Inspection for Live Marine Invertebrates in an Oyster Shell Pile at Drakes Bay Oyster Company

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Background and Site Description

On July 19, 2006 we inspected a pile of oyster shells at Drakes Bay Oyster Company on Drakes Estero. This shell pile is intended to be the source of cultch later this summer for an experimental native oyster restoration project at Marin Rod and Gun Club in San Francisco Bay. The pile is one of five more-or-less distinct shell piles at the site, and consists of old (>1.5 yr. in the pile), unpunctured bottom shells of the Pacific oyster, *Crassostrea gigas*, all or nearly all of which were harvested from Drakes Estero[1] and placed in the pile prior to the purchase of the oyster company by Kevin Lunny on January 2, 2005 (K. Lunny, pers. comm.). All five piles are located immediately landward of a dirt driveway, well above the normal high tide level and somewhat above the highest storm surge that has occurred since January 2, 2005 (K. Lunny, pers. comm.). The driveway, the group of piles, and the bluff behind them all trend along a line from NNW to SSE (Figure 1).

The pile we inspected covers an area of roughly 40 x 45 feet and varies from about 3 to 6 feet in height (Figure 2). It contains an estimated 7500 cubic feet of shell, of which approximately one-quarter is expected to be used in the restoration work this summer (K. Lunny & R. Abbott, pers. comm.). The pile fronts on the aforementioned dirt driveway, backs up against a steep bluff, and abuts other shell piles--of newer bottom shell, punctured and possibly newer bottom shell, and new and old top shell--on either side. The boundaries between the piles are clear in some places, less clear in others.

In the pile we inspected, the shells in the front 3-4 feet appeared to be the newest, based on the presence of a thin, black, dry residuum of adductor muscle tissue on most shells. The shells further back lacked this residuum, the adductor muscle scar being completely clean. The rearmost part of the pile, up against the bluff, has *Rhaphanus* and other plants growing on it, and we judged this part of the pile to be the oldest. At the back of the pile there is also an area with shells in plastic mesh bags, without vegetation on it.

[1] Since the oyster company store has sold oysters purchased from Taylor Shellfish Company, it's possible that some of the discarded shells ended up in the piles, though the number of these must be very small (K. Lunny, pers. comm.).

Figure 1. Sketch of pile locations. Not to scale.

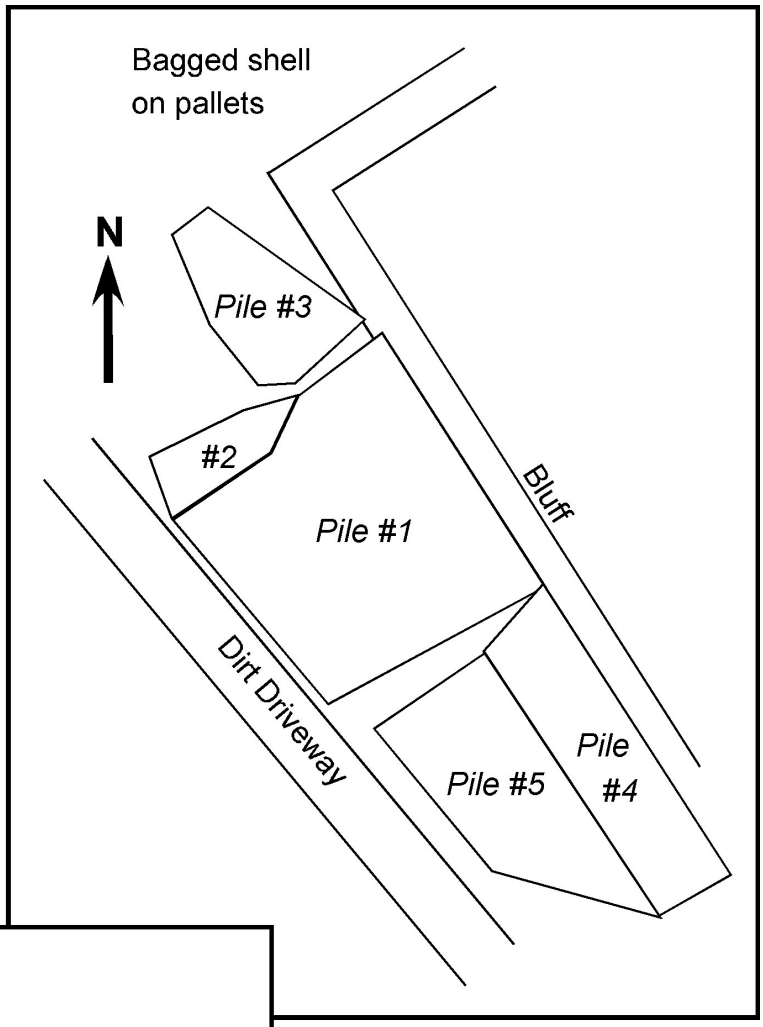
Pile #1: Old (>1.5 yr), unpunctured bottom shell, ≈3-6' high; inspected in this study.

