The Role of Mud in Regional Productivity and Species Diversity

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1. INTRODUCTION

Some muds are released into the nearshore marine environment during dredge disposal operations for Santa Cruz Harbor. In considering the potential impacts of the dredged muds, it is useful to consider the natural role of mud in the Monterey Bay Area (Figure 1). Fine sediments are transported from the regional watersheds into the ocean. The closest major depositional sinks for this mud are the outer continental shelf and the upper slope, especially on the walls of submarine canyons (Figure 1). The mud deposits on the shelf are thickest around 80 m (Griggs and Hein 1980, Eittreim et al. 2002). Moving shoreward from the mud band, wave-generated bottom currents produce a coarser, erosional substrate (Figures 1-2). In water depths of less than 30 m, the substrate is wave swept sand, containing usually much less than 10% mud (Oliver et al. 1980). Offshore from the mud band, the seafloor is again strongly influenced by erosion, not from surface waves, but probably from breaking internal waves as they intercept the shelf-slope break (Cacchione et al. 2002). Therefore, a thick band of mud is sandwiched between two erosional environments: the shelf-slope break and the inner shelf including the surf zone and sandy beach (Figure 2).

2. IMPORTANCE OF MARINE MUDS

One of the most important discoveries in modern oceanography is the critical role of iron as a limiting nutrient for productivity (Gordon et al. 1982, Coale et al. 2004). The primary source of iron is dust and runoff from the land. Changes in iron can explain patterns in global productivity today and over long periods of time (Martin 1990). In addition, iron dynamics has a profound influence on coastal productivity, even in the middle of an upwelling region like the central coast (Bruland et al. 2001). In particular, along the Big Sur coast, little fine sediment is transported to the ocean from the narrow and well-vegetated watersheds. The shelf is narrow, and there is no mud band on the outer shelf. Instead, the sediment is sandy from the surf zone to the shelf-slope break. This is a region of relatively low primary productivity along our coast. In contrast, Monterey Bay and the continental shelf to the north receive large inputs of fine sediment from several major rivers, draining large watersheds that are all highly modified by human activities. The shelf is wider and the middle and outer shelf are covered with a thick band of mud (Figures 1-2). This mud supplies the iron that fuels the high production center in Monterey Bay and to the north (Bruland et al. 2001). In both regions, the inner shelf is dominated by wave disturbance and internal waves break at the edge of the shelf (Oliver et al. in preparation A).

The major difference between the shelf sediments in the Monterey Bay area and Big Sur is the absence of the mud belt along Big Sur. Upwelling water also baths both regions. But this upwelled water is depleted in iron, which is almost completely recycled before it leaves the upper ocean. The high production in our upwelling system depends on a source of iron from the land. Iron is deposited in the mud band and in deeper water. It is remobilized by bioturbation (animals mixing sediment) and bottom currents. Once resuspended, iron fuels the tremendous primary production of our upwelling center, which cannot exist without iron from mud. Similar ecosystem patterns are also documented for the highly productive upwelling system along the west coast of South America (Bruland et al. 2005).

The high primary production is likely the main reason for the very high species diversity in upwelling ecosystems (Oliver et al. in preparation B). For example, the benthic invertebrate communities living on the shelf and upper slope of the Monterey Bay area have one of the highest number of species in the world (Table 1). The most important ecological measure of biodiversity is the number of species (per standard area of sea floor). The highest local diversity is actually at the shelf-slope break (Figure 2). However, the mud band and shelf break are a region of high diversity (Figure 2), despite major changes in the bottom communities from the depositional mud band to the erosional shelf edge. The entire shelf is bathed by highly productive water. Wave disturbance, however, has a significant impact on community diversity along the inner shelf (Oliver et al. 1980). There are no data on the structure of benthic communities along the outer shelf of the Big Sur coast. However, it is expected that there would be lower species diversity, because of the lower primary production.

