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**Evaluating the Effect of Offshore Sandbars on Seagrass Recovery and Restoration in Tampa Bay
Through Ecological Forecasting and Hindcasting of Exposure to Waves**

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Evaluating the Effect of Offshore Sandbars on Seagrass Recovery and Restoration in Tampa Bay Through Ecological Forecasting and Hindcasting of Exposure to Waves

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Photograph by R. Johansson



ABSTRACT

In recent years, large expanses of Tampa Bay have experienced natural seagrass recolonization correlated with the achievement of improved water quality. However, it now appears that seagrass has slowed its rate of recolonization and recovery does not approach that of the historical, pre-impact distributions of the early part of the 20th Century. One theory is that the substantial reduction of long shore sandbars during the mid to late 20th Century has created a situation where waves are now reaching portions of the shoreline that historically had enjoyed a more quiescent setting suitable to the establishment and maintenance of extensive seagrass habitats. Therefore, we employed a wave exposure model (Relative Exposure Index – REI) designed to evaluate the influence of these bars on seagrass cover. Evaluation of historic wind data indicated that exceedance events (top 5% of wind events) and local geomorphology make sites on the eastern side of the Bay particularly vulnerable to storm effects, while those on the western margin of the Bay are relatively sheltered. Model results revealed that the bars in the Tampa Bay system, placed as they are on large shoals along the margins of the bay, might not provide substantial wave reduction effects until they are emergent or nearly emergent from the water. Model output also demonstrated the strong effects of the bars on REI reduction, but location of the bar on the shoal (seaward or landward) logically determined the extent of the effect of the bar on the immediate shoal area, and thus, potential seagrass habitat. Logistic regression revealed that REI and water depth were both strongly influential in the prediction of existing seagrass cover and that the greater the water depth and the greater the REI, the lower the probability of seagrass cover. However, in areas where the REI was ~4000 or less, the role of wave exposure was predicted to be minimal and may not explain the absence of seagrass and its lack of recovery. On average, sample points located landward of bars were forecast to have a much higher probability of seagrass cover than those seaward of the bar, leading us to conclude that the existence of an emergent bar will produce a forecast of substantially higher probabilities of seagrass cover in the lee of the bar. The effects of bridges on seagrass abundance, coupled with field observations suggests that bridges should be modeled as partially permeable structures and that their presence in Old Tampa Bay indicates they have had only local influence on increasing seagrass abundance. Therefore, consistent with past hypotheses, loss of bars, particularly on the relatively exposed eastern margin of the Bay are hindcast to have resulted in the loss of large areas of seagrass, although these losses cannot be unequivocally assigned solely to changes in wave climate. Conversely, placement of emergent bars in these areas, if located at the seaward margin of the shoals, should provide large areas of protected habitat conducive to supporting higher percentages of seafloor cover by seagrass (increased probability of cover). Restoration of these areas without structures that substantially reduce REI below levels of at least 4000 should prove exceedingly difficult using current technologies. It is our recommendation that no restoration efforts aside from experimental investigations be conducted in areas of > 4000 REI without including some REI-reducing techniques. Additional investigation into the effects of other potentially limiting factors, such as propagule limitation and biological disturbance is also recommended.

BACKGROUND

In August 2000, the Tampa Bay Estuary Program (TBEP) convened a meeting to address the perplexing issue of why seagrass recovery has not advanced in accordance with the meeting of water quality goals for the Bay. Hillsborough Bay in particular has enjoyed a high level of compliance with stated water quality goals, and natural recolonization of seagrasses has occurred in apparent response to these improvements (Johansson and Lewis 1992, Lewis et al. 1998, Lewis 2002). However, seagrass now shows signs of having slowed its rate of recolonization. Moreover, the geographic distribution of this recovery does not approach that of the historical, pre-impact distributions of the early part of the 20th Century. In fact, in some areas, seagrass coverage has fluctuated dramatically in the last decade and evinced moderate declines, rather than having strictly increased (e.g., Coffeepot Bayou, pers. Obs).

Despite having achieved important water quality compliance (Lewis et al. 1998), it has been hypothesized that other factors related to modification of the Tampa Bay ecosystem may now be exerting

significant control over the recovery rate of seagrasses. One theory is that the dramatic reduction of long shore sandbars during the early to mid 20th Century has created a situation where waves are now reaching portions of the shoreline that historically had enjoyed a more quiescent setting suitable to the establishment and maintenance of extensive seagrass habitats (Lewis 2002).

The relationship between the decline of seagrass cover and the loss of long shore sandbars may be summarized as follows. Long shore sandbars, formed by a not-fully understood historical geomorphologic process, once existed throughout much of Hillsborough and Tampa Bays. These bars were heavily colonized by seagrasses, which may have played a significant role in the temporal stability of the sandbars. With the deterioration of water quality in the Bay during the early 20th Century, significant acreage of seagrass was lost - running to the thousands of acres (Lewis et al. 1985). With the loss of the seagrass, these bars may have been destabilized, allowing them to be dispersed by wave energy (Lewis et al. 1985). The reduced long shore bar structures may allow higher levels of wave energy to reach the shore by passing through areas historically having high seagrass cover. It has been shown that hydrodynamic setting (i.e., higher waves and stronger currents) is strongly correlated with increasing seagrass bed patchiness (Fonseca and Bell 1998) and susceptibility to storm events (Fonseca et al. 2000, Kelly et al. 2001, Fonseca et al. 2002). Moreover, the maintenance of Tampa Bay's deep shipping channel by dredging may have created a hydraulic situation that has contributed to the loss of long shore sandbars and their ability to recover, by creating a depositional environment that captures sand. These phenomena may be augmented by the periodic long-period waves resulting from the displacement of water within the deep channel by the movement of large ships. Long-period waves may have the potential to elevate horizontal shearing forces at the sediment-water interface and cause sediment movement. Such a shearing effect, should it occur with sufficient intensity and regularity could conceivably work against the vertical accumulation of sand in areas that had sand bars in the past. To our knowledge, this effect has not yet been sufficiently studied to provide a quantitative assessment of its role, if any, in limitation of seagrass distribution.

Other factors besides historical fluctuations in water quality and wave exposure may be at play limiting the recolonization of seagrasses. For example, a lack of seagrass recruitment and disturbance by marine fauna (bioturbation) may also be limiting the recolonization process, but these factors have received limited attention. Taking all these potential factors together leads us to the hypothesis that the recovery of seagrass beds is in an arrested successional state (*sensu* Fonseca et al. 1983) that may be freed only by additional mitigative actions beyond that of water quality improvement, such as reduction of wave energy, reduction of bioturbation, or development of techniques for restoring seagrass in high energy areas which could alleviate propagule limitation; but the technology for this latter approach remains unproven in this country (Fonseca et al. 1998a,b).

OBJECTIVES

We applied our ARCInfo 8.0.1 - based wave exposure model in an eight-stage operation. This operation was designed after a meeting with the TBEP (Jan 17, 2002), which set the target areas for the study and the geographic extent of the modeling exercise. The steps of the operation were as follows:

- 1) wind data, composed of hourly observations of wind speed and direction were provided by TBEP,
- 2) bathymetry data and shoreline data layers were provided by the Florida Marine Research Institute (F. Sargent),
- 3) virtual sand bars were hand-drawn into GIS data layer of Tampa Bay based on the distribution of existing and historical (circa 1950) bars, using a combination of local knowledge and historical aerial photography provided by TBEP; this was accomplished in a meeting at the TBEP in February, 2002,
- 4) the REI model was then run at 1 ha resolution with only present-day bars in the model for all target areas,
- 5) the REI values were then related to the existing categories of seagrass distribution in Tampa Bay (0, < 30% cover, > 30% cover; SWFWMD data layer downloaded from (<http://www.swfwmd.state.fl.us/data/gis/libraries/swim.htm>) and water depth using polytamous multiple

logistic regression,

6) the spatial map of REI was redrawn, substituting predicted seagrass cover, computed for present-day distribution, for REI,

7) steps 4-6 were repeated, but using bar structures of the 1950's as the determinant of REI, and the present day REI-seagrass logistic regression to hindcast 1950's seagrass cover,

8) the differences between hindcast (1950) and present REI as well as hindcast and forecast seagrass cover categories within the target sites were both graphically and statistically compared.

Two ancillary computations were conducted as the result of the January 17th 2002 meeting with TBEP. First was the evaluation of bridges as impermeable structures (to waves) on the REI and thus, seagrass cover in the Old Tampa Bay area where three bridges with large filled causeways have been installed over the last ~50 years. Second was the insertion of bars in Feather Sound to determine whether the introduction of such structures might facilitate the establishment of seagrass beds.

THE RELATIVE WAVE EXPOSURE INDEX MODEL (REI)

The model used in this study was a modification of that which was used by Fonseca and Bell (1998) and previously described by Robbins et al. (2002). In that paper, each of the eight major compass headings, wind speed, frequency of wind from that direction and fetch are combined to produce a relative exposure index (hence the model name - REI), an application modeled after that of Keddy (1982).

$$REI = \sum_{i=1}^8 [(V_i \times P_i \times (idwF_i)]$$

Where:

i = i^{th} compass heading (1-8 [N, NE, E, etc.], in 45° increments), and, based on the three previous year's data,

V = top five percent of hourly wind observations (m s^{-1}) over the preceding three years,

P = percent frequency which wind occurred from the i^{th} direction,

F = effective fetch (m),

idw = application of an Inverse Distance Weighting function on the variable water depth, where weighting is controlled by F .

Fetch was defined as the distance from the site to land along a given compass heading. Fetches longer than 10km were clipped at 10km as this was considered to be a sufficient distance to generate a maximum wave height effect in the Bay. Effective fetch was computed by measuring fetch along 4 lines radiating out from either side of the i^{th} compass heading at increments of 11.25°, including the i^{th} heading ($n=9$). Effective fetch was then calculated by summing the product of the fetch x cosine of the angle of departure from the i^{th} heading over each of the nine lines and dividing by the sum of the cosine of all the angles. This weighting of multiple fetch measures for each compass heading helps account for irregularities in shoreline geometry that could misrepresent the potential of wind wave development from a given compass heading (Shore Protection Manual 1977).

For this project, the number of points for which REI was computed at each site was set to be ~80, equally distributed across the target area. This number was chosen because of machine limitations (a model run of each site with ~80 points required a~24 h to complete). The REI data were plotted on 1 ha increments within the study areas.

POST-MODELING COMPUTATIONS AND GRAPHICS

The REI data were output from ARCInfo were overlain on the seagrass coverage data layer. The identity of seagrass coverage at each point in each target area was interrogated and appended to the REI data points. These data were then output in a text format, with the latitude and longitude of each point plus the water depth and seagrass status. In the case of the present day runs, REI and water depth were

used as independent variables in a polytomous multiple logistic regression (SAS 1995) where coverage category was the dependent variable. The coverage input for each category was chosen to be the midpoint of each class (0 for class 0, 16% for seagrass category < 30% cover, 42% for seagrass category > 30% cover and 100% for continuous cover. The regressions were computed following the method used by Fonseca and Bell (1998; adapted from Narumalani et al. 1997), where:

$$P(\text{grass category}) = p(d=1/x) = 1/(1 + \exp[(B_0 + B_1x_1 + B_2x_2)])$$

Where:

d is the presence (1) or absence (0) of seagrass cover at each 1ha area in the study site, x_1 , and x_2 REI and water depth, respectively, and B_0 , B_1 , and B_2 are coefficients derived from logit regression.

Logit regression was performed using SAS (1995) procedure LOGISTIC. Rank correlations were computed under SAS (1995) to assess the predictive ability of the model. An analysis of maximum likelihood estimates ($P > \text{Chi-Square}$) was used to determine the significance of the two independent variables in predicting the contribution of REI and water depth to P under the stepwise logistic multiple regression. The SAS procedure computed Somer's D, a rank correlation statistic which like r^2 , represents the association of the predicted probabilities versus the observed responses (Appendix I[a]).

The combined REI and predicted seagrass cover class for each point in each site was output to a text file. The text file was then uploaded into Surfer 7 Version 7. A block kriging analysis was performed for the area. This process created a rectangular form based on the upper left and lower right most points in the Study Area polygon within which the kriged data was smoothed and contoured. Surfer plots were all maintained in contouring with the levels of seagrass probability (0.0-1.0) set at increments of 0.1.

MODEL PERFORMANCE

In order to verify the performance of the model prior to its application to the test sites, we conducted a mock simulation of the effect of shoal depth, shoal width and distance between a shoal and a target point. This was done by creating a polygon in Feather Sound and computing the REI for a single fixed point in response to a 3 x 3 x 3 matrix of bar width, depth and distance ($n=27$). The REI resulting for each of the 27 combinations was input into SAS and a spline interpolation run on the response of REI at the point to bar depth, width and distance (Figure 1).

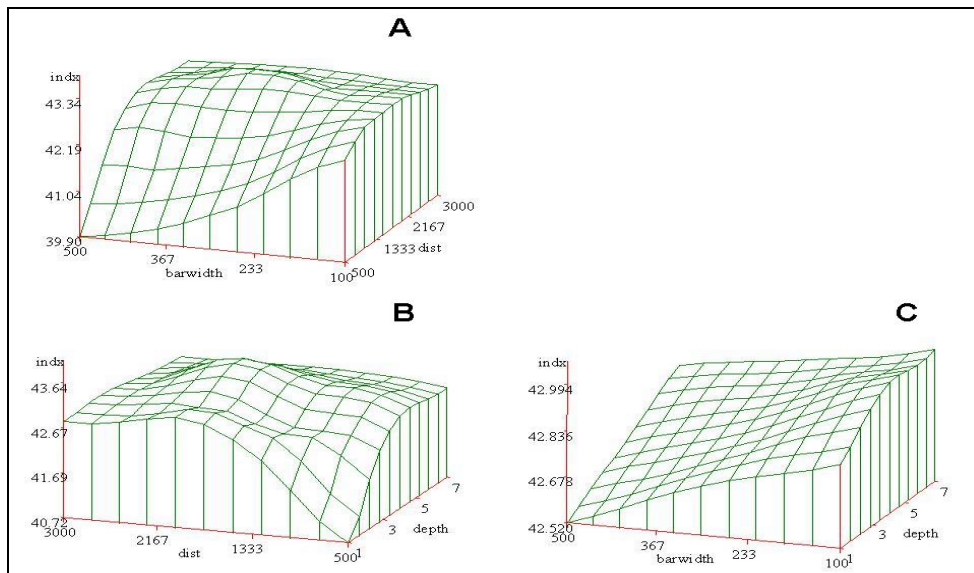


Figure 1. (A) Response of REI to bar width (meters, m) and distance from point to bar (m), (B) response to distance and depth of bar (m), and (C) response to bar width and depth.

SITES

Five of seven sites (Figure 2) represent Target sites and two are Reference sites (Table 1). Target sites are sites where there has been substantial change in bar structure since the 1950's and seagrass recolonization is not proceeding. Reference sites are those where little change in bar structure and seagrass cover has occurred since the 1950's (Table 1). Again, these sites were chosen by TBEP using local knowledge, comparisons of historic and recent aerial photography and published data (Lewis et al. 1985, 1998, Lewis 2002). The eighth or remaining site, Feather Sound, was examined for the potential effect of installing bars that have not been historically present. Finally, sites in Old Tampa Bay (Feather Sound and Fish Creek) were also examined for the effect of local bridges, using bridges as both impermeable structures (i.e., like a shoreline) for wave development in their present day configuration - which includes the large earthen causeways installed during their construction (Table 1). These sites were also reexamined with both the bridges and the causeways removed, essentially providing a hindcast assessment of how the seagrass setting in these areas might have appeared in the early 20th Century. Discussions during the Dec 2001 meeting with the Seagrass Subcommittee of the TBEP called for an evaluation of the bridges as semi-permeable structures to wind waves, and thus, the REI. Literature searches using Aquatic Abstracts and direct requests to the USACOE at the Waterways Experiment Station, in Vicksburg Mississippi revealed no empirical estimates of wave attenuation and this assessment was therefore not performed.

