Pre-Construction Coral Survey
WELLWOOD Grounding Site
April 23-24, 2002

Survey conducted by:
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INTRODUCTION

Surveys conducted between 1984 and 1994 showed that benthic community succession at the grounding site of the M/V WELLWOOD resulted in a community more like that of nearby hard grounds than the original transition zone assemblage that likely inhabited the location prior to the 1984 incident (Precht et al., 2001). Biological assemblages were dominated by a limited number of gorgonian and scleractinian species with high recruitment rates (Gittings et al., 1993; Smith et al., 1998). Gorgonian corals composed most of the cover. Very few framework building hard corals had recruited to the site, and their slow growth precluded the development of pre-existing topographic complexity, a factor vital to continued development of diverse invertebrate and fish assemblages.

Storms in the late 1990s disrupted and/or removed significant portions of destabilized reef framework from the grounding site, as well as attached benthic organisms. Restoration activities planned for 2002 are intended to stabilize remaining at-risk surfaces and enhance community development by the addition of topographic complexity and vertical structure. Transplantation of selected coral species is also planned following the stabilization of the substrate.

This survey was conducted to provide information on coral abundance and cover in the area to be restored as well as reference areas nearby. The data establish a pre-construction baseline in these communities and allow scientists and resource managers to track the trajectory of recovery following enhancement. The purpose is to determine whether this restoration will result in a biological assemblage with the character of the transition community that would exist there had the incident not occurred or whether the assemblage continues to develop the character of a hard ground.

METHODS AND SURVEY AREAS

Population and cover estimates were made in 18 one square meter quadrats in each of three areas at and around the WELLWOOD grounding site (Figure 1). Estimates were made for all observed species of scleractinian and gorgonian corals, hydrocorals of the genus *Millepora*, and zoanthids of the genus *Palythoa*. Because many small specimens were not identifiable in the field to species, some taxa were identified only to genus. Cover estimates were made visually in the four quadrants of each square meter quadrat, then averaged. Gorgonian cover was estimated from above, equivalent to canopy cover for terrestrial vegetation.

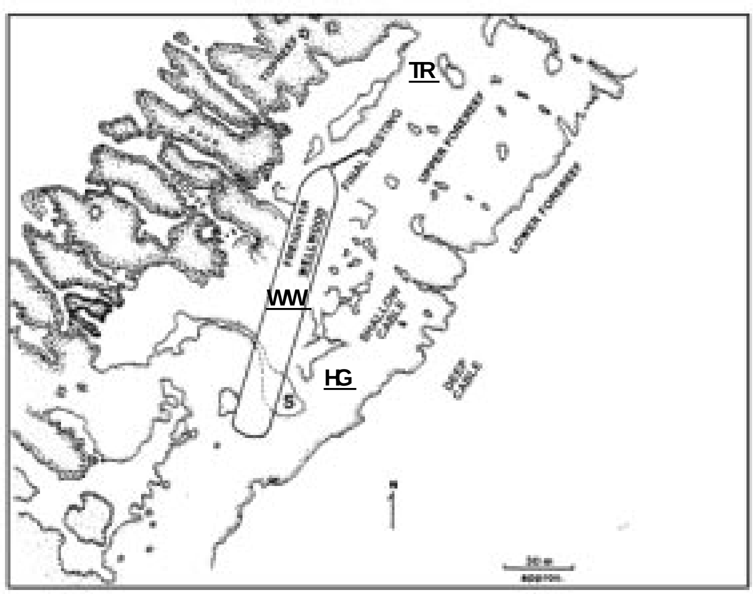

Figure 1. Grounding location of the freighter WELLWOOD, indicating areas of damage and sampling sites occupied in 2002 (WW, HG, and TR; see text for descriptions).

Area WW (WELLWOOD) was the flattened substrate created when the vessel ran aground. Portions of this area were removed by storms and are the target of restoration efforts. In order to make later assessments of the effects of restoration activities within the site, measurements were not made randomly. They were made in square meter quadrats in an alternating pattern along a transect running from the edge of one area to be restored across an area to be left undisturbed to a second crater 25 m from the first.