The mud band is the site of recent sampling to explore potential impacts of sewage discharges into the bay area. This sampling was conducted at 80 m at eight stations located off the Salinas River and extending north of Santa Cruz to Davenport. The major anthropogenic inputs to the mud band are from the watershed and rivers, not from waste discharges into the bay. There is a distinct habitat and community gradient from north to south, which is strongly related to river inputs of sediment. However, the entire region has high benthic diversity. Past sampling confirms this, which extended from Monterey Bay to Davenport (Figure 1), and high diversity was found in a large area of sampling in the major upwelling center (Figure 3, Table 1).

There is a significant temporal change in regional productivity between the cold and warm periods in the California Current. This is the Pacific Decal Oscillation or El Viejo, which has a 20-30 year cycle of warm and then a comparable period of cold surface waters. The cold period is characterized by greater upwelling and higher production. The benthic communities from the inner shelf are radically different at the end of a cold, high production period compared to the end of a warm, poorly fed period (Oliver et al. in review). Community diversity is also lower with lower production during El Viejo cycles.

3. SUMMARY

In summary, the tremendous primary productivity of coastal upwelling centers is dependent on iron eroded from land, bound to mud, and deposited in benthic sinks. Without mud, our coastline would not have the complex, diverse food webs that characterize productive upwelling systems. Benthic invertebrate communities live in the sediment, and are strongly influenced by spatial and temporal variations in water column production. The Monterey Bay area has the highest benthic diversity in the world, and the animals live in muddy deposits along the outer continental shelf (Table 1, Figure 3). The high diversity depends on our high production, which depends on iron in mud, which is transported from the land to the sea.

3. LITERATURE CITED

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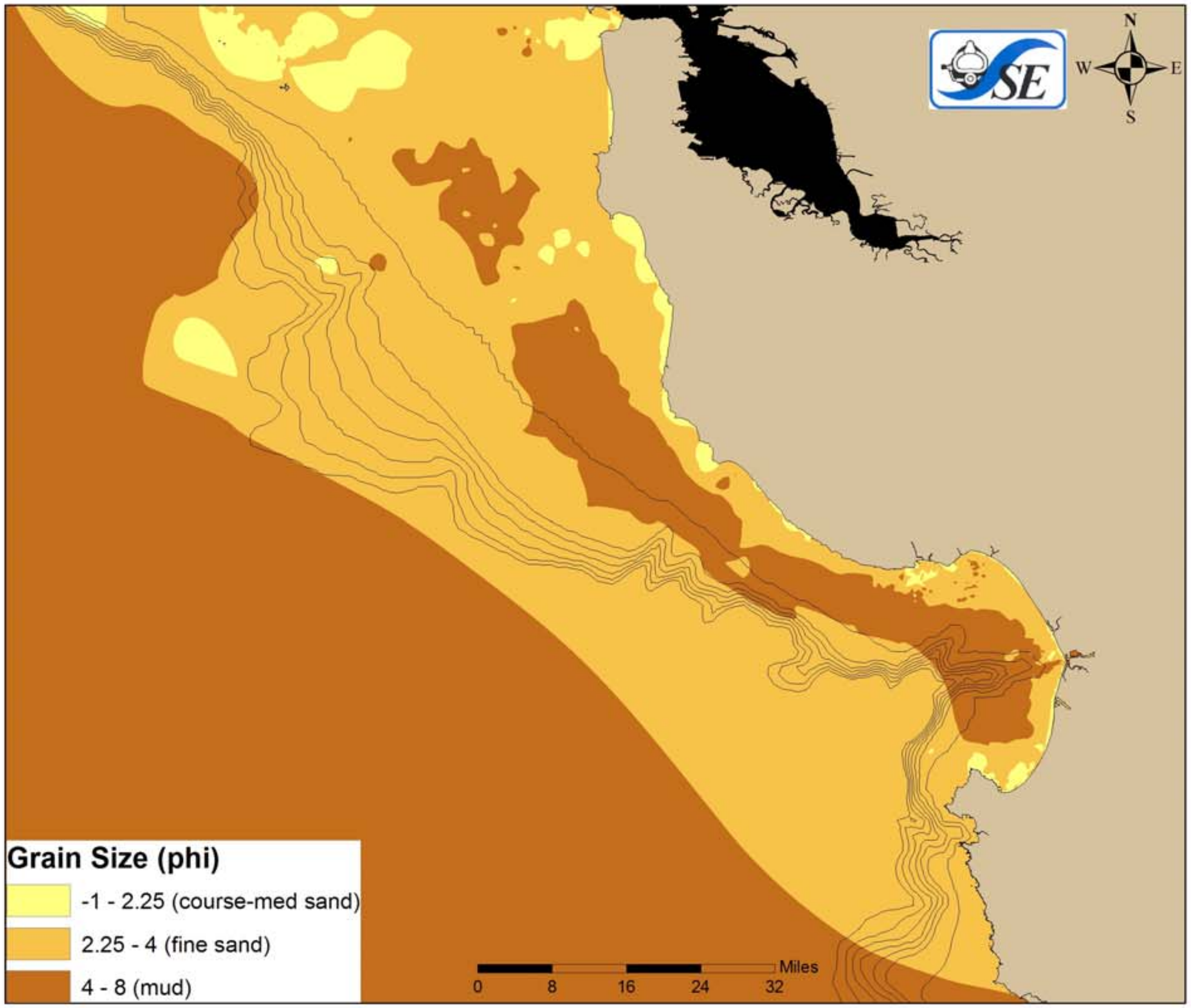