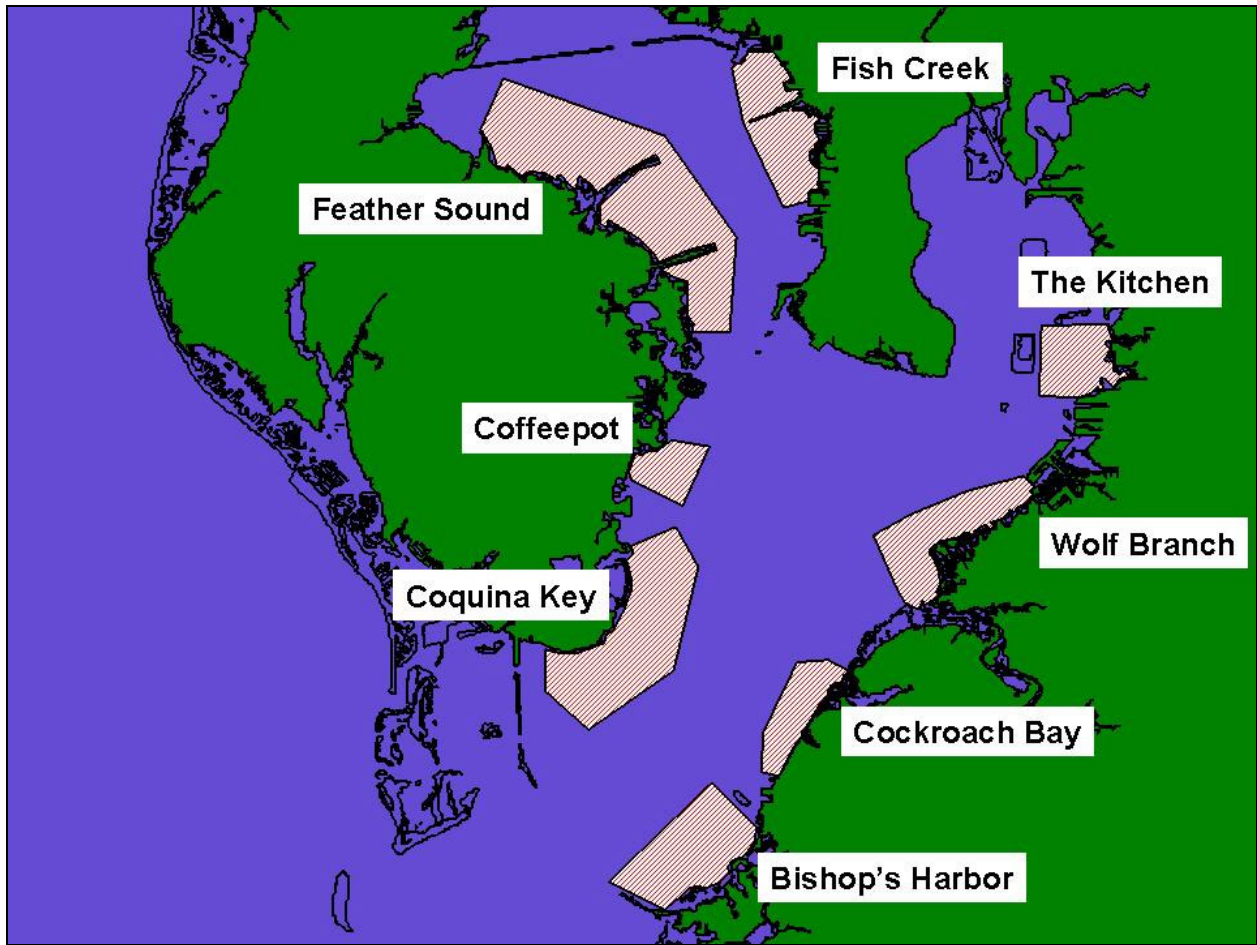


Figure 2. Study site locations in Tampa Bay.

All sites, with the exception of Feather Sound, had bars in the 1950's according to the inspection of aerial photography by TBEP in February, 2002. However, only three sites were found to have significant bar formations by the late 1990's, according to aerial photography; these were Coquina Key, Coffeepot Bayou and Fish Creek. Some remnants of bars existed at Wolf Branch and Cockroach Bay and those were retained for more detailed, present day analyses.

Table 1. Status of sites as a target (sites with bar loss) vs. reference sites (sites with little or no bar loss). Large **X** = indicates an unambiguous fit into the Analysis categories. Small **x** = indicates some bar remnants remained but that the overwhelming majority of the bar structure had disappeared.

* = there is some relic bar structure here, but the TBEP consensus was to model it with no bar.

Site	Status	Analyses				
		with bars 1950	with bars 1999	no bars 1999	w/ bridges	w/o bridges
Bishop Harbor	Target	X		X		
Cockroach Bay	Target	X	x	X		
Coffee Pot	Reference	X	X			
Coquina Key	Reference	X	X			
Feather Sound	Target			X	X	X
Fish Creek	Target	X	X		X	X
Kitchen	Target	X	* <u> </u>	X		
Wolf Branch	Target	X	x			

MODEL INPUT DATA

Wind graphics: The frequency and top five percent of wind speed events (based on mean hourly observations of wind speed over three years; February 21, 1996 - 1999) were computed by each of the eight major compass headings (Figure 3a,b). These data were used as constants across sites in the REI computation.

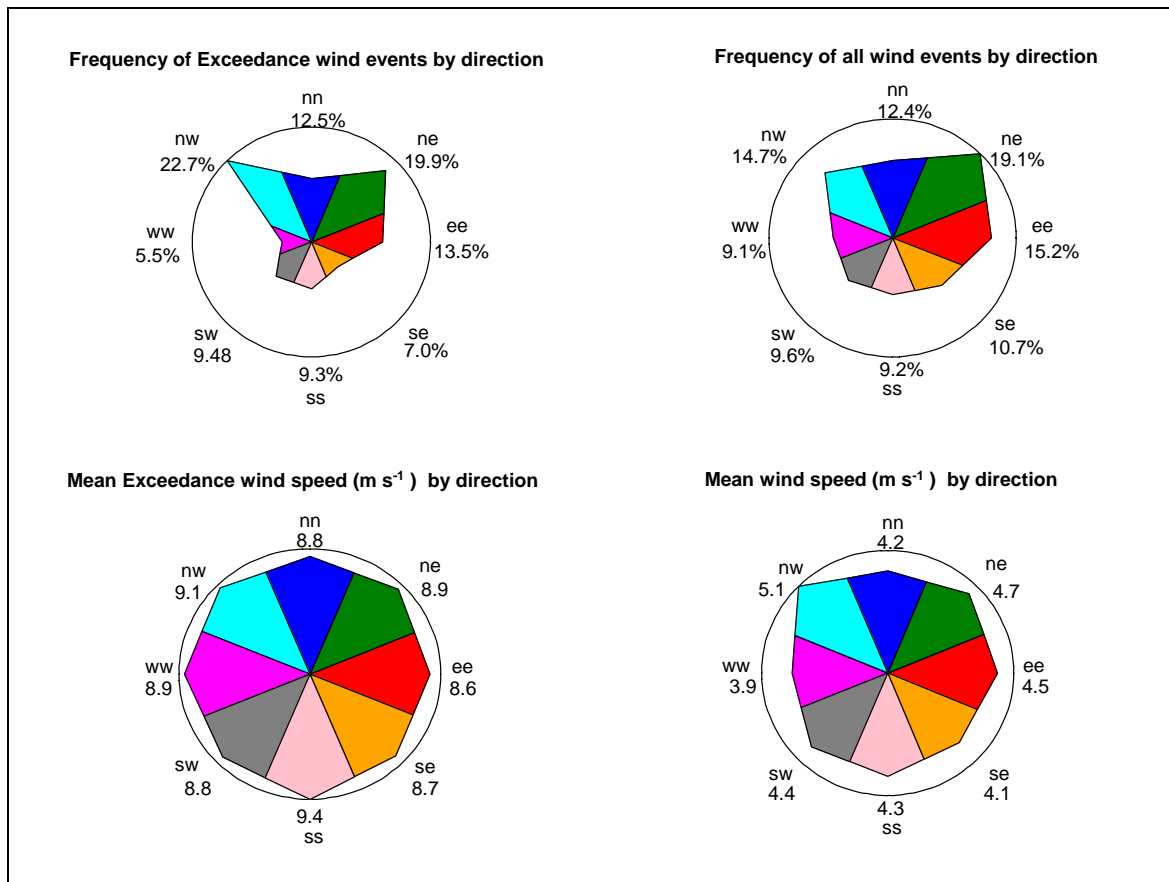


Figure 3. Frequency of wind events (across top) for exceedance and average conditions; speed of wind events for both exceedance and average conditions are shown across the bottom. All figures present data for each of the eight major compass headings.

Bathymetry: The bathymetric data layer was interrogated by the model via the IDW function for the influence of shoals on the REI. For later use in the logistic regression, which developed the mathematical relationship between REI, water depth and seagrass cover, all depths greater than 5m were deleted, as there was no seagrass associated with depths greater than that value. Inclusion of the vast areas of the Bay where depths were > 5m and were not seagrass habitat would have significantly (and erroneously) diminished the influence of REI on the probability of seagrass cover.

Seagrass: The four classes of seagrass coverage (0, < 30%, >30% & <100%, and 100%) were taken from the SWFWMD web site: <http://www.swfwmd.state.fl.us/data/gis/libraries/swim.html> The source of the classification was from combined sets of 1995 and 1997 photography with a 0.5 acre minimum mapping unit, produced as a complete product in 1998 by the Florida Marine Research Institute.

WAVE EXPOSURE MODEL OUTPUT

Bar Configuration Effects: During the Feb 27, 2002 meeting with TBEP, it was determined that the depth of the shoals should be set at -30 cm MSL, considering this to be a rough approximation of what the average depth might be over the bars. All bars were initially run with this water depth. However, when we compared sites that had bars in the 1950's with the conditions of the same site without bars, we began to find that there was virtually no difference in the resultant contouring (Table 2). In retrospect, this is not

surprising. At the agreed-upon resolution, the model would have detected only one or two points within the bar upon which the weighting function would diminish fetch effects. Given that the bars represented only a small horizontal distance across an otherwise broad shoal, shallow subtidal bars superimposed on a broad shallow subtidal bar would be expected to have little effect on a shoreward site. Because of the cost of running these models, we abandoned the submersed bar runs after examining five sites (Appendix 1[b]) and adopted use of an emergent bar system after Lewis et al. (1985). Our emergent bars were imposed in the system based on discussions with TBEP.

With the results of the initial model run with bars at -30 cm showing little effect on REI, we elected to expand the project and re-run the entire set of sites with bars as emergent features (*sensu* Lewis et al. 1985), making the bars essentially act as shorelines. There was a substantial difference (reduction) in REI at most sites when bars were modeled as emergent features. However, even with this modification, some sites, notably Feather Sound and Fish Creek and the Kitchen had comparatively small changes in wave exposure. Upon visually examining the sites, one obvious difference emerges, and that is the proximity of the bars to the shore (landward) or the open sound (seaward) (Table 2). The aforementioned sites that exhibited little change in REI had bar formations located comparatively close to the shoreline. In these situations, the bars influence fairly small areas shoreward of their location and thus, when averaged over the entire site, have a small effect on the difference between having and not having bars as is evidenced in Table 2. Shoreward of the bars, the effect is substantial, but again, covers a small part of the study site.

Another factor in the magnitude of influence of the bars is found when examining the wind data (Figure 3). Sites located on the Eastern side of the Bay are exposed to the most damaging Exceedance wind conditions based on frequency of occurrence and thus, the highest REI values. Therefore, sites such as Coffeepot Bayou (west side, Figure 2) are comparatively sheltered from northwesterly winds, and from northeasterly winds both by local bar structures and at a larger scale, by the MacDill peninsula. These sites tend to exhibit extensive seagrass cover irrespective of where the bar is located or whether it is emergent or subtidal, as it is protected from most Exceedance wind events (Table 2).

Table 2. Differences in REI when bars were used as emergent shoals vs. ~ -30cm when comparing 1950's with present day conditions. * = models not run (after the first five sites revealed large differences, we elected to discontinue these model runs for reasons of efficiency).			
Site	Bars not emergent	Bars emergent	Bar position on shoal (seaward vs. landward edge) – based on TBEP determination
Cockroach Bay	-8	-1504	S
Coffeepot Bayou	-3	2	S
Fish creek	11	-40	L
The Kitchen	4	-236	L
Wolf Branch	58	-1142	S
Bishop's Harbor	*	-605	S
Coquina Key	*	-522	S
Feather Sound	*	-79	L

REI by Site using Emergent Bars: After re-running the eight sites with emergent bars, we produced a composite graphic showing the conditions at each site (Figures 4 and 5). In both Figures 4 and 5, the effect of the emergent bars for both historic and present day bars can be seen as the dark red (high energy) colors are rapidly reduced to lighter (low energy) colors shoreward of the bar system. However, in several sites (south end of Coquina Key study area, Fish Creek, Feather Sound, north end of The Kitchen) the effects of the large shoal on which the bar structures were placed can also be recognized, particularly when the shoal extends far seaward of the bar locations. In all cases, the effect of bars on the wave exposure is visually apparent. From these data the relationship between REI, water depth and seagrass cover can be computed using polytamous multiple logistic regression.

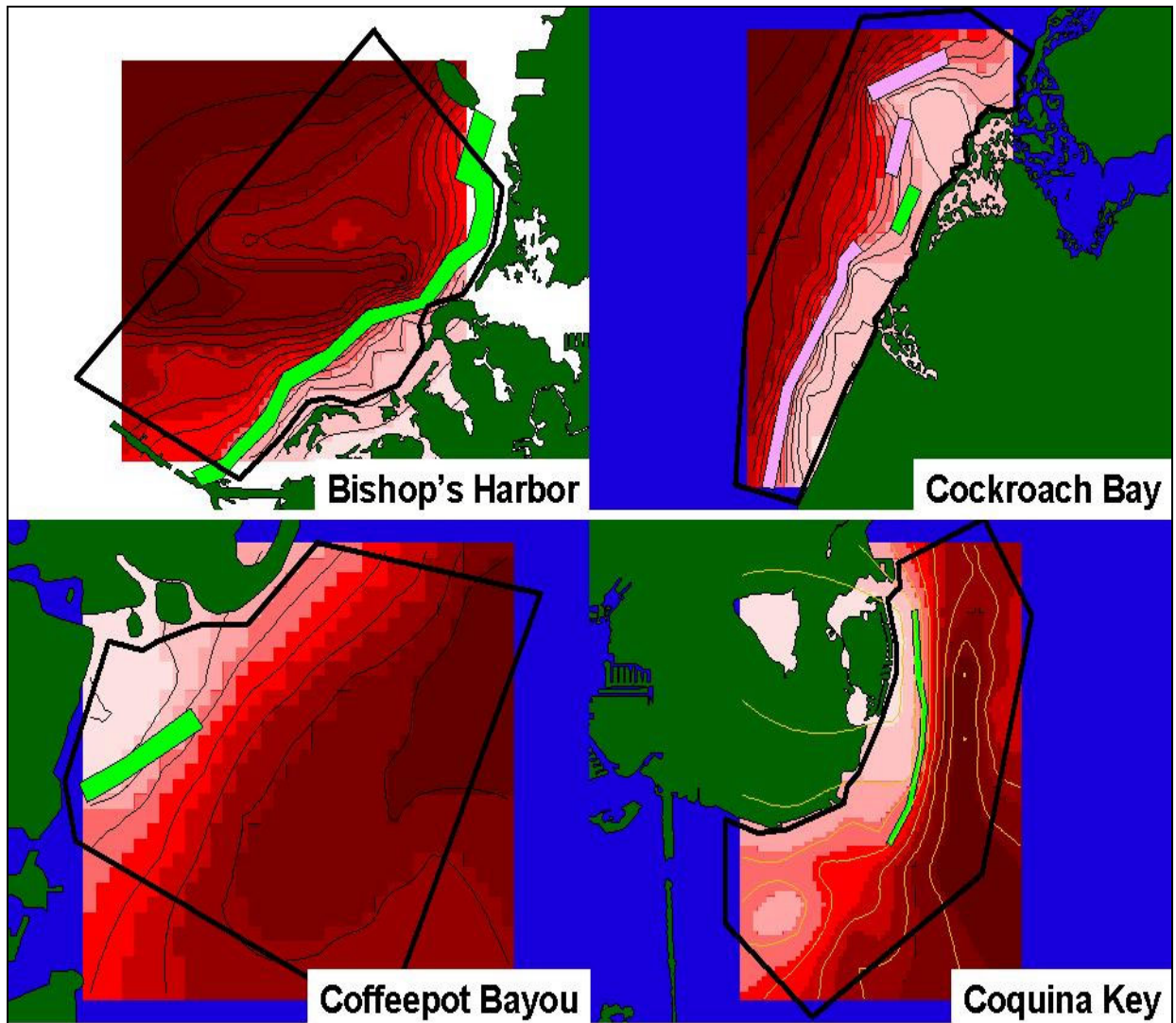


Figure 4. REI values and bar locations for four of the eight sites. Dark red = high energy while lighter colors = relatively low wave energy. Green bars are present day features. Purple bars are 1950's features.