Two “reference areas” were also surveyed near the grounding site. Area HG (hard ground) is an undisturbed area 25-50 m southeast of WW. It contains a hard ground assemblage and limited relief. Surveys conducted since the grounding showed that the recovering coral assemblage at the grounding site is becoming like that of the hard ground (Precht et al., 2001). Area TR (transition zone) is an area that would have been forward (NNE) of the WELLWOOD as it lay aground. It is a transition zone between former shallow *Acropora palmata* stands and deeper hard ground assemblages. It likely contained the type of assemblage destroyed by the grounding. With the relief added to the grounding site by the addition of reef modules, it is expected that the assemblage at the grounding site (corals, fish, etc.) will progress toward that of the transition zone. Therefore, surveys were made in both hard ground and transition zone environments surrounding the grounding site.

Measurements were not made in a shallower, high relief area to the west of the grounding site even though they had been in surveys conducted between 1984 and 1990 (Area XBW of Gittings, 1988 and Gittings et al., 1990, 1993). This is because the shallow water communities in that area do not factor into the restoration objectives. That is, the objective of restoration is to re-establish relief comparable to the transition zone that existed prior to the grounding of the vessel, not that of the shallower zones nearby. Instead, surveys were conducted in Area TR.

FINDINGS

I. Community succession in the area denuded by the WELLWOOD has resulted in an assemblage that is, for the most part, similar in composition to surrounding hard ground areas and transition zones.

Figure 2 shows the abundance of gorgonians, scleractinians, and other significant benthic space competitors (excepting algae) in the three areas surveyed. The grounding site and the transition zone averaged 28 colonies per square meter. The hard ground area had approximately 32 colonies per square meter and a significantly higher abundance of gorgonians than that transition zone (p=0.027, ANOVA). No other significant differences in abundance existed among the areas.

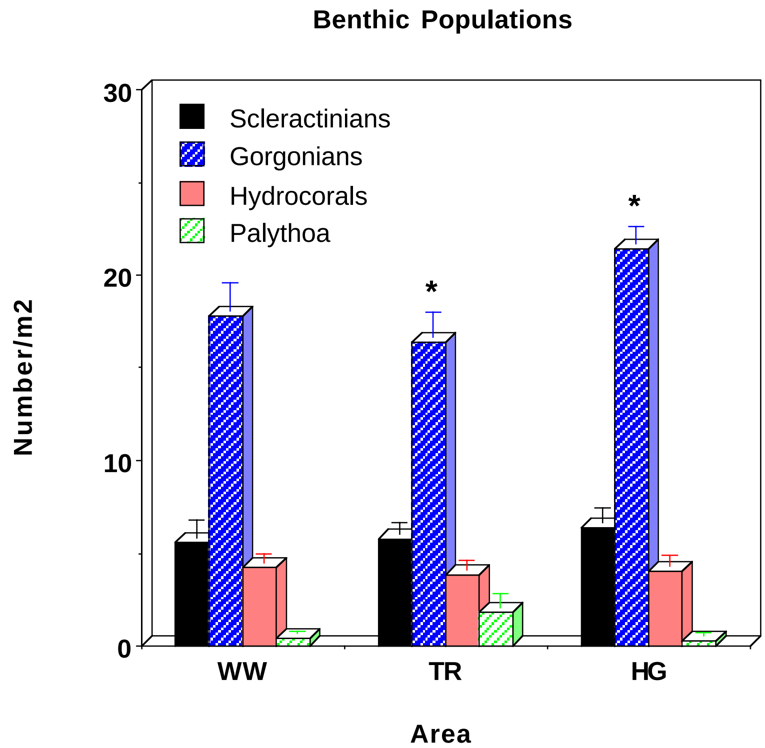

Figure 2. Abundance of selected benthic organisms in the area damaged by the WELLWOOD (WW), in an undamaged transition zone to the northeast of the grounding site (TR) and in an undamaged hard ground community nearby (HG). Standard error bars are shown. (* indicates where significant differences were found)

Richness of the dominant benthic taxa was also similar in all three areas surveyed (see Figure 3), suggesting that recruitment has resulted in substantial recovery in the area damaged by the WELLWOOD in 1984. Approximately 20 taxa (the range was from 19 to 21) were encountered in each of the three areas surveyed.

