish in estuarine and marine ecosystems (reviewed in Peddicord et al. 1975 for invertebrates, Simenstad 1990 for fish).

The following is excerpted from Coen 1995:

> Turbidity can affect immunological, physiological and histopathological systems (Servizi 1990, Simenstad 1990). Estuarine fishes have been classified in lab studies as tolerant, sensitive or highly sensitive, to turbidity levels (O'Connor et al. 1976). For example, mummichog, striped killifish, cusk eel, toadfish, hogchoker were suspension-tolerant, whereas Atlantic silversides, juvenile bluefish and menhaden and young-of-the year white perch were highly sensitive to suspended mineral solids. Neumann et al. (1975) found that toadfish (Opsanus) respiration appears unaffected by elevated turbidity.
>
> Shellfish "dredging" operations have typically not been considered to have deleterious results, since its effects are perceived to be negligible compared to natural environmental variation (e.g., currents, winds and waves). Many of the potential effects are also limited by the scale of the operation (both spatial and temporal), particle grain size (see above), the process itself (immediate return to the bottom) and local hydrology, among other factors (Barnes et al. 1991).
>
> Although the effects of shellfish dredging on turbidity levels have not been studied, the organisms that live in these highly variable, estuarine ecosystems typically encounter elevated and highly variable suspended sediment loads, with ambient seston levels often varying by several orders of magnitude over short durations (e.g., daily, Kyte et al. 1975, Settlemyre and Gardner 1977, Auld and Schubel 1978, Barnes et al. 1991). Hence, they are generally considered tolerant of short-term perturbations (Kyte et

al. 1975). Also, most of the fishes and crustaceans (with the exception of barnacles) are highly mobile.

Simenstad (1990) concluded that most estuarine fishes move out or are adapted to elevated suspended sediments and that most behavioral or sublethal effects seen in the lab are even more ambiguous when extrapolated to the field. Auld and Schubel (1978) concluded the same for eggs and larvae of six Chesapeake Bay species. Thus, while the effects remain unknown, it is unlikely that the limited turbidity plumes created by subtidal or intertidal shellfish dredging operations have a major impact on the biological resources in those habitats.

Turbidity will reduce light levels and the resultant shading could have an impact on plant growth. If dredging activities occur to such an extent that light levels are reduced below ambient levels for extended periods or over wide areas then SAV, benthic macroalgae and phytoplankton might be affected. I was not able to find any papers that documented this impact.

Tarnowsky (2001) reported that hydraulic dredge impacts to turbidity are worst in fine silty clay sediments because the particles remain suspended longest. The maximum distance of detectable deposits resulting from hydraulic dredging was 75 ft. while another study found negligible sedimentation at 15 ft. from a dredging site. Values as high as 584 mg/l of suspended solids were recorded at the conveyor belt of an escalator dredge working in a silt/clay mud flat (Kyte & Chew, 1975). This value rapidly dropped to 89 mg/l at a distance of 61 m (200 ft.) from the dredge, although a plume was still visible. Background silt loadings at the site varied from 4 to 441 mg/l.

I was unable to locate studies on the effects of increased turbidity on winter flounder eggs or larvae. Since the species is adapted to spawn in late winter in the shallow upper reaches of coastal estuaries at a time when winter storms are at their worst, one might assume that they are well adapted to periodic episodes of high turbidity.

See also:

Black, K. P. and Parry, G. D. 1999. Entrainment, dispersal, and settlement of scallop dredge sediment plumes: Field measurements and numerical modeling. Canadian Journal of Fisheries and Aquatic Sciences. 56(12) : 2271-2281.
Abstract: Entrainment, dispersal, and settlement of sediment plumes generated by scallop dredging were measured with an instrumented towed sled and downstream sensors during a series of experiments conducted in the main scallop grounds in Port Phillip Bay in southeastern Australia. When three 36-ha experimental plots were subjected to closely supervised, intensive dredging by commercial fishers, it was found that dredges suspend a thin layer of sediment (similar to 0.5 cm thick) inducing initial near-bed concentrations of 2-15 kg.m(-3) in a billowing turbid plume. At one field site **concentrations reduced after 30 min to about 2% of the initial value**.