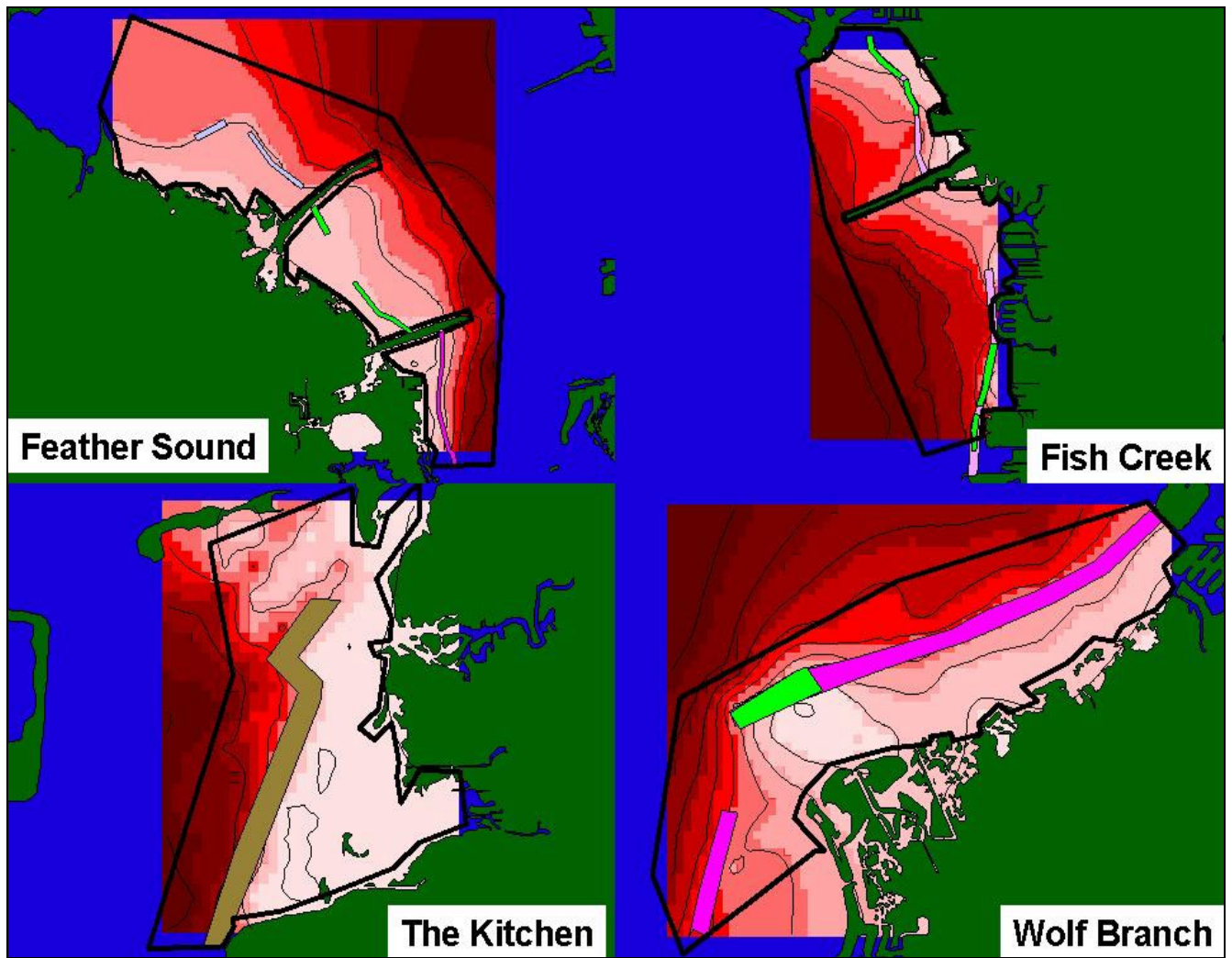


Figure 5. REI values and bar locations for four of the eight sites. Dark red = high energy while lighter colors = relatively low wave energy. Green bars are present day features. Purple bars are 1950's features.

The differences in wave exposure climate for two sites in particular were of interest to the TBEP, Cockroach Bay and Wolf Branch. We have extracted the REI contour lines for both Present Day conditions and those circa 1950 for both sites (Figure 6). The reduction in the bar system from the 1950's to the present reveals the general intrusion of higher energy conditions closer to shore. However, the sustained presence of the large shoals over this time period reveals the strong influence of those features on reduction of wave exposure, because substantial reduction of REI occurs in these areas even in the absence of the bars.

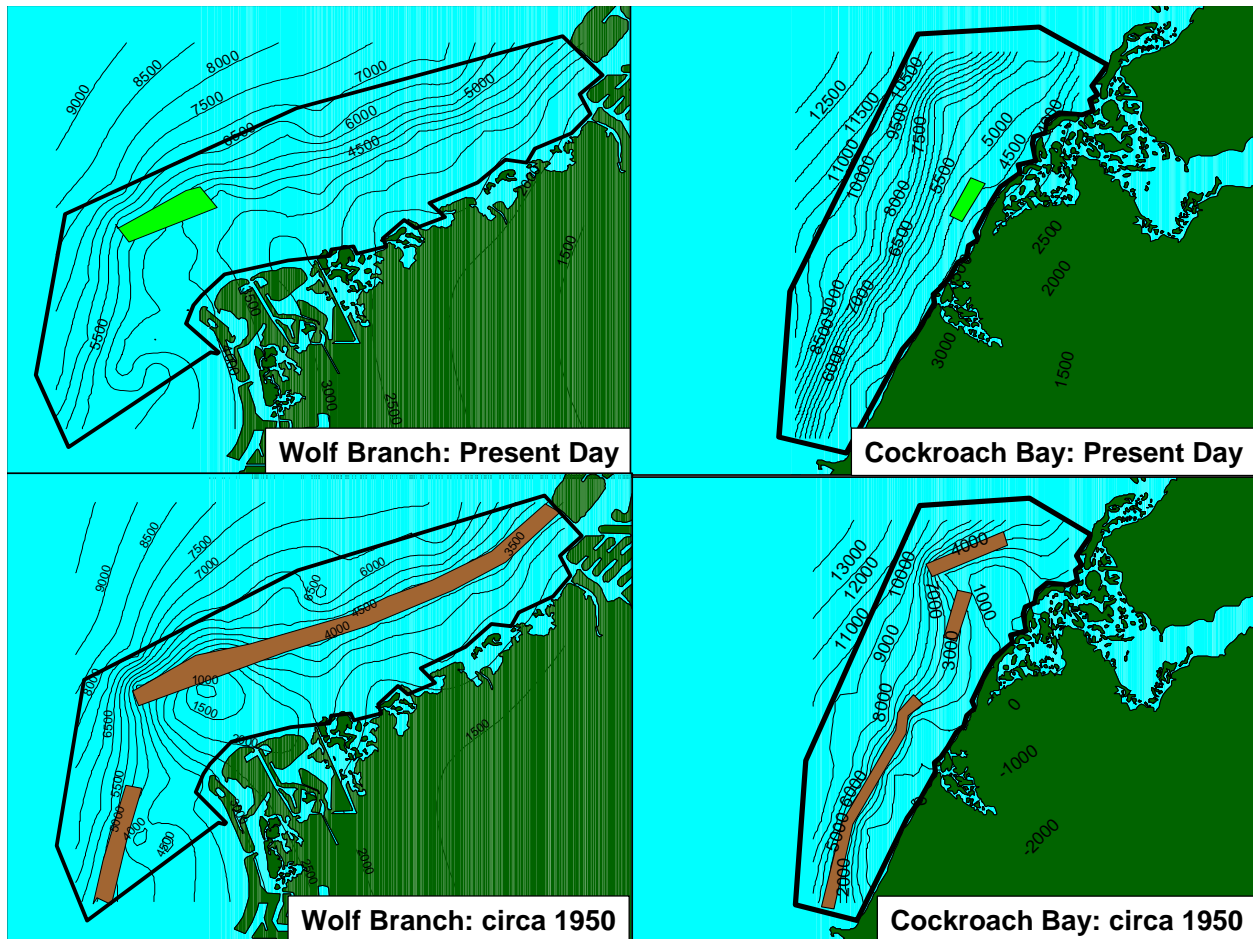


Figure 6. REI contour lines for Wolf Branch and Cockroach Bay, under present day and hindcast conditions for circa 1950. Green bars are present day features. Brown bars are 1950's features.

Present REI vs. seagrass: The relationship between the probability of seagrass cover within the boundaries of the selected sites, water depth and REI (Figure 7) reveals the strong negative influence of REI on probability of seagrass cover (Somer's D value of 0.889; Appendix I[a,b]). The interaction of water depth and REI also indicates that there should be more seagrass at any given depth with lower REI, which is consistent with what we understand about how exposure to waves leads to a more patchy, lower areal cover environment (Fonseca and Bell 1998). REI values above ~ 4000 indicate a rapid drop in the probability of seagrass cover at all water depths. Therefore, sites where REI is lower than ~4000 would probably not have required substantial protection from bars in the past to have developed seagrass cover.

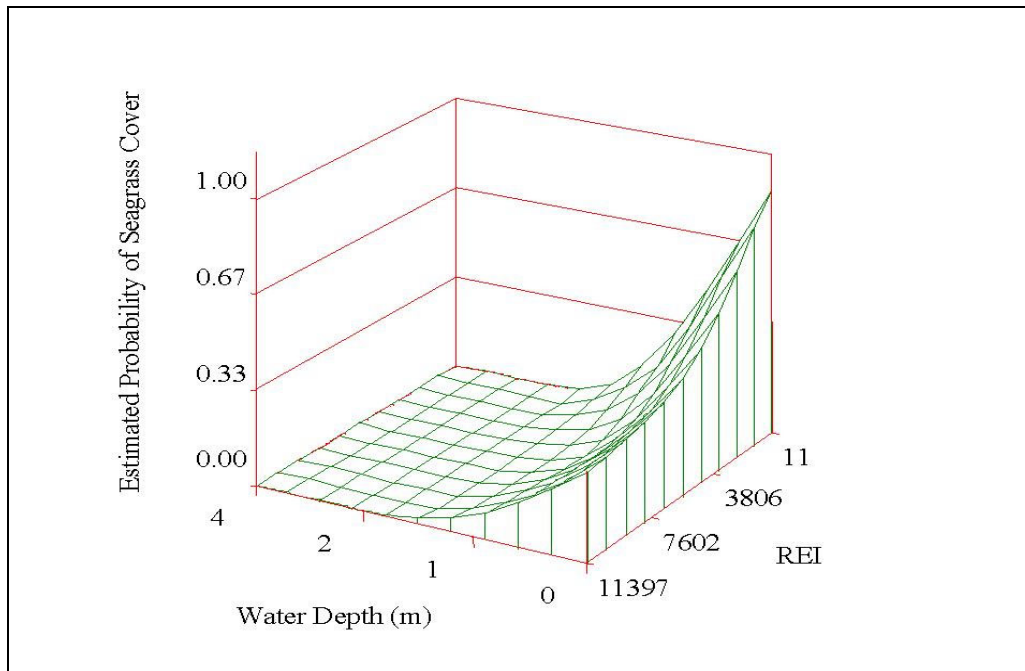


Figure 7. Splined response of probability of seagrass cover (Z axis) to water depth (MSL) and REI.

The predicted values of seagrass cover derived from the logistic regression were block kriged and produced as contour plots in increments of 10% probability of seagrass cover (Figures 8 and 9). As seen with the REI data, the bars provided significant protection from wave exposure. Areas seaward of the bars tend to have a very low probability of seagrass cover, indicating that areas without bar protection may be difficult to naturally recolonize or restore via current transplanting methods. We expect this would be especially true on the more exposed, eastern shore of the Bay.

Each site had a fixed array of points imposed for the computation of REI. Based on where the bars were located, some points fell seaward of the bar while some points fell landward of the bar. Overall, points within each site seaward of the bars had ~ a 9x higher wave exposure. Sites on or landward of the bars were conversely lower in wave energy and, when taken together with depth, had a much greater likelihood of seagrass cover than they would have without bars. Sites on the West side of the bar, generally in the lee of the northwesterly winds that constitute extreme events had a much lower maximum possible difference between samples points seaward of the bar (~10%) and those landward (thus, more sheltered; ~ 1.5%), as compared to those sites on the East side of the Bay (average maximum possible difference seaward ~21.8% vs. ~4.0%) (Table 3). Thus, sites on the windward (East) side of the Bay would have enjoyed a comparatively higher level of protection from bars as opposed to those on the West side. Locations on the lee sides of bars, irrespective of location in the Bay have an ~ 5-10x greater probability of seagrass cover than those exposed to the Bay and seaward of the bars. However, we view these probabilities to be suspiciously low and are likely an artifact of using the extremely coarse categorical data of seagrass abundances (four classes, 0 cover, > 30% gaps, < 30% gaps, and continuous cover), which seems to have favored predictions of lower cover than we observe in some areas. Refining the input data with more continuous and precise coverage estimates associated with the REI computation points should yield a more accurate depiction of abundance, but will not alter the spatial pattern of the response of abundance to REI.

Table 3. Comparisons of probability of seagrass cover among sites on West side of Tampa Bay (top) and East side (Bottom), as well as whether seaward of the imposed bars (Position=exposed) or land ward, sheltered by the imposed bars (lee). Results based on polytomous multiple logistic regressions of seagrass cover classes on water depth and Relative Exposure Index.

SITE and side of Bay (E=east and W=west)	Position: 0=exposed 1=lee	Mean probability with no bars in place	Mean probability with bars in place	Mean difference between with and without bars	Maximum probability with no bars in place	Maximum probability with bars in place	Maximum difference between with and without bars
Coffee W	0	0.182	0.184	0.001	0.477	0.500	0.030
Coffee W	1	0.361	0.459	0.098	0.488	0.607	0.124
Feather W	0	0.045	0.045	0.000	0.593	0.596	0.004
Feather W	1	0.535	0.566	0.031	0.921	0.926	0.073
Bishop E	0	0.006	0.006	0.000	0.080	0.081	0.006
Bishop E	1	0.296	0.556	0.260	0.424	0.609	0.462
Cockroach E	0	0.027	0.035	0.008	0.338	0.468	0.131
Cockroach E	1	0.307	0.521	0.214	0.366	0.608	0.321
Coquina E	0	0.049	0.051	0.002	0.493	0.505	0.012
Coquina E	1	0.331	0.391	0.060	0.518	0.591	0.106
Fishcreek E	0	0.100	0.101	0.000	0.578	0.579	0.001
Fishcreek E	1	0.608	0.624	0.016	0.918	0.924	0.056
Kitchen E	0	0.095	0.098	0.003	0.543	0.607	0.064
Kitchen E	1	0.606	0.653	0.047	0.889	0.926	0.104
Wolf E	0	0.030	0.033	0.003	0.357	0.357	0.026
Wolf E	1	0.315	0.418	0.103	0.833	0.924	0.261

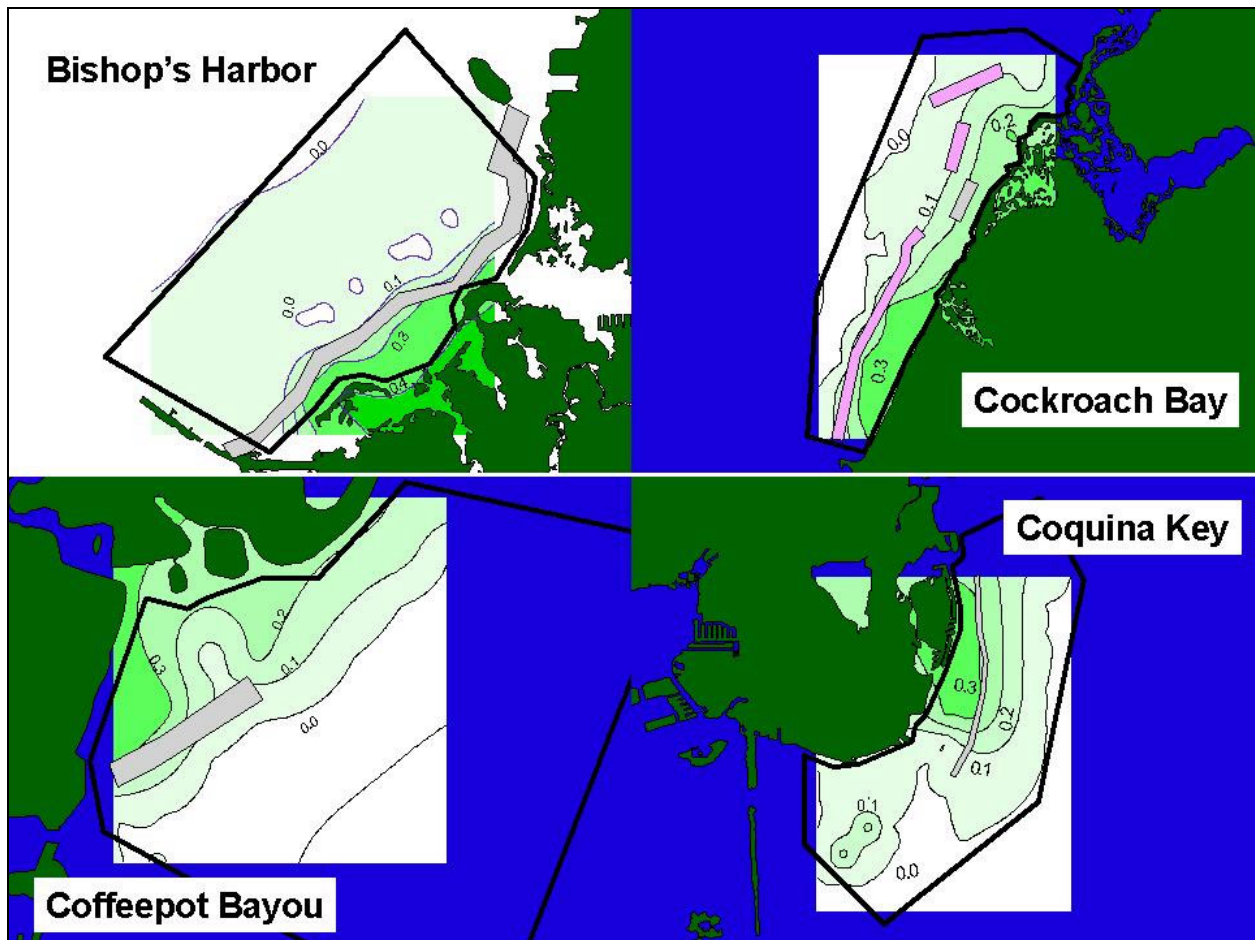


Figure 8. Probability of seagrass cover with all bars in place for four of the eight study sites. Values on contours = probability of seagrass cover.