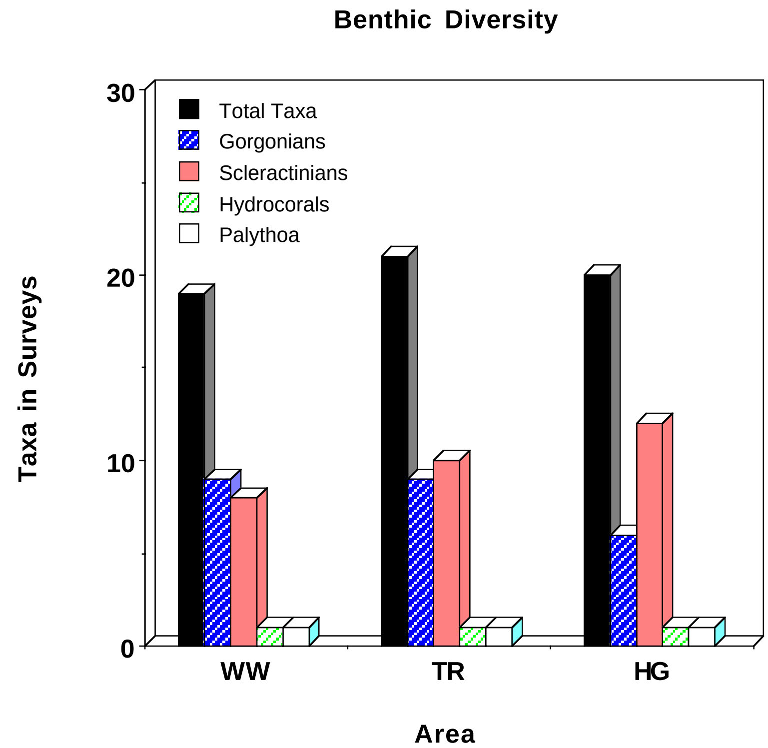

Figure 3. Diversity, measured as the cumulative number of taxa encountered, of scleractinians, gorgonians, zoanthids and hydrocorals in each of the survey areas.

While the overall richness was similar in each area, the average number of taxa per quadrat was lower at the grounding site than at either reference site (Figure 4; p=0.014, ANOVA). The range of the number of taxa in the samples, however, was similar for all areas (between 5 and 11 taxa). Given the similarity in abundance estimates in all three sets of samples, it is not clear how to explain this finding. It is possible that patchiness among individual species has resulted in greater clustering in the grounding site, affecting local (i.e. small scale) richness.

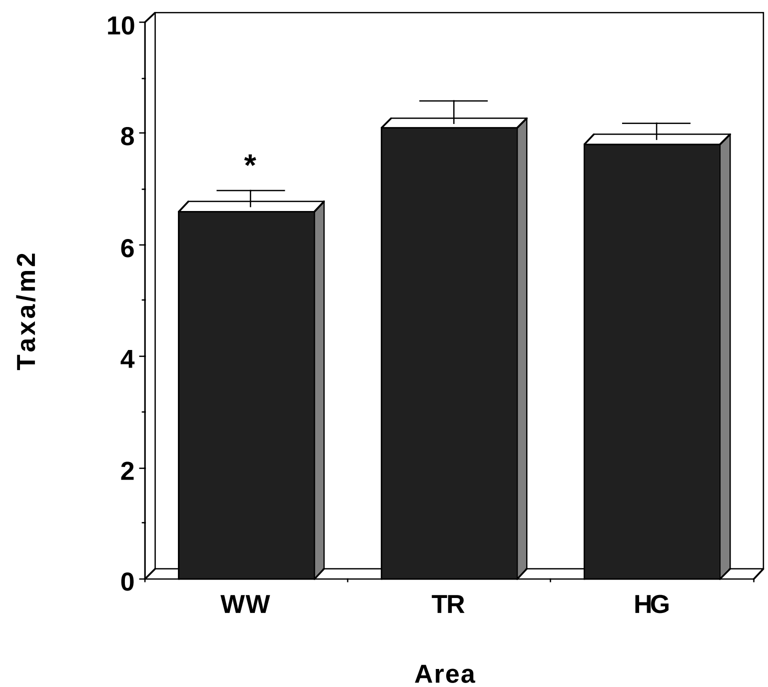

Figure 4. Mean number of taxa per quadrat (with standard error bars) in each of the three areas (n=18 for each area). * indicates where significant differences were found)

Species that compose the recovering community at the grounding site are those found in surrounding areas. Figures 4 and 5 show data from a 1984-1986 study (Gittings, 1988) alongside the 2002 data for all species encountered in quadrats in the grounding site and the hard ground area. Figure 5 shows considerable increases in abundance for several genera, including *Pseudopterogorgia, Gorgonia, Millepora, Porites, Agaricia,* and *Siderastrea*. Significantly, these genera are also dominant in the hard ground area (Figure 6) and abundances for most taxa are similar in both areas.