Gregory, R. S. 1990. Effects of turbidity on benthic foraging and predation risk in juvenile chinook salmon. Pages 64-73 *in* C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific coast fishes. Workshop proceedings, Seattle, September 8-9, Washington Sea Grant Report WSG-WO 90-01.
Abstract: The foraging behavior of juvenile chinook salmon in conditions of elevated turbidity was investigated in laboratory experiments to evaluate reaction distance to invertebrate prey, the perceived risk to a model predator, and the foraging rate of chinook on benthic Tubifex worms, in turbidity conditions ranging from 0 to 800 mg/L. Both reaction distance and perceived risk declined inversely with turbidity. **Foraging rates on Tubifex were highest at intermediate levels (50-200 mg/L)** and lowest at 0 mg/L (control) and 800 mg/L. **The results suggested a tradeoff between the effects of reduced reaction distance and perceived risk to predation**

Hanson, C. H. and Walton, C. P. 1990. Potential effects of dredging on early life stages of striped bass (*Morone saxatilis*) in the San Francisco Bay area: An overview. Pages 38-56 *in* C.A. Simenstad (ed.), Effects of dredging on anadromous Pacific Coast Fishes. Workshop proceedings, Seattle, September 8-9, Washington Sea Grant Report WSG-WO 90-01.
Abstract: Potential relationships between exposure to increased suspended sediment concentrations and striped bass (Morone saxatilis) hatching success, larval foraging, and adult migration and spawning in San Francisco Bay and the Sacramento-San Joaquin Delta, were examined. The limited information that is available suggests that **striped bass are not effected adversely by exposure to increased suspended sediments** at the concentrations encountered.

Hoffman, E. and Dolmer, P. 2000. Effect of closed areas on distribution of fish and epibenthos. ICES Journal of Marine Science. 57(5) : 1310-1314. (mussel dredging fishery)
Abstract: The high blue mussel catches in fjord system in Denmark, the visible effects of dredging by resuspension of bottom sediment and the possible destruction of benthic flora and fauna have all raised concerns about the impact on the ecosystem. The **investigations showed no long-term effects of mussel dredging on the distribution of fish and epibenthic invertebrates, and the closed area appeared to have had no influence on the demersal fish and epibenthic fauna**.

Krost, P. 1990. The impact of otter-trawl fishery on nutrient release from the sediment and macrofauna of Kieler Bucht (western Baltic). Ph.D. dissertation. Berichte aus dem Institut fur Meereskunde an der Christian-Albrechts-Universitat Kiel. Kiel. 200 160 pp.
Summary: This document estimates the total area being trawled globally and makes extrapolations based on lab experiments that produce the worst-case sediment nutrient release. Krost estimates the annual <u>worldwide</u> release of 98-435 t nitrogen and 34-167 t phosphorus, as well as an annual oxygen demand of 491-2656 t O_2 due to the release of hydrogen-sulphide by sediment resuspension. This may sound like a lot, but these numbers are not really significant. Consider that the annual input of nitrogen to Narragansett Bay has been estimated at 532t and the daily flow of nitrogen into the Hudson River is 57 tons. (Nixon 1981)

Impact of Resuspended Sediments : Nutrient Release and Hypoxia

Marine sediments typically become anoxic below the surface due to the consumption of oxygen by bacteria that are decomposing the organic matter that collects on the bottom. The greater the flux of organic matter to the bottom, the greater the rate of oxygen consumption. As you go deeper into the sediment the pore water oxygen becomes depleted and sulfate is reduced to hydrogen sulfide (Nixon 1981). This gives the sediment its characteristic black color and "rotten egg" odor. The depth at which the sediment turns black is called the red-ox layer (short for reduction / oxidation).

In very productive environments the anoxic black layer of sediment is very close to the surface because organic matter being deposited faster than it can be consumed by the bacteria. If you stir these sediments into oxygenated water the hydrogen sulfide will oxidize in a reaction that consumes oxygen (sediment oxygen demand).