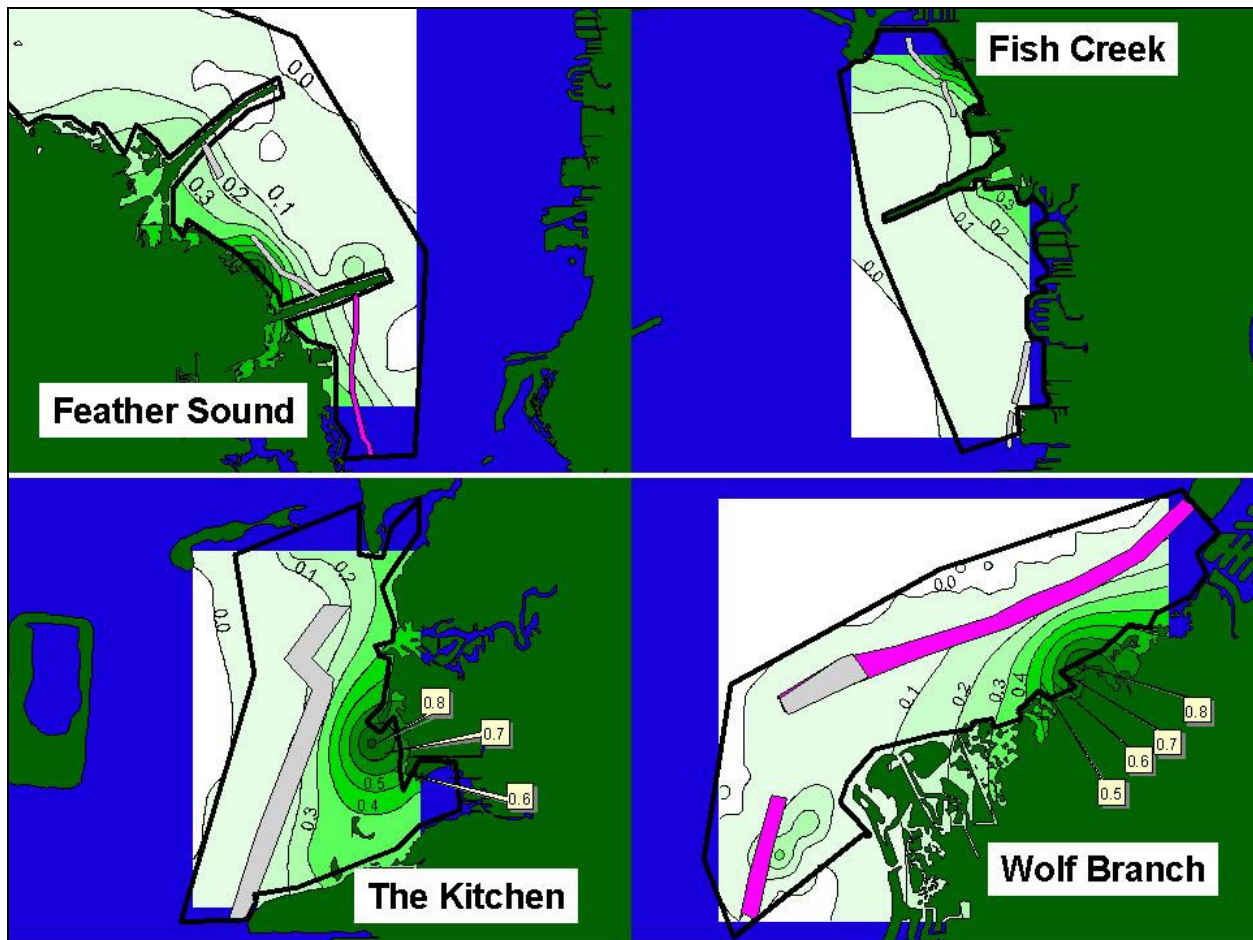


Figure 9. Probability of seagrass cover with all bars in place for four of the eight study sites. Values on contours or callouts = probability of seagrass cover.

EFFECTS OF BRIDGES AND CAUSEWAYS IN OLD TAMPA BAY

We conducted model runs of both the Feather Sound and Fish Creek sites to determine the relative effect of bridges and causeways on REI development as: 1) causeway and bridge modeled as an emergent feature, 2) both causeway and bridge removed from the model, and 3) causeway only, modeled as emergent feature. At the request of TBEP, we also added bars to a location in Feather Sound where they had not been present previously as an exploratory tool for determining the consequences for performing habitat modifications to possibly benefit seagrass recolonization.

Bridges and Causeways: The response of the shoreline manipulations at Feather Sound and Fish Creek are shown in Figures 10 and 11, respectively. In both cases, presence of the causeways had only minor effects on the sites compared to when the causeways and bridges were both modeled as emergent shoreline features (i.e., impermeable to waves). We conducted field observations on May 14th, 2002 when winds were from the direction of typical extreme conditions (winds from the WNW at $\sim 8 \text{ m s}^{-1}$). We observed that wind waves on the north side of the Gandy bridge were $\sim 35 \text{ cm}$ high and had been reduced by $\sim 50\%$ after passing the bridges. Given that the bridge pilings are aligned almost due north-south, and the waves were approaching at an oblique angle that presented the pilings in full profile to the waves, we theorize that this set up of wave train direction and subsequent attenuation represents a near-maximum influence of the bridges on wave abatement. Therefore, it appears that the reality of the effects of the

bridges lay somewhere in the middle of the model output conditions of no bridges and the condition of bridges being wholly impermeable. Nonetheless, even halving the difference in the REI distribution among the conditions of no bridges and impermeable bridges indicates that there is significant potential for a positive influence of these structures on seagrass abundance, although the geographic scope of that influence is comparatively local.

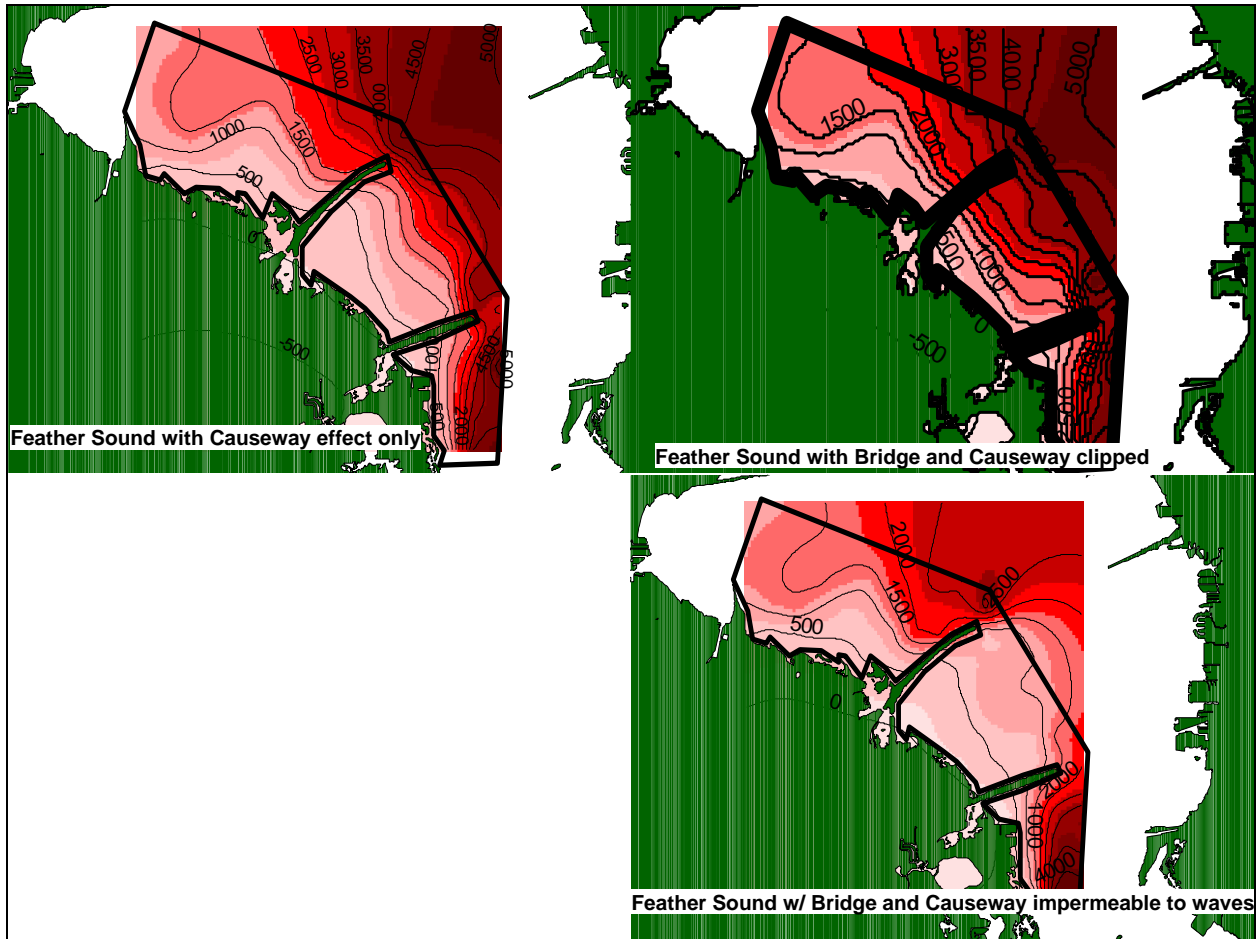


Figure 10. Feather Sound bridge effects. Top left has effect of causeway only with no bridge effect. Top right has no bridge or causeway effect. Bottom right has bridge and causeways impermeable to waves.

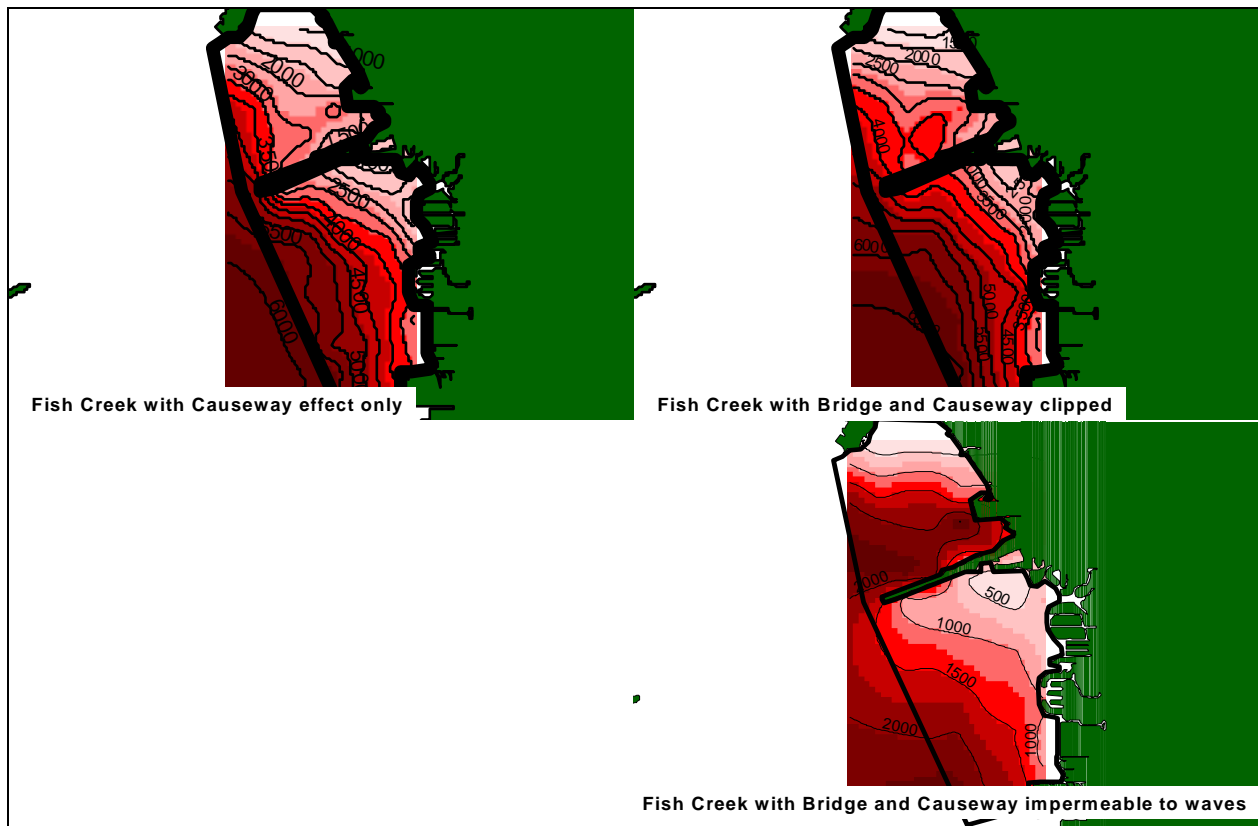


Figure 11. Fish Creek bridge effects. Top left has effect of causeway only with no bridge effect. Top right has no bridge or causeway effect. Bottom right has bridge and causeways impermeable to waves.

SUMMARY AND CONCLUSIONS

The wave exposure model, utilizing a spatially registered technique for detecting shoaling effects was appropriately sensitive to bar depth, width and distance from a point of computation (Figure 1). With these tests, the model was shown to be prepared to integrate complex shoreline and bathymetry into an evaluation of the Relative Exposure Index (REI) (model language in Appendix II), consummate with the chosen resolution.

Evaluation of the historic wind data indicated that exceedance events (top 5% of wind events; after Keddy 1982) tend to occur most frequently from the northwest, making sites on the eastern side of the Bay particularly vulnerable to storm effects, while those on the western margin of Bay shorelines are relatively sheltered. (Figure 3) The model did not account for anthropogenic effects, such as shoreline hardening, vessel waves and local, small-scale alterations in the bathymetry that may not be accurately embedded in the various data sets used here.