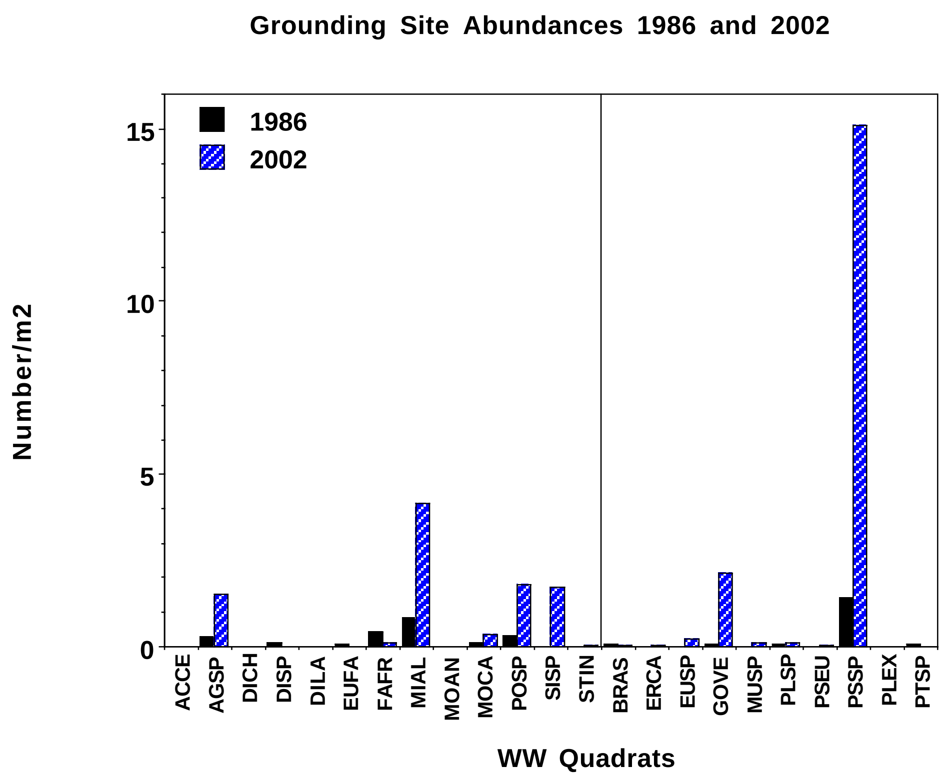

Figure 5. Abundances of species of scleractinians, gorgonians, hydrocorals, and zoanthids found at the grounding site of the M/V WELLWOOD in 1986 by Gittings (1988) and in 2002 (this assessment). Taxon codes are those found in Table 1. Vertical line separates gorgonians (right side) from other benthic competitors.