Pile #2: Punctured bottom shell, ≈ 2-3' high, possibly newer than Pile #1.

Pile #3: Newer (<1.5 yr) bottom shell, ≈ 3' high.

Pile #4: Old (>1.5 yr) top shell, ≈ 6' high.

Pile #5: Newer (<1.5 yr) top shell, ≈2' high.



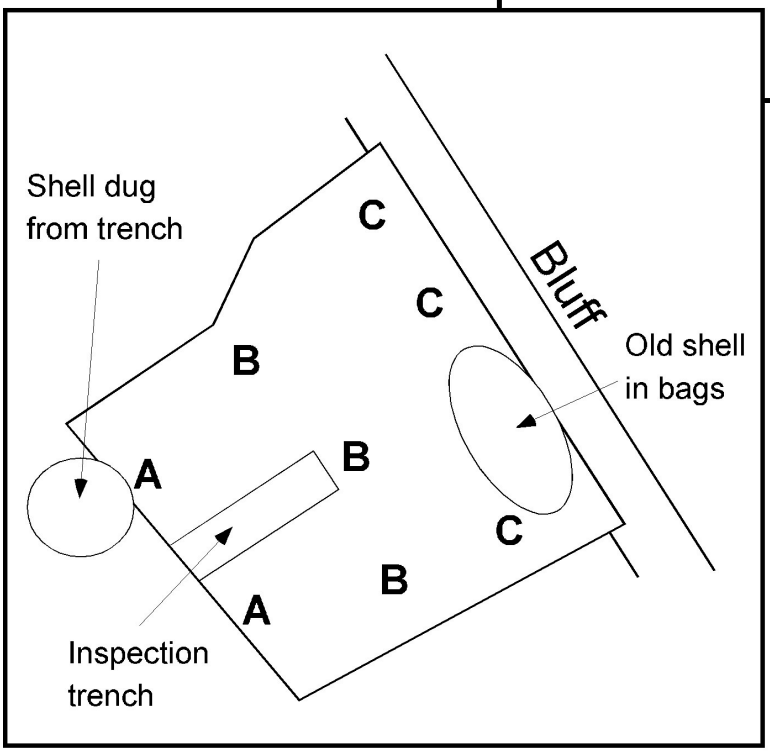


Figure 2. Sketch of inspected pile. Not to scale.

A: General area of newest shell in pile, with residuum of adductor muscle tissue.

B: General area of older shell in pile, with no adductor muscle residuum.

C: General area of vegetation growing on pile, thought to indicate oldest shell.

Methods

To enable us to sample the shells, Kevin Lunny excavated a trench at our direction that extended from the front of the pile perpendicular to the driveway to about the middle of the pile. The trench was about 5 feet wide, 18 feet long and extended down to the soil at the bottom of the pile. We qualitatively sampled shells from the whole length of the trench, examining shells from both sides and the back and from all depths, but concentrating on shells in the lower part of the pile. We looked for pockets of moisture, and had refractometers with us to determine the salinity of any water found in sufficient quantity to measure (i.e. enough to collect a drop in an eyedropper). We also collected a dozen shells from the top layer at the front, back and sides of the pile. We initially examined shells in the field using 10x hand lenses looking for and collecting any live or dead organisms that were potentially marine, and noting but not collecting obvious terrestrial organisms (insects, spiders and one snail). This part of the inspection took about 1.5 hours of work by 2 taxonomists, assisted by a data recorder.[2] We then took the organisms collected, selected shells of interest, and some shell clusters that we broke up, into the oyster company building where we further examined the organisms and shells under 60x dissecting microscopes. This part of the inspection took about 1 hour of work by 2 taxonomists. We sorted and saved the organisms that we found for final identification 2 days later under a 100x dissecting microscope.