Running of the model revealed that the bars in the Tampa Bay system, placed as they are on large shoals along the margins of the bay, may not provide substantial wave reduction effects until they are emergent (Table 2). Given the broad shoal structure and the relatively narrow bars, this is not surprising – but it does not mean that bars must necessarily be emergent at all tide stages. The model does not evaluate what proportion of the time that a bar must be emergent or effectively emergent to create the forecast reduction in REI. We take these findings to mean that the bars must be significantly higher in elevation than the surrounding shoals to be effective (*sensu* Lewis et al. 1985) and that periodic, regular emergence or near-emergence is likely an important attribute of the bar system for it to affect wave

reduction. Graphics of the effects of bars revealed the strong effects of the bars on REI reduction (Figures 4 and 5). Location of the bar on the shoal (seaward or landward) logically determined the extent of the effect of the bar on the immediate shoal area; bars closer to shore had less of an overall influence on the shoal wave climate while those located further seaward, acted to protect larger portions of the shoal landward of their location. These findings are generally consistent with a number of past studies regarding the relationship of bed pattern and dynamic response to disturbance in submersed aquatic vegetation (Fonseca and Bell 1998, Fonseca et al. 1998b, 2000, Keddy 1982, Kelly et al. 2001, Narumalani et al. 1997, Robbins and Bell 1994, 2000).

A polytomous multiple logistic regression revealed that REI and water depth were both strongly influential in the prediction of existing seagrass cover (Figure 7). The greater the water depth and the greater the REI, the lower the probability of seagrass cover. With this finding, we can conclude that the creation of an emergent bar will produce a forecast of substantially higher probabilities of seagrass cover in the lee of the bar (Figures 8 and 9). Refining of the seagrass classification scheme to a more continuous variable, rather than four categories used here (0, < 30%, >30% & <100%, and 100%) should result in substantial improvement of prediction accuracy and increased probability levels of seagrass cover.

We conclude that consistent with Lewis et al's hypothesis (1985) that the loss of bars, particularly on the relatively exposed eastern margin of the Bay, may have contributed to the loss of large areas of seagrass. Placement of bars in these areas, if located at the seaward margin of the shoals and constructed to be emergent, should provide large areas of protected habitat conducive to supporting higher percentages of seafloor cover by seagrass (increased probability of cover). Conversely, poor recovery by seagrass at Feather Sound and Fish Creek, protected as they are by broad shoals and inherently low (<4000) REI over much of the area seaward of the bars, cannot be explained by limitations brought by wave exposure. Restoration of these areas without structures that substantially reduce REI below levels of at least 4000 within the depth range of the existing seagrass areas (typically < 2 m) should prove exceedingly difficult using current technologies. It is our recommendation that no restoration efforts aside from experimental investigations be conducted in areas of > 4000 REI without including some REI-reducing techniques.

We also recommend that investigations into other potentially limiting factors be considered. Based on our previous experience in the Bay (Fonseca et al. 1994), ongoing personal observations, and from others around the country (Suchanek 1983, Lewis et al. 1994, and see review in Fonseca et al. 1998) the influence of biological disturbance in limiting recolonization may be profound. Other factors such as propagule limitation, taken in concert with biological disturbance and high exposure to waves, may arrest recovery for extended periods of time if they remain non-quantified and unmanaged.

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APPENDIX I: REI AND PROBABILITY OF SEAGRASS COVER FOR ALL SAMPLE POINTS AT ALL SITES

A. SAS results of polytomous multiple logistic regression of Relative Exposure Index and water depth, using seagrass categories of 0%, > 30% gap, < 30% gap, and continuous cover. emerge_d_range = depth in m (MSL); emergentbar_indx is the REI based on having emergent bars.

Descriptive Statistics for Continuous Variables

Variable	SG Cover Category	Mean	Deviation	Minimum	Maximum
Depth	1.0	0.984138	0.239829	0.920000	1.850000
	0.6	0.961304	0.551481	0	3.710000
	0	3.179507	0.894132	0.920000	3.710000
REI	1.0	862	997	14.27	3681
	0.6	1164	1348	11.02	4638
	0	4528	2897	11.18	11397

Total		3801.322122	2992.305612	11.024610	11397

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	1.8930	0.4765	15.7802	<.0001
Intercept2	1	4.0983	0.5632	52.9490	<.0001
emerge_d_range	1	-2.6141	0.4207	38.6095	<.0001
emergentbar_indx	1	-0.00034	0.000132	6.7686	0.0093

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
emerge_d_range	0.073	0.032	0.167
emergentbar_indx	1.000	0.999	1.000

Association of Predicted Probabilities and Observed Responses

Percent Concordant	93.8	Somers' D	0.889
Percent Discordant	4.9	Gamma	0.901
Percent Tied	1.3	Tau-a	0.313
Pairs	22634	c	0.944

B. Output of Appendix I(a) solved for sites with and without bars, based on present-day bar and seagrass configuration.

Site	X coord in Albers	Y coord in Albers	Probability of seagrass cover without bars	Probability of seagrass cover with bars	Difference in probability
bishop	535100	399758.9	0.000126	0.000128	1.39E-06
bishop	535100	400258.9	0.000146	0.000148	1.81E-06
bishop	535600	399258.9	0.000315	0.000318	3.42E-06
bishop	535600	399758.9	0.00015	0.000152	2.02E-06
bishop	535600	400258.9	0.000173	0.000176	2.66E-06
bishop	536100	399258.9	0.000332	0.000336	3.71E-06
bishop	536100	399758.9	0.000226	0.000229	3.39E-06
bishop	536100	400258.9	0.000189	0.000193	3.86E-06
bishop	536100	400758.9	3.97E-05	4.05E-05	7.77E-07
bishop	536600	399258.9	0.000357	0.000362	4.74E-06
bishop	536600	399758.9	0.000219	0.000223	4.02E-06
bishop	536600	400258.9	0.000162	0.000166	3.77E-06
bishop	536600	400758.9	4.21E-05	4.3E-05	9.6E-07
bishop	536600	401258.9	4.12E-05	4.21E-05	8.85E-07
bishop	536600	401758.9	0.000122	0.000125	2.72E-06
bishop	537100	398758.9	0.087584	0.18628	0.098697
bishop	537100	399258.9	0.061149	0.061734	0.000585
bishop	537100	399758.9	0.029371	0.029772	0.000401
bishop	537100	400258.9	0.000141	0.000144	3.55E-06
bishop	537100	400758.9	5.66E-05	5.8E-05	1.42E-06
bishop	537100	401258.9	4.82E-05	4.96E-05	1.36E-06
bishop	537100	401758.9	0.000137	0.000141	4.32E-06
bishop	537600	399258.9	0.424001	0.609015	0.185014
bishop	537600	400258.9	0.000222	0.000227	4.41E-06
bishop	537600	400758.9	5.37E-05	5.54E-05	1.67E-06
bishop	537600	401258.9	4.88E-05	5.02E-05	1.5E-06
bishop	537600	401758.9	0.000146	0.000151	5.32E-06
bishop	538100	399758.9	0.389971	0.60881	0.21884
bishop	538100	400258.9	0.033584	0.034046	0.000463
bishop	538100	400758.9	5.81E-05	6E-05	1.84E-06
bishop	538100	401258.9	5.02E-05	5.18E-05	1.58E-06
bishop	538100	401758.9	0.000149	0.000154	4.87E-06
bishop	538100	402258.9	1E-04	0.000103	3.52E-06
bishop	538600	400758.9	0.009262	0.009477	0.000216
bishop	538600	401258.9	5.07E-05	5.26E-05	1.92E-06
bishop	538600	401758.9	0.000177	0.000183	5.97E-06
bishop	538600	402258.9	0.00014	0.000144	4.45E-06
bishop	538600	402758.9	8.33E-05	8.58E-05	2.5E-06
bishop	539100	399758.9	0.39938	0.607592	0.208212

bishop	539100	400258.9	0.335452	0.608218	0.272766
bishop	539100	401258.9	4.97E-05	5.16E-05	1.88E-06
bishop	539100	401758.9	0.00015	0.000157	6.29E-06
bishop	539100	402258.9	0.000131	0.000136	4.7E-06
bishop	539100	402758.9	0.000106	0.00011	3.8E-06
bishop	539100	403258.9	8.16E-05	8.44E-05	2.75E-06
bishop	539100	403758.9	4.28E-05	4.41E-05	1.27E-06
bishop	539600	400258.9	0.32416	0.607838	0.283678
bishop	539600	400758.9	0.146848	0.608456	0.461608
bishop	539600	401258.9	4.23E-05	4.42E-05	1.95E-06
bishop	539600	401758.9	0.000119	0.000137	1.79E-05
bishop	539600	402258.9	0.000119	0.000125	6.09E-06
bishop	539600	402758.9	0.000107	0.000112	5.27E-06
bishop	539600	403258.9	0.012398	0.012952	0.000554
bishop	539600	403758.9	6.46E-05	6.78E-05	3.24E-06
bishop	540100	401758.9	0.000137	0.000163	2.68E-05
bishop	540100	402258.9	0.000168	0.000177	9.18E-06
bishop	540100	403758.9	0.014268	0.014812	0.000544
bishop	540600	401258.9	0.259937	0.608917	0.34898
bishop	540600	402258.9	0.048703	0.05442	0.005717
bishop	540600	403258.9	0.079728	0.081236	0.001508
cockroach	541609.1	405262.6	0.016467	0.017602	0.001135
cockroach	541609.1	405612.6	9.43E-05	0.000104	9.99E-06
cockroach	541609.1	405962.6	6.94E-05	7.87E-05	9.27E-06
cockroach	541959.1	406312.6	0.000125	0.000136	1.09E-05
cockroach	541959.1	406662.6	8.27E-05	9.39E-05	1.12E-05
cockroach	542309.1	405262.6	0.317826	0.554897	0.237071
cockroach	542309.1	405612.6	0.325381	0.608285	0.282904
cockroach	542309.1	405962.6	0.331494	0.608217	0.276723
cockroach	542309.1	406312.6	0.284397	0.605127	0.32073
cockroach	542309.1	407012.6	0.015294	0.016793	0.001499
cockroach	542309.1	407362.6	9.85E-05	0.000111	1.23E-05
cockroach	542309.1	407712.6	7.72E-05	8.76E-05	1.04E-05
cockroach	542309.1	408062.6	6.09E-05	6.61E-05	5.25E-06
cockroach	542309.1	408412.6	6.25E-05	6.88E-05	6.32E-06
cockroach	542309.1	408762.6	5.09E-05	5.33E-05	2.42E-06
cockroach	542659.1	405962.6	0.366147	0.602313	0.236166
cockroach	542659.1	406312.6	0.316749	0.607969	0.29122
cockroach	542659.1	406662.6	0.295763	0.604609	0.308846
cockroach	542659.1	407012.6	0.285991	0.605104	0.319113
cockroach	542659.1	407712.6	0.00011	0.000122	1.2E-05
cockroach	542659.1	408062.6	0.000106	0.000118	1.22E-05
cockroach	542659.1	408412.6	9.78E-05	0.00011	1.21E-05
cockroach	542659.1	408762.6	8.18E-05	8.96E-05	7.82E-06
cockroach	542659.1	409112.6	6.74E-05	7.4E-05	6.66E-06
cockroach	543009.1	406662.6	0.342311	0.601817	0.259506

cockroach	543009.1	407012.6	0.327811	0.607396	0.279585
cockroach	543009.1	408412.6	0.017853	0.019817	0.001964
cockroach	543009.1	408762.6	0.013816	0.015595	0.00178
cockroach	543009.1	409112.6	9.51E-05	0.000106	1.12E-05
cockroach	543009.1	409462.6	8.71E-05	9.75E-05	1.04E-05
cockroach	543359.1	407362.6	0.348585	0.560286	0.211701
cockroach	543359.1	407712.6	0.315801	0.527603	0.211802
cockroach	543359.1	408412.6	0.273275	0.330598	0.057323
cockroach	543359.1	409112.6	0.025909	0.035029	0.00912
cockroach	543359.1	410162.6	0.000101	0.000107	6.53E-06
cockroach	543359.1	410512.6	5.88E-05	6.13E-05	2.52E-06
cockroach	543709.1	408062.6	0.357287	0.488539	0.131252
cockroach	543709.1	408412.6	0.337534	0.468002	0.130468
cockroach	543709.1	410512.6	6.73E-05	7.6E-05	8.75E-06
cockroach	544059.1	408762.6	0.31242	0.534639	0.222219
cockroach	544059.1	410512.6	0.014303	0.021247	0.006943
cockroach	544409.1	409112.6	0.325848	0.534721	0.208873
cockroach	544409.1	409462.6	0.309096	0.56729	0.258194
cockroach	544409.1	410162.6	0.257124	0.400792	0.143668
cockroach	544409.1	410512.6	0.030876	0.040752	0.009876
cockroach	544759.1	409812.6	0.307026	0.447322	0.140296
cockroach	544759.1	410162.6	0.039282	0.066603	0.02732
cockroach	545109.1	410162.6	0.358821	0.44188	0.083059
cockroach	545109.1	410512.6	0.325233	0.372266	0.047033
coffee	535409	419856.7	0.000854	0.000831	-2.3E-05
coffee	535409	420156.7	0.483355	0.607081	0.123727
coffee	535709	419556.7	0.000632	0.000613	-1.8E-05
coffee	535709	419856.7	0.00075	0.000727	-2.3E-05
coffee	535709	420456.7	0.488135	0.60731	0.119175
coffee	536009	420156.7	0.000705	0.000679	-2.6E-05
coffee	536009	420756.7	0.112861	0.163013	0.050152
coffee	536309	420456.7	0.078654	0.075583	-0.00307
coffee	536309	420756.7	0.45544	0.485236	0.029795
coffee	536309	421056.7	0.47652	0.500227	0.023707
coffee	536609	420456.7	0.000451	0.00043	-2.1E-05
coffee	536909	420756.7	0.00049	0.000463	-2.7E-05
coffee	536909	421356.7	0.445409	0.438935	-0.00647
coffee	537209	421056.7	0.000504	0.000474	-3E-05
coffee	537209	421356.7	0.407644	0.398417	-0.00923
coffee	537209	421656.7	0.450352	0.442637	-0.00771
coffee	537509	421356.7	0.000532	0.000499	-3.3E-05
coffee	537509	421656.7	0.417276	0.407867	-0.00941
coquina	531742.7	409047.8	0.001033	0.001069	3.62E-05
coquina	531742.7	409697.8	0.001004	0.001025	2.1E-05
coquina	531742.7	410347.8	0.000979	0.000975	-3.8E-06
coquina	531742.7	410997.8	0.001122	0.00114	1.76E-05

coquina	532392.7	408397.8	0.000783	0.000831	4.84E-05
coquina	532392.7	409047.8	0.489876	0.500717	0.010842
coquina	532392.7	409697.8	0.110311	0.117304	0.006994
coquina	532392.7	410347.8	0.105126	0.10636	0.001234
coquina	532392.7	410997.8	0.12626	0.128199	0.001939
coquina	533042.7	408397.8	0.000676	0.000728	5.17E-05
coquina	533042.7	409047.8	0.102878	0.109338	0.006461
coquina	533042.7	409697.8	0.493254	0.505379	0.012125
coquina	533042.7	410347.8	0.000835	0.000898	6.31E-05
coquina	533042.7	410997.8	0.124981	0.128297	0.003316
coquina	533692.7	407747.8	0.000484	0.00049	6.09E-06
coquina	533692.7	408397.8	0.000483	0.000499	1.61E-05
coquina	533692.7	409047.8	0.000635	0.000694	5.86E-05
coquina	533692.7	409697.8	0.000679	0.000795	0.000117
coquina	533692.7	410997.8	0.105826	0.115282	0.009456
coquina	534342.7	409697.8	0.000577	0.00063	5.24E-05
coquina	534342.7	410347.8	0.000566	0.000679	0.000113
coquina	534342.7	410997.8	0.000714	0.000882	0.000168
coquina	534342.7	411647.8	0.101341	0.121989	0.020648
coquina	534992.7	409047.8	0.000463	0.000468	5.06E-06
coquina	534992.7	409697.8	0.00051	0.000513	2.97E-06
coquina	534992.7	410347.8	0.000512	0.000529	1.7E-05
coquina	534992.7	410997.8	0.085116	0.107717	0.022602
coquina	534992.7	411647.8	0.000786	0.001243	0.000458
coquina	534992.7	412297.8	0.484957	0.557795	0.072838
coquina	534992.7	412947.8	0.517708	0.575882	0.058173
coquina	535642.7	409047.8	0.000298	0.00035	5.24E-05
coquina	535642.7	412297.8	0.475191	0.581445	0.106255
coquina	535642.7	412947.8	0.484677	0.588546	0.103869
coquina	535642.7	413597.8	0.497967	0.58654	0.088573
coquina	535642.7	414247.8	0.500091	0.589434	0.089343
coquina	535642.7	414897.8	0.496248	0.59142	0.095172
coquina	536292.7	409697.8	0.000257	0.000273	1.64E-05
coquina	537592.7	411647.8	0.00025	0.000297	4.71E-05
coquina	537592.7	412297.8	0.000305	0.000358	5.3E-05
coquina	537592.7	412947.8	0.000362	0.000418	5.52E-05
coquina	537592.7	413597.8	0.049653	0.057292	0.007639
coquina	537592.7	414247.8	0.000306	0.000366	5.99E-05
coquina	537592.7	414897.8	0.000323	0.000394	7.06E-05
coquina	538242.7	414247.8	0.000426	0.000467	4.07E-05
coquina	538242.7	414897.8	0.000445	0.000488	4.3E-05
coquina	538242.7	415547.8	0.000466	0.000515	4.85E-05
feather	528832.5	437041.7	0.001312	0.001312	0
feather	528832.5	437841.7	0.001319	0.001319	0
feather	529632.5	436241.7	0.00135	0.00135	0
feather	529632.5	437041.7	0.00126	0.00126	0