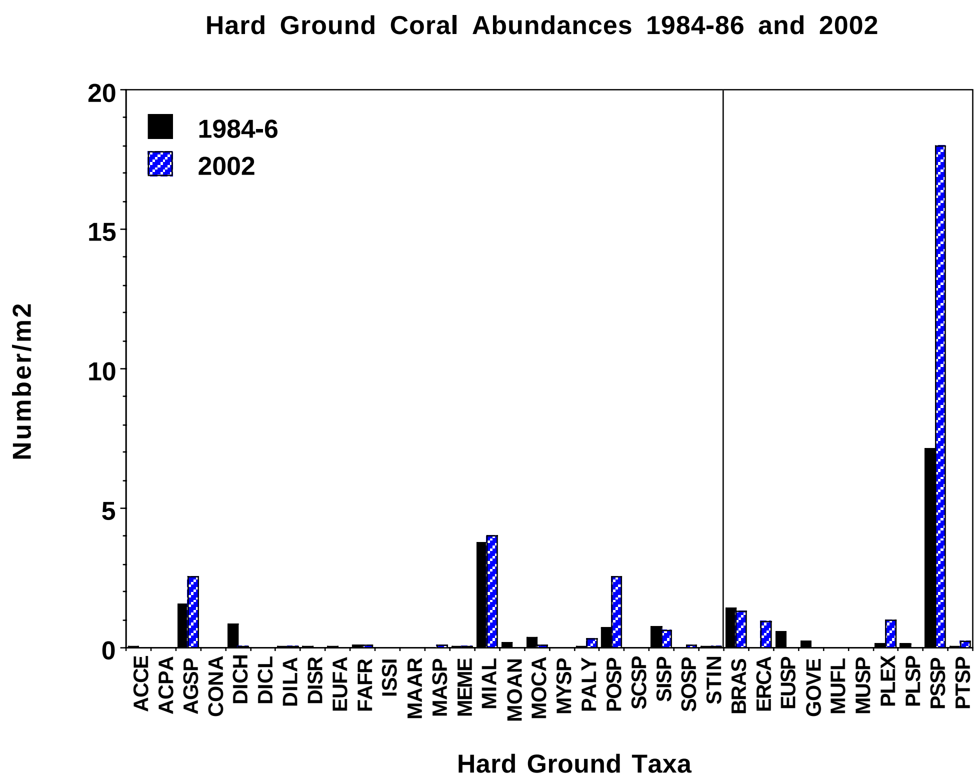

Figure 6. Abundances of species of scleractinians, gorgonians, hydrocorals, and zoanthids found in the hard ground area between 1984 and 1986 by Gittings (1988) and in 2002. Taxon codes are those found in Table 1. Vertical line separates gorgonians (right side) from other benthic competitors.

II. The grounding site is poorly developed with respect to scleractinian colony size and cover compared to surrounding areas.

Coral cover data (Figure 7) show that the three areas surveyed have similar gorgonian cover, averaging around 7%. Furthermore, total cover (ranging from 7 to 10%) did not differ significantly among areas. Scleractinian cover, however, was very low in the damaged area, accounting for almost none of the measurable cover in the 18 quadrats surveyed. Though high variation among samples resulted in only a borderline significant difference between this and the other areas ($p=0.06$), it is clear that scleractinian cover remains very low even after 18 years of recovery from the impacts of the ship grounding.

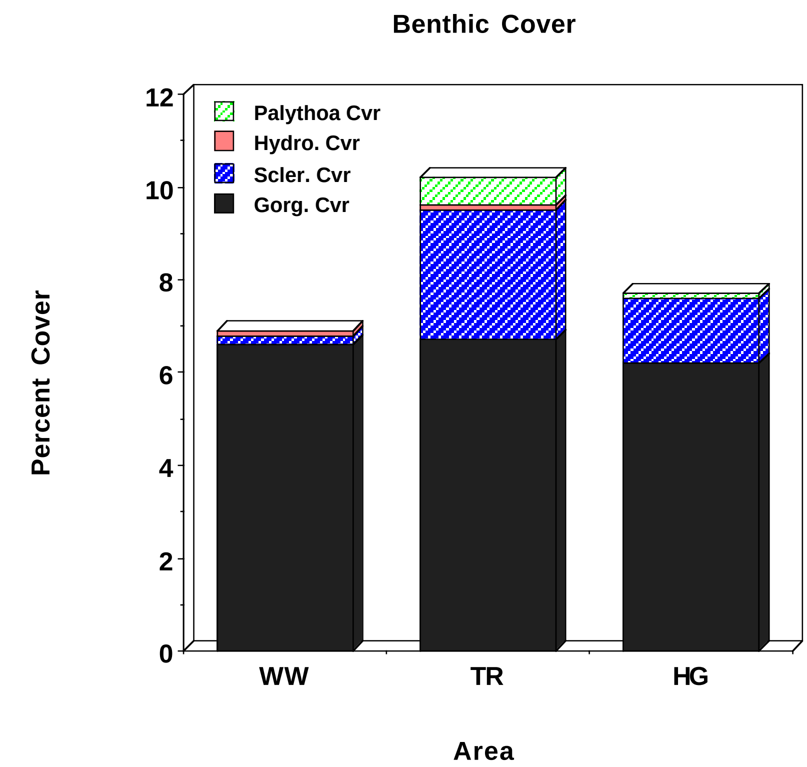

Figure 7. Percent cover of gorgonians, scleractinians, hydrocorals, and zoanthids in the three study areas.

The difference in scleractinian community development is clearly seen in data related to the size of colonies (Figure 8). Nearly 70% of colonies encountered in the grounding area were less than 4 cm in diameter (a size generally considered to represent juveniles). The remaining colonies were only slightly larger. In the other areas, only 36% of colonies were less than 4 cm, and a large number of substantially larger colonies were observed. It should be noted, however, that there are a few larger scleractinians in the grounding area that survived the incident by being in depressions that were not impacted by the hull of the vessel, but none of these were in the quadrats surveyed during the 2002 site visit.