Results

The soil at the bottom of the trench was damp to the touch. The shells in the pile were nearly all dry, except for a few shells in one spot near the bottom of the pile that were visibly moist. There was not enough water on these to measure the salinity with a refractometer.

We found no live marine organisms. We found the remains or tubes of 23 species of dead marine organisms (Table 1), including a sponge, polychaete worms, barnacles, an isopod, an amphipod, crabs, a limpet, clams, mussels and bryozoans. We found several individuals of a protozoan, *Gromia* sp. on one oyster shell. These resembled a common marine species in central California, *Gromia* cf. *oviformis*; though it's possible they were a freshwater/terrestrial species. We are uncertain whether they were alive or dead, though *Gromia* reportedly have no resting stage and are unlikely to survive long out of moisture (J.T. Carlton, pers. comm.). We saw or collected several types of live terrestrial arthropods, including insects, a snail, spiders and isopods. Many shells in the lower part of the pile had a green coloration that we surmised might be a mold or alga.

[2] Rena Obernolte of MacTec. Robert Abbott of MacTec also assisted with characterization of the shell pile.

Table 1. Species collected from an oyster shell pile at Drakes Bay Oyster Company, in Drakes Estero, California, on July 19, 2006

Higher Taxon	Species	Status
Marine Organisms		
Protozoa	*Gromia* cf. *oviformis**	not known
Porifera	unidentified sponge	dead
Porifera	unidentified boring sponge	dead
Annelida: Polychaeta	unidentified serpulid #1	dead
Annelida: Polychaeta	unidentified serpulid #2	dead
Annelida: Polychaeta	unidentified spirorbid #1	dead
Annelida: Polychaeta	unidentified spirorbid #2	dead
Arthropoda: Crustacea: Cirripedia	*Balanus glandula*	dead
Arthropoda: Crustacea: Cirripedia	*Chthamalus dalli*	dead
Arthropoda: Crustacea: Isopoda	*Paracereis cordata*	dead
Arthropoda: Crustacea: Amphipoda	unidentified gammarid	dead
Arthropoda: Crustacea: Decapoda	*?Cancer* sp.	dead
Arthropoda: Crustacea: Decapoda	*Pachygrapsus crassipes*	dead
Mollusca: Gastropoda	*Collisella ?limatula*	dead
Mollusca: Bivalvia	*Hiatella arctica*	dead
Mollusca: Bivalvia	*Modiolus rectus*	dead
Mollusca: Bivalvia	*Mytilus* sp.	dead
Mollusca: Bivalvia	unidentified bivalve #1	dead
Mollusca: Bivalvia	unidentified bivalve #2	dead
Bryozoa: Ctenostomata	*Amathia* sp.	dead
Bryozoa: Cheilostomata	*Bugula neritina*	dead
Bryozoa: Cheilostomata	*Cryptosula pallasiana*	dead
Bryozoa: Cheilostomata	*Schizoporella japonica* (=*S. unicornis*)	dead
Bryozoa: Cheilostomata	*Watersipora subtorquata*	dead
Terrestrial Organisms		
?	Green mold? on oyster shells	live?
Mollusca: Gastropoda	*Helix aspersa*	live
Arthropoda: Crustacea: Isopoda	*Armadillidium vulgare*	live
Arthropoda: Crustacea: Isopoda	*Porcellio scaber*	live
Arthropoda: Hexapoda: Insecta	unidentified insects, several species	live
Arthropoda: Hexapoda:Insecta	?Dipteran pupae	dead?
Arthropoda: Chelicerata: Arachnida	unidentified spiders, several species	live

* Resembles this marine form, but might possibly be a freshwater/terrestrial species.