feather	529632.5	437841.7	0.001253	0.001253	0
feather	529632.5	438641.7	0.001278	0.001278	0
feather	529632.5	439441.7	0.001364	0.001364	0
feather	530432.5	436241.7	0.001274	0.001274	0
feather	530432.5	437041.7	0.001132	0.001132	0
feather	530432.5	437841.7	0.001193	0.001193	0
feather	530432.5	438641.7	0.001233	0.001233	0
feather	531232.5	437041.7	0.001139	0.001139	0
feather	531232.5	437841.7	0.001164	0.001164	0
feather	531232.5	438641.7	0.001186	0.001186	0
feather	532032.5	437041.7	0.129008	0.129008	0
feather	532032.5	437841.7	0.001114	0.001114	0
feather	532032.5	438641.7	0.001158	0.001158	0
feather	532832.5	437041.7	0.135521	0.135521	0
feather	532832.5	437841.7	0.001097	0.001097	0
feather	533632.5	436241.7	0.001215	0.001215	0
feather	533632.5	437041.7	0.001034	0.001034	0
feather	533632.5	437841.7	0.000997	0.000997	0
feather	534432.5	434641.7	0.556993	0.556993	0
feather	534432.5	435441.7	0.001049	0.001049	0
feather	534432.5	436241.7	0.000969	0.000969	0
feather	534432.5	437041.7	0.000935	0.000935	0
feather	535232.5	432241.7	0.592926	0.595455	0.002529
feather	535232.5	434641.7	0.001696	0.001736	4.01E-05
feather	535232.5	435441.7	0.000941	0.000941	0
feather	535232.5	436241.7	0.000873	0.000873	0
feather	536032.5	431441.7	0.921071	0.92577	0.004699
feather	536032.5	433841.7	0.001583	0.001608	2.44E-05
feather	536032.5	434641.7	0.001522	0.001552	2.99E-05
feather	536032.5	436241.7	0.000766	0.000766	0
feather	536032.5	437041.7	0.000653	0.000653	0
feather	536832.5	432241.7	0.152922	0.154138	0.001216
feather	536832.5	433041.7	0.001361	0.001379	1.84E-05
feather	536832.5	433841.7	0.001297	0.001321	2.47E-05
feather	536832.5	434641.7	0.001252	0.001266	1.35E-05
feather	536832.5	435441.7	0.000918	0.000936	1.71E-05
feather	537632.5	431441.7	0.146912	0.150141	0.003229
feather	537632.5	432241.7	0.142643	0.143626	0.000983
feather	537632.5	433041.7	0.123177	0.12524	0.002063
feather	537632.5	433841.7	0.000901	0.000919	1.73E-05
feather	537632.5	434641.7	0.000842	0.000852	1.08E-05
feather	538432.5	428241.7	0.524305	0.596938	0.072634
feather	538432.5	430641.7	0.136656	0.184979	0.048323
feather	538432.5	431441.7	0.54879	0.552448	0.003658
feather	538432.5	432241.7	0.128591	0.129709	0.001118
feather	538432.5	433041.7	0.104412	0.105526	0.001115

feather	538432.5	433841.7	0.000722	0.000735	1.33E-05
feather	538432.5	434641.7	0.000728	0.000736	8.13E-06
feather	539232.5	429041.7	0.000601	0.000676	7.56E-05
feather	539232.5	429841.7	0.000714	0.000774	5.94E-05
feather	539232.5	430641.7	0.107892	0.110452	0.00256
feather	539232.5	433041.7	0.000715	0.000725	9.89E-06
feather	540032.5	428241.7	0.05318	0.056728	0.003548
feather	540032.5	429041.7	0.000459	0.000485	2.6E-05
feather	540032.5	430641.7	0.000524	0.000542	1.82E-05
feather	540032.5	431441.7	0.086113	0.088197	0.002085
fishcreek	540314.6	438947.3	0.000533	0.000535	1.52E-06
fishcreek	540814.6	437447.3	0.000392	0.000398	5.94E-06
fishcreek	540814.6	437947.3	0.000558	0.00056	2.79E-06
fishcreek	540814.6	438447.3	0.000614	0.000616	2.67E-06
fishcreek	540814.6	438947.3	0.000616	0.000619	2.47E-06
fishcreek	540814.6	439947.3	0.499678	0.500055	0.000377
fishcreek	540814.6	440447.3	0.554289	0.554634	0.000345
fishcreek	541314.6	436947.3	0.000465	0.000469	3.99E-06
fishcreek	541314.6	437447.3	0.001034	0.001039	4.81E-06
fishcreek	541314.6	437947.3	0.000869	0.000873	3.78E-06
fishcreek	541314.6	438447.3	0.000784	0.000788	4.12E-06
fishcreek	541314.6	438947.3	0.000956	0.00096	3.9E-06
fishcreek	541314.6	440447.3	0.577967	0.578517	0.00055
fishcreek	541814.6	436447.3	0.000323	0.000326	2.72E-06
fishcreek	541814.6	436947.3	0.000508	0.00051	2.46E-06
fishcreek	541814.6	437447.3	0.000853	0.000859	6.76E-06
fishcreek	541814.6	437947.3	0.000935	0.000944	9.22E-06
fishcreek	541814.6	438447.3	0.000834	0.000842	8.44E-06
fishcreek	541814.6	438947.3	0.000982	0.000997	1.48E-05
fishcreek	541814.6	439447.3	0.00109	0.001104	1.32E-05
fishcreek	542314.6	435947.3	0.000364	0.000367	3.22E-06
fishcreek	542314.6	436447.3	0.000515	0.000521	5.03E-06
fishcreek	542314.6	436947.3	0.000733	0.000737	4.78E-06
fishcreek	542314.6	439947.3	0.550245	0.60628	0.056035
fishcreek	542314.6	440447.3	0.917997	0.924268	0.006272
fishcreek	542814.6	433447.3	0.000389	0.000391	2.14E-06
fishcreek	542814.6	433947.3	0.000432	0.000434	2.72E-06
fishcreek	542814.6	434447.3	0.000396	0.000399	3.01E-06
fishcreek	542814.6	434947.3	0.000474	0.000479	4.37E-06
fishcreek	542814.6	435447.3	0.000523	0.000529	6.07E-06
fishcreek	542814.6	435947.3	0.000492	0.000496	3.46E-06
fishcreek	542814.6	436447.3	0.000653	0.000658	5.26E-06
fishcreek	542814.6	437947.3	0.55731	0.557595	0.000285
fishcreek	542814.6	438447.3	0.481625	0.483189	0.001563
fishcreek	542814.6	438947.3	0.481425	0.481425	0
fishcreek	543314.6	434947.3	0.000588	0.000594	6.72E-06

fishcreek	543314.6	435447.3	0.000551	0.000556	5.37E-06
fishcreek	543314.6	435947.3	0.000623	0.000627	4.54E-06
fishcreek	543314.6	436447.3	0.000682	0.000687	4.12E-06
fishcreek	543314.6	437447.3	0.52321	0.523762	0.000553
fishcreek	543314.6	437947.3	0.56339	0.563839	0.000449
fishcreek	543814.6	435447.3	0.079508	0.079799	0.000291
fishcreek	543814.6	436947.3	0.542605	0.543145	0.000541
kitchen	555441.4	423748.1	0.00049	0.000518	2.83E-05
kitchen	555441.4	424048.1	0.000439	0.00047	3.08E-05
kitchen	555741.4	423748.1	0.064002	0.065055	0.001052
kitchen	555741.4	424048.1	0.00051	0.00052	1.01E-05
kitchen	555741.4	424348.1	0.000575	0.000591	1.56E-05
kitchen	555741.4	424648.1	0.00054	0.000552	1.21E-05
kitchen	555741.4	424948.1	0.000622	0.000637	1.45E-05
kitchen	556041.4	424348.1	0.065389	0.066415	0.001026
kitchen	556041.4	424648.1	0.069997	0.071161	0.001165
kitchen	556041.4	424948.1	0.000634	0.000651	1.64E-05
kitchen	556041.4	425248.1	0.000585	0.000605	1.91E-05
kitchen	556041.4	425548.1	0.000728	0.000753	2.49E-05
kitchen	556041.4	425848.1	0.000505	0.000519	1.48E-05
kitchen	556041.4	427048.1	0.080737	0.082537	0.0018
kitchen	556041.4	427348.1	0.001466	0.001508	4.15E-05
kitchen	556341.4	424948.1	0.093649	0.094675	0.001026
kitchen	556341.4	425248.1	0.086427	0.088031	0.001604
kitchen	556341.4	425548.1	0.089616	0.091343	0.001727
kitchen	556341.4	425848.1	0.102114	0.103927	0.001813
kitchen	556341.4	426148.1	0.084941	0.086305	0.001364
kitchen	556341.4	426448.1	0.094151	0.095557	0.001407
kitchen	556341.4	426748.1	0.142147	0.144487	0.00234
kitchen	556341.4	427048.1	0.153686	0.156088	0.002402
kitchen	556341.4	427348.1	0.106583	0.108176	0.001592
kitchen	556341.4	427648.1	0.163514	0.165924	0.00241
kitchen	556641.4	425848.1	0.108588	0.110793	0.002204
kitchen	556641.4	426148.1	0.105512	0.108319	0.002807
kitchen	556641.4	426748.1	0.101284	0.104567	0.003282
kitchen	556641.4	427348.1	0.16421	0.165865	0.001655
kitchen	556641.4	427648.1	0.494546	0.497134	0.002588
kitchen	556941.4	424348.1	0.50405	0.607637	0.103587
kitchen	556941.4	427048.1	0.119364	0.123707	0.004343
kitchen	557241.4	424648.1	0.527615	0.606824	0.079209
kitchen	557541.4	424348.1	0.570463	0.608396	0.037932
kitchen	557541.4	424648.1	0.586139	0.606901	0.020762
kitchen	557541.4	425548.1	0.888945	0.925669	0.036724
kitchen	557841.4	424648.1	0.581765	0.606728	0.024962
kitchen	557841.4	427648.1	0.542732	0.607087	0.064355
kitchen	558141.4	424948.1	0.585076	0.607357	0.022282

wolf	547575.2	414984.4	0.000188	0.000206	1.78E-05
wolf	547575.2	415384.4	0.000165	0.000184	1.88E-05
wolf	547575.2	415784.4	0.00017	0.000184	1.45E-05
wolf	547575.2	416184.4	0.000155	0.000166	1.18E-05
wolf	547975.2	414584.4	0.000332	0.001122	0.00079
wolf	547975.2	415784.4	0.027358	0.029665	0.002307
wolf	547975.2	416184.4	0.000214	0.000236	2.2E-05
wolf	547975.2	416584.4	0.000185	0.000201	1.6E-05
wolf	547975.2	416984.4	0.000177	0.000182	5.7E-06
wolf	547975.2	417384.4	0.000149	0.000153	4.21E-06
wolf	548375.2	414984.4	0.000341	0.001924	0.001583
wolf	548375.2	415384.4	0.342532	0.60356	0.261028
wolf	548375.2	415784.4	0.321878	0.33861	0.016731
wolf	548375.2	416184.4	0.0414	0.06729	0.02589
wolf	548375.2	416584.4	0.039391	0.044708	0.005317
wolf	548375.2	417784.4	0.000144	0.00015	6.01E-06
wolf	548775.2	415384.4	0.000322	0.001866	0.001543
wolf	548775.2	415784.4	0.355256	0.552936	0.197681
wolf	548775.2	417784.4	0.031827	0.034684	0.002857
wolf	549175.2	415784.4	0.057038	0.13467	0.077632
wolf	549175.2	418184.4	0.000233	0.000262	2.87E-05
wolf	549575.2	418184.4	0.000242	0.000305	6.37E-05
wolf	549975.2	418184.4	0.034677	0.044342	0.009665
wolf	549975.2	418584.4	0.000216	0.000298	8.19E-05
wolf	550375.2	418184.4	0.040343	0.051549	0.011206
wolf	550375.2	418584.4	0.000256	0.000372	0.000116
wolf	550775.2	418184.4	0.309327	0.31601	0.006683
wolf	550775.2	418584.4	0.00019	0.000256	6.68E-05
wolf	550775.2	418984.4	0.00018	0.000249	6.93E-05
wolf	551175.2	418584.4	0.000268	0.000349	8.09E-05
wolf	551175.2	418984.4	0.000206	0.000293	8.76E-05
wolf	551575.2	417384.4	0.458673	0.602506	0.143833
wolf	551575.2	418584.4	0.040982	0.050567	0.009585
wolf	551575.2	418984.4	0.00023	0.000312	8.21E-05
wolf	551975.2	418584.4	0.357408	0.357355	-5.3E-05
wolf	551975.2	418984.4	0.000267	0.000375	0.000108
wolf	551975.2	419384.4	0.000203	0.000283	7.97E-05
wolf	552375.2	417784.4	0.832594	0.92396	0.091366
wolf	552375.2	418984.4	0.035321	0.03903	0.00371
wolf	552375.2	419384.4	0.000189	0.000261	7.28E-05
wolf	552775.2	419384.4	0.000292	0.000322	3.06E-05
wolf	553175.2	419384.4	0.047041	0.053431	0.00639
wolf	553575.2	418584.4	0.46878	0.602283	0.133503
wolf	553575.2	419784.4	0.050682	0.05386	0.003178