Figure 1. The mud band extending from Monterey Bay to San Francisco Bay, and the location of the four shelf and upper slope transects where benthic invertebrate communities and sedimentary habitats were sampled extensively in 1999.

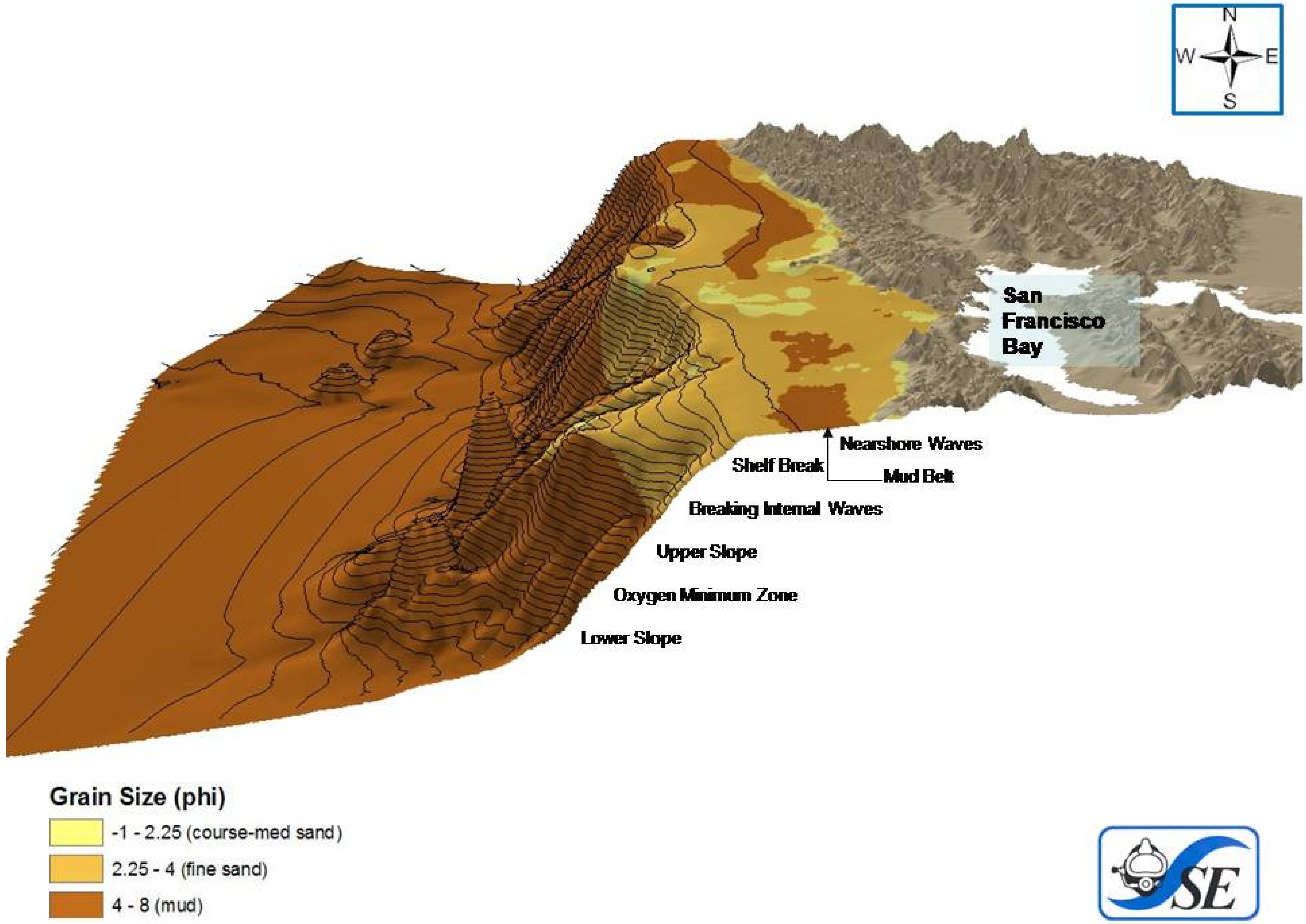

Figure 2. Cross section of the continental shelf and upper slope showing the erosional, wave-swept inner shelf (30 m to the sandy beach); the depositional mud band along the mid and outer shelf (40-90 m); the shelf-slope edge eroded by breaking internal waves (100-200m); and the oxygen minimum zone from 500-1000 m.

Location	Depth	Sample Area 0.1m2	1.6m2	2.4m2	>9m2	Individuals/m2
Shelf/Slope						
Monterey Bay Area California, USA Oliver et al. in prep.	10-2000m 109-150m	187 187	500 550	630 no data	915 (9.5m2) no data	1000-18,000 4000-16,000
Bass Straight Australia Gray et al. 1997 Coleman et al. 1997	11-51m	187	480	575	803 (10.6m2)	6,000
Santa Maria California, USA Hyland et al. 1991	90-565m	158	no data	419	886 (23.1m2)	15,000-21,000
Mussel Bed Washington, USA Suchanek 1979	Intertidal Rocky	133	no data	no data	no data	118,000
Bathyl Deep Sea						
San Francisco Deep California, USA SAIC 1992; Blake pers. comm.	1200-3000m	146	no data	458 (2.9m2)	800 (13.5m2)	750-12,000
Northwest Atlantic Eastern USA	1500-2100m	135	351	425	798 (21m2)	4,600

Grassle and Maciolek 1992						
San Diego Trench California, USA Jumars 1976	1230m	no data	315 (1.25m2)	no data	no data	2,250

			Sample Area			
Location	**Depth**	**0.1m2**	**1.6m2**	**2.4m2**	**>9m2**	**Individuals/m2**
Northwest Atlantic Eastern, USA Grassle and Morse-Porteous 1987	3600m	no data	250 (0.68m2)	no data	no data	no data
Northeast Atlantic Europe Gage 1979	1800-2900m	no data	146 (0.25m2)	no data	no data	no data

Table 1. Number of macrofaunal invertebrate species from the most diverse marine benthic infaunal communities in the world. Note that sample areas from the last four locations vary from the four sample areas at the table top.
From Oliver et al. in preparation.