Discussion and Conclusions

Quantities of Pacific oyster (*Crassostrea gigas*) shell, taken from oyster farming operations in other bays on the Pacific Coast, have been placed in San Francisco Bay beginning around 2000 for a variety of purposes, including the creation of "bird islands" as mitigation for a highway construction project, the use of shell as collectors for research on crabs, and the placement of shell in various configurations (on strings, stakes, pallets and frames) as experimental settling substrate for the native oyster, *Ostrea conchaphila,* as part of a developing effort to create reefs of native oysters (Table 2). This latter effort is expected to eventually require the placement of much larger quantities of imported shell in the Bay.

Table 2. Recent Placements of Oyster Shell in San Francisco Bay
(Information compiled by Natalie Cosentino-Manning and Andrew Cohen.)

When	What	Placed Where	Source of Shell
1999-2000	≈60 cu. yds. of shell in 2 mounds covered with *C. gigas* shell, for "bird islands" as mitigation for a highway project	Richmond shoreline between Cerrito Creek and Point Isabel	Tomales Bay
Summer 2001	200 *C. gigas* shells on strings at each site; in place for <1 yr	Sausal Creek; Audubon Richardson Bay Sanctuary; Redwood Creek; Coyote Point; San Pablo Creek	Taylor Shellfish (WA)
March 2004	150 bags of *C. gigas* shell (≈22,500 shells) on 12 pallets	6 pallets at Lyford House & 6 at Blackie's Pasture, in Audubon Richardson Bay Sanctuary	Taylor Shellfish (WA)
March 2005	80 bags of *C. gigas* shell (≈12,000 shells) on 8 pallets, 400 shells on 40 stakes, and 1200 shells on 30 strings	Pallets and stakes north of Marin Rod and Gun Club pier; strings on pier	Taylor Shellfish (WA)
May 2005	40 bags of *C. gigas* shell (≈6,000 shells) on 4 pallets, and 60 bags (9,000 shells) on 4 frames	Bair Island	Taylor Shellfish (WA)
?	*C. gigas* shell used in experimental crab collectors	?	Taylor Shellfish (WA)

On January 5, 2006, NOAA held a meeting of agency staff, restoration workers and area scientists to discuss the development of a protocol for handling oyster shell to be placed in San Francisco Bay to minimize the risk of introducing novel exotic species. Although most participants agreed that a

protocol was a good idea, two participants stated that it was unnecessary. NOAA agreed to look for funds for an inspection project that would determine how long oyster shell needed to be held in piles out of reach of the tides in order to kill all marine organisms. Funds for this have not yet been found.

In the interim, MacTec and the Marin Rod and Gun Club (MRGC) hope to use shell from the Drakes Bay Oyster Company to create four experimental reefs north of the MRGC pier. We were engaged by MacTec to inspect the oyster shells at the Oyster Company, in order to provide information that will help the California Department of Fish and Game (CDFG) determine whether MacTec and MRGC can use this shell this summer. Our methods were developed after consultation with Robert Abbott of Mactec, Jim Moore of CDFG and Michael Connor of the San Francisco Estuary Institute.

Our conclusion is that use of the shell from the pile we inspected (Pile #1 in Figure 1) would be unlikely to introduce live marine organisms into San Francisco Bay. We base this on the following specific factors:

- The pile being at least 19.5 months old (according to Kevin Lunny).
- Tides and storm surges not having reached the pile for at least 19.5 months (according to Kevin Lunny).
- Our inspection of the site appearing to be completely consistent with these two statements (no evidence of obviously younger shells in the pile, no evidence of tides or storm surge reaching the pile).
- The apparent age of the shells in the pile (no tissue other than a thin, dry residuum of adductor muscle tissue in the apparently youngest part of the pile).
- The general dryness of the shells in the pile (moisture only detected in the soil under the pile, and on a few of the lowest shells).
- Our failure to find any live marine invertebrates.

Regarding the last factor, we caution that our inspection was only designed to detect and determine the viability of marine invertebrates. We found one probable marine protozoan which we suspect was dead, but we did not determine that directly. Our methods would have been less effective at detecting protozoans, single-celled algae and related forms, and their resting stages, than they were at detecting invertebrates; and completely ineffective at detecting bacteria or viruses.