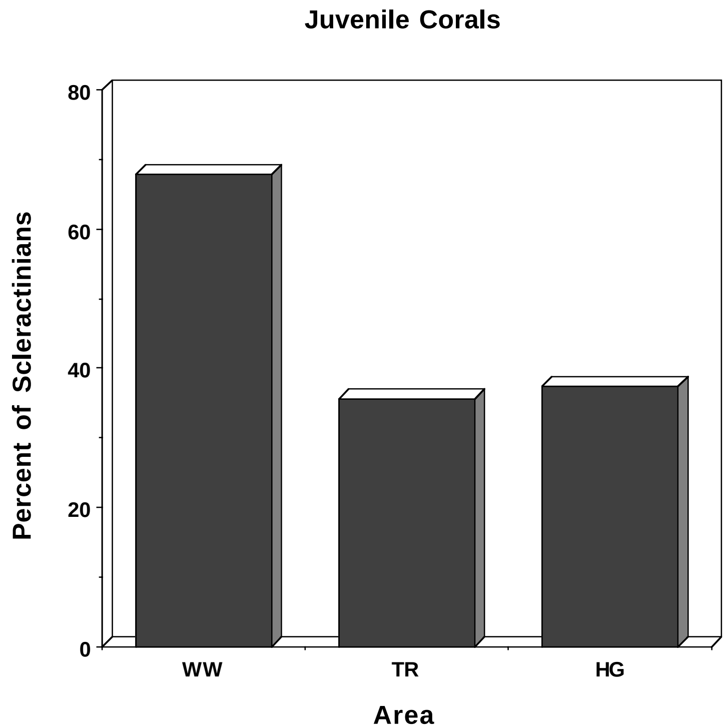

Figure 8. The proportion of scleractinian corals surveyed in each area that were less than 4 cm in diameter and therefore considered to be non-reproductive juvenile colonies.

III. Key scleractinian species necessary for the development of topographic relief in the area denuded by the grounding are not well represented in the current community.

Of the 28 taxa encountered in the 54 quadrats surveyed, between 19 and 21 occurred in any single area (see Table 1). Among the scleractinians, it may be significant that certain species found in the undamaged references areas were not found at the grounding site. Specifically, frame-building species like *Montastraea faveolata*, *M. franksi*, and *Diploria* spp. were absent from samples in the grounding site, a finding consistent with previous studies here and at other grounding sites (e.g. Gittings et al., 1990; Smith et al., 1998; Miller and Barimo, 2001). On the other hand, *Siderastrea siderea*, which can also form large colonies over time, was present. These species are broadcast spawning corals, which generally are found only rarely as recruits on reefs. Most of the recruits found at the grounding site brood larvae following internal fertilization, resulting in considerably more localized recruitment. This may account for the differences in abundance among species. It should also be noted that even in the reference areas, the abundance of frame-building species was low, and all three areas were dominated by small colonies of species in the genera *Agaricia* and *Porites*, few of which contribute substantially to habitat relief.

Table 1. Scleractinians, gorgonians, hydrocorals, and zoanthids encountered in each of the three survey areas (in number of colonies/m^2). Codes after each species refer to those in Figures 5 and 6.

TAXA	WELLWOOD (WW)	Transition Zone (TR)	Hard Ground (HG)
Scleractinians			
Agaricia spp. (AGSP)	1.5	3.1	2.6
Dichocoenia stokesii (DICH)		0.2	0.1
Diploria labrynthiformes (DILA)		0.1	0.1
Favia fragum (FAFR)	0.1	0.1	0.1
Leptoseris cucullata (LECU)	0.1	0.2	
Madracis decactis (MADE)			0.1
Meandrina meandrites (MEME)			0.1
Montastraea cavernosa (MOCA)	0.4	0.1	0.1
Montastraea faveolata (MOAN)		0.1	
Montastraea franski (MOAN)		0.1	
Porites spp. (POSP)	1.8	1.2	2.6
Siderastrea radians (SISP)	0.4		0.2
Siderastrea sidereal (SISP)	1.3	0.7	0.4
Solenastrea hyades (SOSP)			0.1
Stephanocoenia intersepta (STIN)	0.1		0.1
Gorgonians			
Briareum asbestinum (BRAS)	0.1	0.9	1.3
Erythropodium caribaeorum (ERCA)	0.1	0.1	0.9
Eunicea spp. (EUSP)	0.2	0.1	
Gorgonia flabellum		0.1	
Gorgonia ventalina (GOVE)	2.1	0.8	
Muricea spp. (MUSP)	0.1		
Plexaura spp. (PLEX)	0.1	0.3	1.0
Pseudoplexaura spp. (PSEU)	0.1		
Pseudopterogorgia americana (PSSP)	14.6	12.4	17.0
Pseudopterogorgia bipinnata (PSSP)	0.5	1.2	1.0
Pterogorgia spp. (PTSP)		0.6	0.2
Hydrocorals			
Millepora spp. (MIAL)	4.2	3.8	4.0
Zoanthids - Colonial anemones			
Palythoa spp. (PALY)	0.4	1.8	0.3
Total Number of Taxa	19	21	20