APPENDIX II: RELATIVE WAVE EXPOSURE MODEL

This is the ARCInfo macro code used in the computation of the REI.

```
/* Exposure Model
/* EPA/ORD/NHEERL/WED/CEB -- Brad Robbins
/* NOAA/NOS -- Mark Fonseca
/* OAO -- Pat Clinton
/*Defining ARC/INFO parameters
&args cover bathy pnt_id x_coord y_coord dist point tide cells extent ~
spd_w dur_w spd_s-w dur_s-w spd_s dur_s spd_s-e dur_s-e spd_e ~
dur_e spd_n-e dur_n-e spd_n dur_n spd_n-w dur_n-w shore isle useshore
&station 9999
precision double double
&severity &warning &ignore
&severity &error &routine exit
&type This AML calculates an Exposure Index based on wind
&type direction, wind duration, fetch, and bathymetry for a body
&type of water. Exposure measures the effect of wind driven
&type waves across a body of water and its relationship to
&type aquatic vegetation (Keddy 1982).The AML first calculates
&type fetch from the shoreline to each point defined by a
&type regularly spaced grid or a user supplied point coverage
&type for 16 compass wind directions. These data are then used to
&type calculate effective fetch for 8 compass directions. Effective
&type fetch is combined with wind speed and duration data to calculate
&type exposure with consideration for water depth. This AML has
&type the option to calculate exposure for the entire water body
&type or for a smaller study area within the body of water.
&type There is also the option of using an existing shoreline coverage
&type or of creating a shoreline at a specified depth using a
&type a bathymetric grid.
&type This AML was written for ArcInfo v. 7.1.2 on an NT platform
&type and may require editing for use on Unix platforms.
/* &pause &seconds 3
&type The AML requires ARC/INFO with GRID and (optionally) COGO.
/*&pause &seconds 3
&type The AML requires a shoreline coverage, a bathymetric grid
&type and knowledge of tidal amplitude, wind speed and wind duration.
/*&pause &seconds 3
&type Warning: All coverages previously created by this AML will be deleted.
&type To save previously created coverages use unique coverage names for each
&type AML run.
&type Input coverages and grids will not be impacted, but may be duplicated.
/*&pause &seconds 2
/*&if [Response 'Continue? y or n'] = n &then
/*&return &inform Please try again with renamed coverages.
/*Defining AML variables and coverage names
&setvar dist [response 'Enter the maximum fetch in the body of water(in map
units)']
&sv bathy [response 'Enter the name of the bathymetric grid']
&if [response 'Set Shoreline at a specific depth? y or n'] = n &then
&do
&sv shore [response 'Enter the name of the Shoreline coverage']
/* There is some confusion between shore and cover depending on options
&if [response 'Use an Island coverage in calculation? y or n'] = y &then
&sv isle = [Response 'Enter the name of the Island coverage']
&end
```

```

&else
&do
&setvar tide [response 'Enter the maximum desired tidal height (in integer z
units)']
&pause variable isle has not been set!
&sv cover %bathy%%tide%
&end
&if [response 'Do you wish to use an existing point coverage? y or n'] = n
&then
&do
&sv point [response 'Enter a name for the point coverage to be created']
&sv cells [response 'Enter the distance between points (in map units)']
&end
&else
&sv point [response 'Enter the name of the point coverage']
&type The point coverage will have the suffix cov appended.
&type The point coverage with the suffix exp will have exposure data
&type as point attributes
&if [response 'Do you wish to calculate fetch for entire coverage? y or n'] =
y &then
&sv extent def
&else
&do
&type Please enter extents of study area in map units.
&sv xmin [response 'Enter xmin']
&sv ymin [response 'Enter ymin']
&sv xmax [response 'Enter xmax']
&sv ymax [response 'Enter ymax']
&sv extent := %xmin% %ymin% %xmax% %ymax%
&end
/* The following routine has wind speed and duration supplied
/* To enter your own, remove the numbers and comments (/*)
&sv spd_w 31.41 /* [response 'Enter mean Westerly wind speed']
&sv dur_w 8.76 /*[response 'Enter percent Westerly wind duration']
&sv spd_s-w 28.39 /*[response 'Enter mean Southwesterly wind speed']
&sv dur_s-w 4.76 /*[response 'Enter percent Southwesterly wind duration']
&sv spd_s 29.29 /*[response 'Enter mean Southerly wind speed']
&sv dur_s 12.92 /*[response 'Enter percent Southerly wind duration']
&sv spd_s-e 28.35 /*[response 'Enter mean Southeasterly wind speed']
&sv dur_s-e 10.91 /*[response 'Enter percent Southeasterly wind duration']
&sv spd_e 26.28 /*[response 'Enter mean Easterly wind speed']
&sv dur_e 2.22 /*[response 'Enter percent Easterly wind duration']
&sv spd_n-e 25.64 /*[response 'Enter mean Northeasterly wind speed']
&sv dur_n-e 1.58 /*[response 'Enter percent Northeasterly wind duration']
&sv spd_n 28.74 /*[response 'Enter mean Northerly wind speed']
&sv dur_n 11.00 /*[response 'Enter percent Northerly wind duration']
&sv spd_n-w 29.45 /*[response 'Enter mean Northwesterly wind speed']
&sv dur_n-w 47.85 /*[response 'Enter percent Northwesterly wind duration']
/* Cleaning up clutter from previous AML runs
&type Killing files, coverages, and grids of same name from previous
iterations
/* Terminating prompts, messages
&echo &on
/*&messages &off &info
&if [exists %point%cov -cover] &then kill %point%cov all
&if [exists %point% -cover] &then copy %point% %point%cov
&if [exists %point%exp -cover] &then kill %point%exp all
&if [exists %point%grd -grid] &then kill %point%grd all

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&if [exists %cover%grd -grid] &then kill %cover%grd all
&if [exists %cover%lat -grid] &then kill %cover%lat all
&if [exists %bathy%abs -grid] &then kill %bathy%abs all
&if [exists %cover%a -cover] &then kill %cover%a all
&if [exists %cover% -cover] &then kill %cover% all
&if [exists %shore%cov -cover] &then kill %shore%cov all
&if [exists %shore% -cover] &then copy %shore% %shore%cov
&if [exists eraser -cover] &then kill eraser all
&if [exists %isle% -cover] &then copy %isle% eraser
&if [exists %point%list.txt -file] &then &sys del %point%list.txt
&if [exists depthinfo.inf -info] &then kill depthinfo info
&if [exists stats.inf -info] &then kill stats info
&if [exists 1.txt -file] &then &sys del 1.txt
&if [exists 1.inf -info] &then kill 1 info
&if [exists 2.txt -file] &then &sys del 2.txt
&if [exists 2.inf -info] &then kill 2 info
&if [exists 3.txt -file] &then &sys del 3.txt
&if [exists 3.inf -info] &then kill 3 info
&if [exists 4.txt -file] &then &sys del 4.txt
&if [exists 4.inf -info] &then kill 4 info
&if [exists 5.txt -file] &then &sys del 5.txt
&if [exists 5.inf -info] &then kill 5 info
&if [exists 6.txt -file] &then &sys del 6.txt
&if [exists 6.inf -info] &then kill 6 info
&if [exists 7.txt -file] &then &sys del 7.txt
&if [exists 7.inf -info] &then kill 7 info
&if [exists 8.txt -file] &then &sys del 8.txt
&if [exists 8.inf -info] &then kill 8 info
&if [exists 9.txt -file] &then &sys del 9.txt
&if [exists 9.inf -info] &then kill 9 info
&if [exists 10.txt -file] &then &sys del 10.txt
&if [exists 10.inf -info] &then kill 10 info
&if [exists 11.txt -file] &then &sys del 11.txt
&if [exists 11.inf -info] &then kill 11 info
&if [exists 12.txt -file] &then &sys del 12.txt
&if [exists 12.inf -info] &then kill 12 info
&if [exists 13.txt -file] &then &sys del 13.txt
&if [exists 13.inf -info] &then kill 13 info
&if [exists 14.txt -file] &then &sys del 14.txt
&if [exists 14.inf -info] &then kill 14 info
&if [exists 15.txt -file] &then &sys del 15.txt
&if [exists 15.inf -info] &then kill 15 info
&if [exists 16.txt -file] &then &sys del 16.txt
&if [exists 16.inf -info] &then kill 16 info
&if [exists 17.txt -file] &then &sys del 17.txt
&if [exists 17.inf -info] &then kill 17 info
&if [exists 18.txt -file] &then &sys del 18.txt
&if [exists 18.inf -info] &then kill 18 info
&if [exists 19.txt -file] &then &sys del 19.txt
&if [exists 19.inf -info] &then kill 19 info
&if [exists 20.txt -file] &then &sys del 20.txt
&if [exists 20.inf -info] &then kill 20 info
&if [exists 21.txt -file] &then &sys del 21.txt
&if [exists 21.inf -info] &then kill 21 info
&if [exists 22.txt -file] &then &sys del 22.txt
&if [exists 22.inf -info] &then kill 22 info
&if [exists 23.txt -file] &then &sys del 23.txt
&if [exists 23.inf -info] &then kill 23 info

```

```

&if [exists 24.txt -file] &then &sys del 24.txt
&if [exists 24.inf -info] &then kill 24 info
&if [exists 25.txt -file] &then &sys del 25.txt
&if [exists 25.inf -info] &then kill 25 info
&if [exists 26.txt -file] &then &sys del 26.txt
&if [exists 26.inf -info] &then kill 26 info
&if [exists 27.txt -file] &then &sys del 27.txt
&if [exists 27.inf -info] &then kill 27 info
&if [exists 28.txt -file] &then &sys del 28.txt
&if [exists 28.inf -info] &then kill 28 info
&if [exists 29.txt -file] &then &sys del 29.txt
&if [exists 29.inf -info] &then kill 29 info
&if [exists 30.txt -file] &then &sys del 20.txt
&if [exists 30.inf -info] &then kill 30 info
&if [exists 31.txt -file] &then &sys del 31.txt
&if [exists 31.inf -info] &then kill 31 info
&if [exists 32.txt -file] &then &sys del 32.txt
&if [exists 32.inf -info] &then kill 32 info
&if [exists %cover% -cover] &then &call makeshore
&if [exists eraser -cover] &then build eraser
/* The following sequence uses a given point coverage or
/* generates regularly spaced points and
/* sets the analysis window for calculation of fetch and a table
/* of x y values that the aml can iteratively read
grid
&if [exists %cover% -cover] &then %cover%a = gridpoly(%bathy%)
/* the if statements that follow create a new regularly spaced point coverage
&if [exists %point%cov -cover] = .FALSE. &then setcell %cells%
&if [exists %point%cov -cover] = .FALSE. &then setwindow %cover%
&if [exists %point%cov -cover] = .FALSE. &then %cover%grd = polygrid(%cover%)
&if [exists %point%cov -cover] = .FALSE. &then setmask %cover%lat
&if [exists %point%cov -cover] = .FALSE. &then %point%grd = 1
&if [exists %point%cov -cover] = .FALSE. &then %point%cov =
gridpoint(%point%grd)
q
&if [exists %shore% -cover] &then &sv cover %shore%
build %point%cov point
addxy %point%cov point
ae
ec %point%cov
de lab
ef point
bc %cover%
be arcs
/*mape def
draw
mape %extent%
draw
sel screen
nset
mape def
/*draw
/*draws
&IF [SHOW NUMBER SELECTED] > 0 &THEN delete
&ELSE
&type The whole coverage will be processed.
save
q

```

```

/* The following will remove any points within island boundaries
&if [exists eraser -cover] &then erase %point%cov eraser temp point
&if [exists eraser -cover] &then kill %point%cov all
&if [exists eraser -cover] &then rename temp %point%cov
build %point%cov point
tables
sel %point%cov.pat
calc %point%cov-id = %point%cov#
unload %point%list.txt %point%cov-id x-coord y-coord columnar %point%list.fmt
q
/* the following 'do loop' reads an x y point file, generates arcs at 16
equally
/* spaced angles, clips the arc to fetch, and stores fetch length in text
files
/* the following three commands begin the loop and were liberally adapted from
/* Fonseca's fetch AML
&sv data := 'start'
&sv file1 [open %point%list.txt openstatus -r]
&setvar DATA := [read %file1% readstat]
&do &while %READSTAT% = 0
&if [exists rays -cover] &then kill rays all
&if [exists rayclp -cover] &then kill rayclp all
&if [exists rayclp1 -cover] &then kill rayclp1 all
&if [exists depthinfo.inf -info] &then kill depthinfo info
&if [exists stats.inf -info] &then kill stats info
/*&type If an AML error is detected immediately following this message
/*&type examine %cover%covlist.txt and adjust the following three
/*&type commands for [SUBSTR <string> <position> {num_chars}]
/*&type for <position> - the position where extraction is to begin (integer)
/*&type and {num_chars} - the number of characters to extract (integer)
&sv pnt_id [trim [substr %data% 1 5] -both]
&sv x_coord [trim [substr %data% 12 12] -both]
&sv y_coord [trim [substr %data% 30 12] -both]
&type Processing point number %pnt_id%
&type what am I choking on here?
/* The following routine generates 32 rays that will be used
/* to measure fetch from each point
/* line id 1 will be east; ids proceed counter-clockwise
&sv xang1 = [calc %x_coord% + [cos [angrad 0]] * %dist% ]
&sv yang1 = [calc %y_coord% + [sin [angrad 0]] * %dist% ]
&sv xang2 = [calc %x_coord% + [cos [angrad 11.25]] * %dist% ]
&sv yang2 = [calc %y_coord% + [sin [angrad 11.25]] * %dist% ]
&sv xang3 = [calc %x_coord% + [cos [angrad 22.5]] * %dist% ]
&sv yang3 = [calc %y_coord% + [sin [angrad 22.5]] * %dist% ]
&sv xang4 = [calc %x_coord% + [cos [angrad 33.75]] * %dist% ]
&sv yang4 = [calc %y_coord% + [sin [angrad 33.75]] * %dist% ]
&sv xang5 = [calc %x_coord% + [cos [angrad 45]] * %dist% ]
&sv yang5 = [calc %y_coord% + [sin [angrad 45]] * %dist% ]
&sv xang6 = [calc %x_coord% + [cos [angrad 56.25]] * %dist% ]
&sv yang6 = [calc %y_coord% + [sin [angrad 56.25]] * %dist% ]
&sv xang7 = [calc %x_coord% + [cos [angrad 67.5]] * %dist% ]
&sv yang7 = [calc %y_coord% + [sin [angrad 67.5]] * %dist% ]
&sv xang8 = [calc %x_coord% + [cos [angrad 78.75]] * %dist% ]
&sv yang8 = [calc %y_coord% + [sin [angrad 78.75]] * %dist% ]
&sv xang9 = [calc %x_coord% + [cos [angrad 90]] * %dist% ]
&sv yang9 = [calc %y_coord% + [sin [angrad 90]] * %dist% ]
&sv xang10 = [calc %x_coord% + [cos [angrad 101.25]] * %dist% ]
&sv yang10 = [calc %y_coord% + [sin [angrad 101.25]] * %dist% ]

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&sv xang11 = [calc %x_coord% + [cos [angrad 112.5]] * %dist% ]
&sv yang11 = [calc %y_coord% + [sin [angrad 112.5]] * %dist% ]
&sv xang12 = [calc %x_coord% + [cos [angrad 123.75]] * %dist% ]
&sv yang12 = [calc %y_coord% + [sin [angrad 123.75]] * %dist% ]
&sv xang13 = [calc %x_coord% + [cos [angrad 135]] * %dist% ]
&sv yang13 = [calc %y_coord% + [sin [angrad 135]] * %dist% ]
&sv xang14 = [calc %x_coord% + [cos [angrad 146.25]] * %dist% ]
&sv yang14 = [calc %y_coord% + [sin [angrad 146.25]] * %dist% ]
&sv xang15 = [calc %x_coord% + [cos [angrad 157.5]] * %dist% ]
&sv yang15 = [calc %y_coord% + [sin [angrad 157.5]] * %dist% ]
&sv xang16 = [calc %x_coord% + [cos [angrad 168.75]] * %dist% ]
&sv yang16 = [calc %y_coord% + [sin [angrad 168.75]] * %dist% ]
&sv xang17 = [calc %x_coord% + [cos [angrad 180]] * %dist% ]
&sv yang17 = [calc %y_coord% + [sin [angrad 180]] * %dist% ]
&sv xang18 = [calc %x_coord% + [cos [angrad 191.25]] * %dist% ]
&sv yang18 = [calc %y_coord% + [sin [angrad 191.25]] * %dist% ]
&sv xang19 = [calc %x_coord% + [cos [angrad 202.5]] * %dist% ]
&sv yang19 = [calc %y_coord% + [sin [angrad 202.5]] * %dist% ]
&sv xang20 = [calc %x_coord% + [cos [angrad 213.75]] * %dist% ]
&sv yang20 = [calc %y_coord% + [sin [angrad 213.75]] * %dist% ]
&sv xang21 = [calc %x_coord% + [cos [angrad 225]] * %dist% ]
&sv yang21 = [calc %y_coord% + [sin [angrad 225]] * %dist% ]
&sv xang22 = [calc %x_coord% + [cos [angrad 236.25]] * %dist% ]
&sv yang22 = [calc %y_coord% + [sin [angrad 236.25]] * %dist% ]
&sv xang23 = [calc %x_coord% + [cos [angrad 247.5]] * %dist% ]
&sv yang23 = [calc %y_coord% + [sin [angrad 247.5]] * %dist% ]
&sv xang24 = [calc %x_coord% + [cos [angrad 258.75]] * %dist% ]
&sv yang24 = [calc %y_coord% + [sin [angrad 258.75]] * %dist% ]
&sv xang25 = [calc %x_coord% + [cos [angrad 270]] * %dist% ]
&sv yang25 = [calc %y_coord% + [sin [angrad 270]] * %dist% ]
&sv xang26 = [calc %x_coord% + [cos [angrad 281.25]] * %dist% ]
&sv yang26 = [calc %y_coord% + [sin [angrad 281.25]] * %dist% ]
&sv xang27 = [calc %x_coord% + [cos [angrad 292.5]] * %dist% ]
&sv yang27 = [calc %y_coord% + [sin [angrad 292.5]] * %dist% ]
&sv xang28 = [calc %x_coord% + [cos [angrad 303.75]] * %dist% ]
&sv yang28 = [calc %y_coord% + [sin [angrad 303.75]] * %dist% ]
&sv xang29 = [calc %x_coord% + [cos [angrad 315]] * %dist% ]
&sv yang29 = [calc %y_coord% + [sin [angrad 315]] * %dist% ]
&sv xang30 = [calc %x_coord% + [cos [angrad 326.25]] * %dist% ]
&sv yang30 = [calc %y_coord% + [sin [angrad 326.25]] * %dist% ]
&sv xang31 = [calc %x_coord% + [cos [angrad 337.5]] * %dist% ]
&sv yang31 = [calc %y_coord% + [sin [angrad 337.5]] * %dist% ]
&sv xang32 = [calc %x_coord% + [cos [angrad 348.75]] * %dist% ]
&sv yang32 = [calc %y_coord% + [sin [angrad 348.75]] * %dist% ]
generate rays
line
1
&type I am making rays now
&type %x_coord% %y_coord%
%x_coord% %y_coord%
%xang1% %yang1%
end
2
%x_coord% %y_coord%
%xang2% %yang2%
end
3
%x_coord% %y_coord%