Organic matter also contains nutrients such as nitrogen and phosphate. As organic matter decomposes these nutrients which are bound in tissues are remineralized into soluble forms and released into the sediment pore water (Nixon 1981). Stirring the sediments can temporarily cause an acceleration of the release of nutirents, but the total amount released over time is not affected by disrupting the sediments unless the dredge digs deep enough to stir up nutrients that have been "buried" or sediments where pore waters no longer travel. (Barnes et al. 1991).

Most of the literature that describes this potential impact is related to dredging for channel or harbor maintenance. The magnitude of sediment resuspension when one is excavating and then dumping tons of sediments is clearly far greater than the disturbances caused by a hydraulic dredge scraping a few centimeters off the top.

Few studies document this impact from fishing gear. Krost 1990 estimated an annual oxygen demand of 491-2656 t O_2 due to the release of hydrogen-sulphide by sediment resuspension caused by **global** trawling. Dispersed over the estimated area being fished annually (333km2 or 82,251 acres) this is insignificant, however locally the impacts might be measurable.

Kyte et al. 1975 found that harvesting had little long-term effect on the local ecosystem. Ambient seston levels (6.9-441 mg/1) often met or exceeded those associated with harvesting, thus obscuring any potential short-term effects. Few consistent effects on water column chemistry were observed (e.g., nutrients, DO, H2S).

The process of oxygenating reduced sediments is essentially in local equilibrium. If you alter the equilibrium locally by dispersing and oxygenating sediments, then those suspended sediments will have less oxygen demand after the disturbance. There is therefore no <u>net</u> loss of oxygen from the water column, just local, short-term oxygen reduction due to the local disturbance. Logically, if the oxygen demand related to resuspended sediment was significant there would be mass mortalities following every storm event since these events kick up far more sediment than fishing activities could. If the local impacts were severe then fish would likely avoid sediment plumes. Instead researchers report that fish will follow dredges to scavenge for exposed worms and fishermen report good bottom fishing in areas that have been recently dredges (Rivarra pers. comm.).

Impact of Resuspended Sediments: Release of Contaminants

DEC speculates that disturbing buried sediments will release contaminants such as industrial chemicals and metals into the water column. Barnes et al. (1991) summarized relevant concepts for shellfish dredging. "There is presently little or no evidence to support the hypothesis that the use of escalator harvesters causes the release of contaminants" (Coen 1995), however, this is largely due to the fact that shellfish growing areas require high water quality and are not areas where industrial chemicals have been dumped.

By-catch mortality is a common issue with deep water fishing gear. When trawlers haul their nets they discard great numbers of fish. Some of these are regulatory discards (fish discarded because they are too small, out of season or in excess of quota) while some are discarded because they are undesirable. Many are killed because they were packed in the bottom of a net full of fish for hours, or because their swim-bladder exploded when they were exposed to low pressures at the surface. Shellfish farmers rarely see this problem because 1) they tow slowly 2) their gear is designed to catch shellfish not fish, 3) tows are very short (they know where their shellfish are) and 4) they are working shallow waters.

In Summary:
Both of the review works designed to weigh the impacts of hydraulic harvesters in shallow estuaries (Coen and Tarnowsky) concluded that the impacts were reversible, short-term, and (due to the constrained scale of the activity) unlikey to have significant adverse impacts (except in the case of dredging in SAVs which is not legal in most states).

From Coen 1995

> Overall, findings consistently support the same conclusion: the short-term effects of subtidal escalator harvesters are minimal, with no long-term chronic effects, even under worst case scenarios. Observed effects are often indistinguishable from ambient levels or natural variability. These conclusions are based on field experimentation and knowledge of natural estuarine variation (physical, chemical and biological). The most obvious effects (e.g., sediment plume) cease when operations are halted, but natural events are continuous. Naturally high turbidities and variable river discharges are common to South Carolina, hence it is predictable that direct effects are probably within previously observed norms.
>
> Estuarine communities appear, in general, to be tolerant of the short-term harvester effects including resuspension/turbidity, direct

burial/smothering, nutrient release and decreased water quality due to elevated BOD, and direct disturbance or removal of infauna.

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