IV. While gorgonian cover and richness is similar in all study areas, gorgonian community recovery in the damaged area is not complete.

Among the gorgonians, all areas were dominated by the sea plume *Pseudopterogorgia americana*, both in terms of abundance and cover, with the most disproportionate population occurring in the grounding area. Table 2 shows that roughly half of all benthic colonies in each area were *P. americana*, and nearly all gorgonian cover is accounted for by this species. Figure 9 shows that the apportionment of individuals among gorgonian species (i.e., evenness) is lowest in the grounding area, a fact that is explained by the higher proportion of *P. americana* relative to other species. Lower diversity measures in the grounding area suggest that even though gorgonian cover is similar among the sites, gorgonian community development has still not recovered completely.

Table 2. Proportion of abundance and cover of gorgonians and all benthic space competitors accounted for by *Pseudopterogorgia americana*.

Pseudopterogorgia americana as a percent of:	WELLWOOD (WW)	Transition Zone (TR)	Hard Ground (HG)
Gorgonian Colonies	82%	75%	79%
Gorgonian Cover	99	99	92
All Benthic Colonies	52	45	53
All Benthic Cover	97	66	83

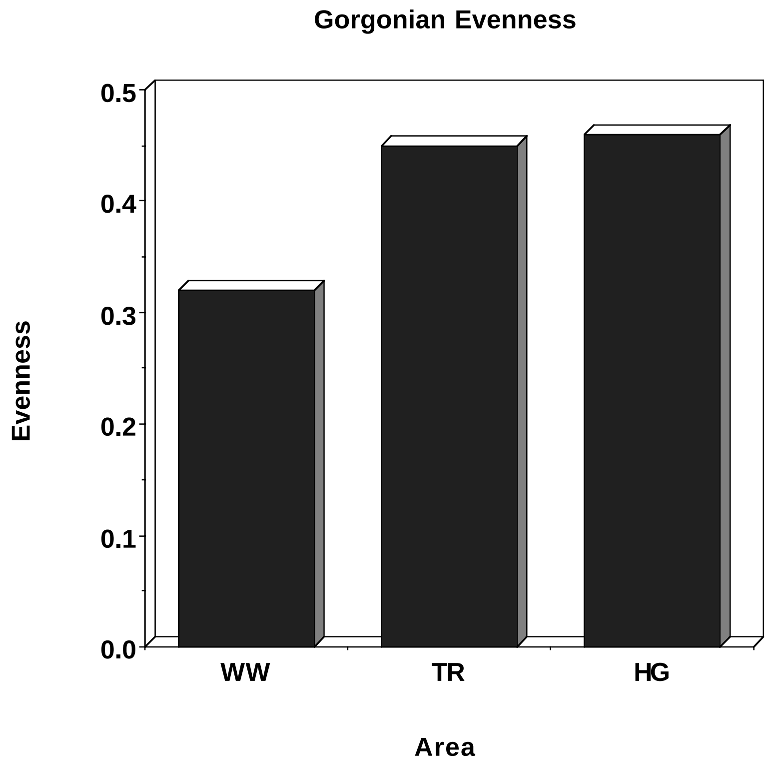

Figure 9. Evenness of gorgonian community in the three study areas. Evenness was measured as H'/ln(S), where H' is Shannon-Weaver species diversity and S is the number of taxa observed.

DISCUSSION

The casual observer swimming over the WELLWOOD grounding site would most likely not recognize it as having been disturbed. It is clearly a low relief area that is quite different in character from what it was prior to the grounding, but not knowing that, the observer would find it similar in appearance to hard ground areas nearby. Coral cover, diversity, and abundances are all similar to those in surrounding communities with similar relief. Dr. Margaret Miller, who surveyed the site in 1999, has a largely similar impression of the current status of the site (unpubl. data, pers. comm.).