Two factors which had been mentioned in our consultations but which we found less compelling are:

- The proximity of Drakes Estero to San Francisco Bay. There are many cases of exotic species being present and abundant in one bay for several decades without appearing or becoming established in nearby bays with seemingly appropriate habitat. Thus, it shouldn't be assumed that all the exotic species in Drakes Estero are already in San Francisco Bay or will quickly invade San Francisco Bay on their own. Other things being equal, however, it's probably better to transfer shell from a nearby bay than from a distant one. An indirect advantage of using a nearby bay as a source is that agency staff responsible for the recipient bay and restoration workers working in the recipient bay can more easily inspect and monitor the management of the shell in the source bay.
- The short list of exotic species known from Drakes Estero. First, there has been virtually no investigation of the exotic species in Drakes Estero for the last quarter century, and the list is clearly incomplete. In a cursory examination of strings of live oysters from Drakes Estero we observed two exotic species that had not been previously reported from the Estero (the colonial tunicates *Botrylloides violaceus* and *Didemnum* sp. A), and in the shell pile we inspected we found the remains of a genus of ctenostome bryozoan that had not previously been reported from central California (*Amathia*). Second, although most of the exotic species reported from Drakes Estero were already reported from San Francisco Bay, the Japanese hornsnail *Batillaria attramentaria* was only recently found in San Francisco Bay, long after its discovery in Drakes Estero. The San Francisco Bay population of this snail is small and occupies a very small area, the snail has nonplanktonic larvae and is thus unlikely to spread quickly, and there is an effort underway to eradicate it which may therefore have a reasonable chance of success. In a few central California bays *B. attramentaria* may have contributed to the decline or eradication of the native hornsnail *Cerithidea californica*, whose San Francisco Bay population is already greatly reduced due to competition with an Atlantic snail, *Ilyanassa obsoleta*. For these reasons, further introductions of *B. attramentaria* into San Francisco Bay should be avoided. We found *B. attramentaria* to be common at the Drakes Bay Oyster Company on discarded oyster shell in the high intertidal zone. Third, even if the exotic *species* in Drakes Estero were all already present in San Francisco Bay, the Estero might nonetheless contribute novel *genes* to San Francisco Bay, which could be more invasive or harmful than those already present. A short list of known exotic species is thus no assurance that a bay won't be a source of novel exotic species or novel exotic genes; though, other things being equal, a bay with a short list is probably preferable to a bay with a long list.

We emphasize that our conclusion that the shell is unlikely to introduce live marine organisms is limited to the shell from Pile #1 of Figure 1. We did not inspect any shell from the other piles, and do not recommend transferring these shells to San Francisco Bay without appropriate inspection. As an additional precaution, we recommend that no shell be taken from the front 3-4 feet of Pile #1 (where the shells generally contain a residuum of adductor muscle tissue, and are therefore presumably newer); that no shell be taken from the pile created by the excavation of the trench (see Figure 2), which contains a mixture of shell from the interior and from the front 3-4 feet of the pile; that no shell be taken from the bags of shell at the back of Pile #1 (which we did not examine, and which may possibly have been tossed on the pile at a more recent date than the shell around them); and that care be taken not to include shell from the adjoining piles #2-5, which in several places are not clearly separated from Pile #1. We surmise that shell further back in Pile #1 may be older, and therefore safer, with the possible exception of the bags of shell at the back of the pile.

With regard to possible future use of shell from Drakes Bay Oyster Company or from other sites, we recommend that each year's shell be placed in a different pile, well-separated from other piles, and clearly marked, to avoid inadvertent mixing of shell from different years. These piles should, of course, be placed well above the level of the highest tides and storm surges. If shell is stored in this manner, inspections (using our methods or others) could determine how long shell must be stored in piles to ensure that no live marine organisms remain in the piles, and thus provide a simple protocol for managing the extremely large quantities of shell that are expected to eventually be used for native oyster restoration in San Francisco Bay and elsewhere.

Finally, we caution that the conclusion of the inspection reported here applies only to this particular pile of oyster shell, and cannot be used to determine even a rudimentary management protocol for other piles. While we believe that this pile is at least 19.5 months old, we have no information regarding how much older it may be: it may be a 2-year-old pile, a 5-year-old pile, a 10-year-old pile--we just don't know. We therefore cannot, based on this inspection, conclude that any particular minimum age will suffice to eliminate live marine organisms from an oyster shell pile.