It is only with detailed examination of the species assemblages that one can distinguish the grounding site from other areas at similar depth. A good observer might notice the lack of large corals in the grounding area, but the areal extent of the flattened reef is small enough that larger colonies beyond the area might be visible, leaving few signs of the location's uniqueness.

Nevertheless, the grounding site has certainly not recovered its original character, which was that of a transitional area between a shallow, *Acropora palmata* dominated zone and a slightly deeper hard ground assemblage. It contained moderate to high relief (see Precht et al., 2001) and diversity. While species diversity and population levels are currently close to those of transition zone and hard ground assemblages in the vicinity, cover of hard corals and the populations of certain key species necessary for continued structural development are lacking.

As has been noted previously, natural recovery of topographic relief at the grounding site of the WELLWOOD will take decades (Gittings, 1988; Gittings et al., 1990, 1993; Precht et al., 2001). Data from this survey show that even two decades of biological production has not been enough to create substantive relief at the site. This limits the potential for recovery of other assemblages that depend on vertical relief and habitat complexity, including fish and benthic infauna (Szmant, 1997; Ebersole, 2001; Precht et al., 2001).

On the other hand, physical processes have created substantial relief at the site. Storms during the last several years have mobilized framework originally loosened by the grounding, excavating depressions over a meter deep and several meters in diameter. The result is a habitat with greater complexity than existed at any time since the grounding, and with newly available interstices and vertical relief. While very little coral growth currently exists on the exposed reef rock, it is likely that one to two decades of recruitment would result in populations comparable to surrounding undamaged areas.

Unfortunately, there may be additional reef material that was destabilized by the grounding. Future storms would be likely to interrupt community development by further excavating the damaged area and causing collateral damage. Stabilization of these areas may help deter such events, but care should be taken to limit to the extent possible the loss of recently created habitats during upcoming restoration efforts.

Where extensive concrete addition is required, attempts should be made to maintain as high a structural complexity as possible, particularly microhabitat complexity. During this survey, counts in a $1m^2$ quadrat on top of a smooth concrete slab poured soon after the grounding (H. Hudson, pers. comm.) yielded the lowest abundances of any made during the visit. Coral abundances were only 54% of the mean elsewhere in the area (56% for gorgonians and 36% for scleractinians). Cover was only 15% of the area mean. A large number of fish bites (scrape marks) were visible on the slab, suggesting that fish may limit coral recruitment on such surfaces. This may be because the flat surfaces are more easily accessible than the complex surfaces of natural reef material. High microhabitat structural complexity in framework restored by humans may be necessary to limit grazing effects on recruitment.

Transplantation work will follow construction efforts directed at stabilizing substrate and increasing three-dimensional structure. It should be recognized that most, if not all, the species present in undamaged zones adjacent to the grounding are also present at the grounding site itself. Nearly all have recruited since 1984, but some adults survived the grounding and remain in place. Thus, the objective of transplantation need not be to ensure full diversity at the grounding site. More appropriate would be to transplant large adult colonies of species that are important habitat creators, such as the *Montastraea* *annularis* and *Diploria* spp. complexes. This may help restore a more natural appearance to the area as well as serve a function in generating attractive habitat for fish and benthic organisms (see Spieler et al., 2001). With regards to gorgonian transplantation, it is recommended that species selected be those that are rare in the damaged area compared to surrounding hard ground and transition areas. These include *Briareum asbestinum*, *Plexaura* spp. and *Pterogorgia* spp. While these will not significantly enhance topographic aspects of the environment, they will increase complexity and diversity within the restored area, improving its appearance. Large *Gorgonia ventalina* sea fans would have a similar effect, but they currently appear to be fairly rare in the vicinity of the grounding site. In fact, more *G. ventalina* were found in the grounding site than in surrounding habitats during the survey, though all were very small specimens.

The grounding site and the restoration efforts also provides an opportunity to employ new methods of restoration that may enhance the rate or quality of community recovery. The addition of sea urchins such as *Diadema antillarum* could reduce algae competition and enhance coral growth. Techniques could also be used to enhance the settlement of corals, including the use of chemical attractants (Morse et al., 1994) and seeding of the reef or reef modules with larvae taken from adult corals (Szmant, 1997) during spawning episodes.

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