```

```
%xang3% %yang3%
end
4
%x_coord% %y_coord%
%xang4% %yang4%
end
5
%x_coord% %y_coord%
%xang5% %yang5%
end
6
%x_coord% %y_coord%
%xang6% %yang6%
end
7
%x_coord% %y_coord%
%xang7% %yang7%
end
8
%x_coord% %y_coord%
%xang8% %yang8%
end
9
%x_coord% %y_coord%
%xang9% %yang9%
end
10
%x_coord% %y_coord%
%xang10% %yang10%
end
11
%x_coord% %y_coord%
%xang11% %yang11%
end
12
%x_coord% %y_coord%
%xang12% %yang12%
end
13
%x_coord% %y_coord%
%xang13% %yang13%
end
14
%x_coord% %y_coord%
%xang14% %yang14%
end
15
%x_coord% %y_coord%
%xang15% %yang15%
end
16
%x_coord% %y_coord%
%xang16% %yang16%
end
17
%x_coord% %y_coord%
%xang17% %yang17%
end
```

```
18
%x_coord% %y_coord%
%xang18% %yang18%
end
19
%x_coord% %y_coord%
%xang19% %yang19%
end
20
%x_coord% %y_coord%
%xang20% %yang20%
end
21
%x_coord% %y_coord%
%xang21% %yang21%
end
22
%x_coord% %y_coord%
%xang22% %yang22%
end
23
%x_coord% %y_coord%
%xang23% %yang23%
end
24
%x_coord% %y_coord%
%xang24% %yang24%
end
25
%x_coord% %y_coord%
%xang25% %yang25%
end
26
%x_coord% %y_coord%
%xang26% %yang26%
end
27
%x_coord% %y_coord%
%xang27% %yang27%
end
28
%x_coord% %y_coord%
%xang28% %yang28%
end
29
%x_coord% %y_coord%
%xang29% %yang29%
end
30
%x_coord% %y_coord%
%xang30% %yang30%
end
31
%x_coord% %y_coord%
%xang31% %yang31%
end
32
%x_coord% %y_coord%
```



```

%xang32% %yang32%
end
end
quit
/* End ray generation
&type I am done with drawing the 32 rays
/* End of COGOSUB
build rays line
&type What cover?
clip rays %cover% rayclp1 line 0.000001
build rayclp1 line
&if [exists eraser -cover] &then
&do
&type I am erasing rayclp1 with eraser now!
&pause is this thing erasing or not?
erase rayclp1 eraser rayclp line 0.000001
&end
&else
&do
&type I did not erase rayclp1 with eraser!!
Kill cow all
copy rayclp1 rayclp
&end
build rayclp line
&type rayclp built
&type rays built
ae
/*comment out the draw if you want to go faster
ec rayclp
bc rayclp1 4
make rayclp
&type What command?1
bc %cover% 3
&type What command?2
be arcs
&type What command?3
de arcs
&type What command?4
ef arcs
&type am I croaking here? This is line 391!
draw
/* the following selects arcs radiating from the point and discards 'orphans'

/* using 30 map units because 5 map units didn't work
&sv x_edge := %x_coord% + 40
&sv Y_edge := %y_coord% + 40
&type %x_edge% x_edge %y_edge% y_edge
coordinate keyboard
select circle passthru
%x_coord% %y_coord%
&type line 400 this is after select circle passthru
%x_edge% %y_edge%
draw
&type this is after draw and before draws line 403
draws
&pause &seconds 2
nset
&type is the program getting this far? Line 406

```

```

&IF [SHOW NUMBER SELECTED] > 0 &THEN delete
&ELSE
&type Out of Bounds
save
sel all
draw
&pause &seconds 1
q
/* The following sequence retrieves inverse distance weighted depth indices
/* in eight principal directions at bathymetric grid cellsize resolution
grid
&describe %bathy%
&if [value grd$zmin] le 0 &then
/* can't divide by zero this may need more work
%bathy%abs = (%bathy% + [abs [value grd$zmin] ] + 1)
q
tables
define depthinfo.inf
PX          8      18      F      5
PY          8      18      F      5
SECTION-ID  4       5      B
SURFACE-ID  4       5      B
DISTANCE    4      12      F      3
SPOT        4      12      F      3
~
q
ap
&if [exists %bathy%abs -grid] &then surface lattice %bathy%abs
&else surface lattice %bathy%
&if [exists %bathy%abs -grid] &then &describe %bathy%abs
&else &describe %bathy%
surfacexsection rayclp 1 depthinfo.inf [value grd$dx]
q
tables
additem depthinfo.inf rayclp# 4 5 b
sel depthinfo.inf
calc rayclp# = section-id
sel rayclp.aat
alter
length
~
~
~
3
~
~
q
joinitem depthinfo.inf rayclp.aat depthinfo.inf rayclp# spot
tables
additem depthinfo.inf idw 12 12 n 2
additem depthinfo.inf var1 12 12 n 3
additem depthinfo.inf var2 12 12 n 6
/* if fails check var2 = 0 and change decimal places
&type I am going to reselect now
sel depthinfo.inf
resel spot ne -9999
resel distance ne 0
resel length ne 0

```

```

CALC VAR1 = DISTANCE / LENGTH
CALC VAR2 = VAR1 / SPOT
CALC IDW = ( ( 1 - VAR1 ) ** 2 ) / VAR2
&type I am done calcng for idw
statistics rayclp-id stats.inf
sum idw
~
N
N
Q
Joinitem rayclp.aat stats.inf rayclp.aat rayclp-id length
/* The following sequence creates text files of fetch data in Tables
&type going back to tables to reselect rayclp-id
tables
additem rayclp.aat pnt_id 10 12 n 0
sel rayclp.aat
calc pnt_id = %pnt_id%
resel rayclp-id = 1
unload 1.txt pnt_id length sum-idw
nssel
resel rayclp-id = 2
unload 2.txt pnt_id length sum-idw
nssel
resel rayclp-id = 3
unload 3.txt pnt_id length sum-idw
nssel
resel rayclp-id = 4
unload 4.txt pnt_id length sum-idw
nssel
resel rayclp-id = 5
unload 5.txt pnt_id length sum-idw
nssel
resel rayclp-id = 6
unload 6.txt pnt_id length sum-idw
nssel
resel rayclp-id = 7
unload 7.txt pnt_id length sum-idw
nssel
resel rayclp-id = 8
unload 8.txt pnt_id length sum-idw
nssel
resel rayclp-id = 9
unload 9.txt pnt_id length sum-idw
nssel
resel rayclp-id = 10
unload 10.txt pnt_id length sum-idw
nssel
resel rayclp-id = 11
unload 11.txt pnt_id length sum-idw
nssel
resel rayclp-id = 12
unload 12.txt pnt_id length sum-idw
nssel
resel rayclp-id = 13
unload 13.txt pnt_id length sum-idw
nssel
resel rayclp-id = 14
unload 14.txt pnt_id length sum-idw

```

```

nsetl
resel rayclp-id = 15
unload 15.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 16
unload 16.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 17
unload 17.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 18
unload 18.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 19
unload 19.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 20
unload 20.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 21
unload 21.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 22
unload 22.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 23
unload 23.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 24
unload 24.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 25
unload 25.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 26
unload 26.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 27
unload 27.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 28
unload 28.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 29
unload 29.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 30
unload 30.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 31
unload 31.txt pnt_id length sum-idw
nsetl
resel rayclp-id = 32
unload 32.txt pnt_id length sum-idw
q
/*kill rays all
/*kill rayclp all
&setvar DATA := [read %fileE1% readstat]

```

```

&end
&sv a [close %file1%]
/* do loop over, the next process creates join files from data generated above
/* in Tables
tables
define 1.inf
%point%cov-id 10 12 n 0
a1 16 18 n 5
a1-idw 16 18 n 2
~
add from 1.txt
define 2.inf
%point%cov-id 10 12 n 0
a2 16 18 n 5
a2-idw 16 18 n 2
~
add from 2.txt
define 3.inf
%point%cov-id 10 12 n 0
a3 16 18 n 5
a3-idw 16 18 n 2
~
add from 3.txt
define 4.inf
%point%cov-id 10 12 n 0
a4 16 18 n 5
a4-idw 16 18 n 2
~
add from 4.txt
define 5.inf
%point%cov-id 10 12 n 0
a5 16 18 n 5
a5-idw 16 18 n 2
~
add from 5.txt
define 6.inf
%point%cov-id 10 12 n 0
a6 16 18 n 5
a6-idw 16 18 n 2
~
add from 6.txt
define 7.inf
%point%cov-id 10 12 n 0
a7 16 18 n 5
a7-idw 16 18 n 2
~
add from 7.txt
define 8.inf
%point%cov-id 10 12 n 0
a8 16 18 n 5
a8-idw 16 18 n 2
~
add from 8.txt
define 9.inf
%point%cov-id 10 12 n 0
a9 16 18 n 5
a9-idw 16 18 n 2
~

```

```
add from 9.txt
define 10.inf
%point%cov-id 10 12 n 0
a10 16 18 n 5
a10-idw 16 18 n 2
~
add from 10.txt
define 11.inf
%point%cov-id 10 12 n 0
a11 16 18 n 5
a11-idw 16 18 n 2
~
add from 11.txt
define 12.inf
%point%cov-id 10 12 n 0
a12 16 18 n 5
a12-idw 16 18 n 2
~
add from 12.txt
define 13.inf
%point%cov-id 10 12 n 0
a13 16 18 n 5
a13-idw 16 18 n 2
~
add from 13.txt
define 14.inf
%point%cov-id 10 12 n 0
a14 16 18 n 5
a14-idw 16 18 n 2
~
add from 14.txt
define 15.inf
%point%cov-id 10 12 n 0
a15 16 18 n 5
a15-idw 16 18 n 2
~
add from 15.txt
define 16.inf
%point%cov-id 10 12 n 0
a16 16 18 n 5
a16-idw 16 18 n 2
~
add from 16.txt
define 17.inf
%point%cov-id 10 12 n 0
a17 16 18 n 5
a17-idw 16 18 n 2
~
add from 17.txt
define 18.inf
%point%cov-id 10 12 n 0
a18 16 18 n 5
a18-idw 16 18 n 2
~
add from 18.txt
define 19.inf
%point%cov-id 10 12 n 0
a19 16 18 n 5
```

```
a19-idw 16 18 n 2
~
add from 19.txt
define 20.inf
%point%cov-id 10 12 n 0
a20 16 18 n 5
a20-idw 16 18 n 2
~
add from 20.txt
define 21.inf
%point%cov-id 10 12 n 0
a21 16 18 n 5
a21-idw 16 18 n 2
~
add from 21.txt
define 22.inf
%point%cov-id 10 12 n 0
a22 16 18 n 5
a22-idw 16 18 n 2
~
add from 22.txt
define 23.inf
%point%cov-id 10 12 n 0
a23 16 18 n 5
a23-idw 16 18 n 2
~
add from 23.txt
define 24.inf
%point%cov-id 10 12 n 0
a24 16 18 n 5
a24-idw 16 18 n 2
~
add from 24.txt
define 25.inf
%point%cov-id 10 12 n 0
a25 16 18 n 5
a25-idw 16 18 n 2
~
add from 25.txt
define 26.inf
%point%cov-id 10 12 n 0
a26 16 18 n 5
a26-idw 16 18 n 2
~
add from 26.txt
define 27.inf
%point%cov-id 10 12 n 0
a27 16 18 n 5
a27-idw 16 18 n 2
~
add from 27.txt
define 28.inf
%point%cov-id 10 12 n 0
a28 16 18 n 5
a28-idw 16 18 n 2
~
add from 28.txt
define 29.inf
```

```

%point%cov-id 10 12 n 0
a29 16 18 n 5
a29-idw 16 18 n 2
~
add from 29.txt
define 30.inf
%point%cov-id 10 12 n 0
a30 16 18 n 5
a30-idw 16 18 n 2
~
add from 30.txt
define 31.inf
%point%cov-id 10 12 n 0
a31 16 18 n 5
a31-idw 16 18 n 2
~
add from 31.txt
define 32.inf
%point%cov-id 10 12 n 0
a32 16 18 n 5
a32-idw 16 18 n 2
~
add from 32.txt
/* item a# is fetch; a#-idw is inverse distance depth weighted fetch
q
/* the following appends fetch length to the point coverage
joinitem %point%cov.pat 1.inf %point%cov.pat %point%cov-id y-coord
joinitem %point%cov.pat 2.inf %point%cov.pat %point%cov-id a1-idw
joinitem %point%cov.pat 3.inf %point%cov.pat %point%cov-id a2-idw
joinitem %point%cov.pat 4.inf %point%cov.pat %point%cov-id a3-idw
joinitem %point%cov.pat 5.inf %point%cov.pat %point%cov-id a4-idw
joinitem %point%cov.pat 6.inf %point%cov.pat %point%cov-id a5-idw
joinitem %point%cov.pat 7.inf %point%cov.pat %point%cov-id a6-idw
joinitem %point%cov.pat 8.inf %point%cov.pat %point%cov-id a7-idw
joinitem %point%cov.pat 9.inf %point%cov.pat %point%cov-id a8-idw
joinitem %point%cov.pat 10.inf %point%cov.pat %point%cov-id a9-idw
joinitem %point%cov.pat 11.inf %point%cov.pat %point%cov-id a10-idw
joinitem %point%cov.pat 12.inf %point%cov.pat %point%cov-id a11-idw
joinitem %point%cov.pat 13.inf %point%cov.pat %point%cov-id a12-idw
joinitem %point%cov.pat 14.inf %point%cov.pat %point%cov-id a13-idw
joinitem %point%cov.pat 15.inf %point%cov.pat %point%cov-id a14-idw
joinitem %point%cov.pat 16.inf %point%cov.pat %point%cov-id a15-idw
joinitem %point%cov.pat 17.inf %point%cov.pat %point%cov-id a16-idw
joinitem %point%cov.pat 18.inf %point%cov.pat %point%cov-id a17-idw
joinitem %point%cov.pat 19.inf %point%cov.pat %point%cov-id a18-idw
joinitem %point%cov.pat 20.inf %point%cov.pat %point%cov-id a19-idw
joinitem %point%cov.pat 21.inf %point%cov.pat %point%cov-id a20-idw
joinitem %point%cov.pat 22.inf %point%cov.pat %point%cov-id a21-idw
joinitem %point%cov.pat 23.inf %point%cov.pat %point%cov-id a22-idw
joinitem %point%cov.pat 24.inf %point%cov.pat %point%cov-id a23-idw
joinitem %point%cov.pat 25.inf %point%cov.pat %point%cov-id a24-idw
joinitem %point%cov.pat 26.inf %point%cov.pat %point%cov-id a25-idw
joinitem %point%cov.pat 27.inf %point%cov.pat %point%cov-id a26-idw
joinitem %point%cov.pat 28.inf %point%cov.pat %point%cov-id a27-idw
joinitem %point%cov.pat 29.inf %point%cov.pat %point%cov-id a28-idw
joinitem %point%cov.pat 30.inf %point%cov.pat %point%cov-id a29-idw
joinitem %point%cov.pat 31.inf %point%cov.pat %point%cov-id a30-idw
joinitem %point%cov.pat 32.inf %point%cov.pat %point%cov-id a31-idw

```



```

&type Processing.....
/* items are used in fetch and exposure calculations
tables
additem %point%cov.pat wt_eff_w 16 18 n 5
additem %point%cov.pat wt_eff_s-w 16 18 n 5
additem %point%cov.pat wt_eff_s 16 18 n 5
additem %point%cov.pat wt_eff_s-e 16 18 n 5
additem %point%cov.pat wt_eff_e 16 18 n 5
additem %point%cov.pat wt_eff_n-e 16 18 n 5
additem %point%cov.pat wt_eff_n 16 18 n 5
additem %point%cov.pat wt_eff_n-w 16 18 n 5
additem %point%cov.pat wt_eff_tot 16 18 n 5
additem %point%cov.pat wt_eff_avg 16 18 n 5
additem %point%cov.pat exp_w 16 18 n 5
additem %point%cov.pat exp_s-w 16 18 n 5
additem %point%cov.pat exp_s 16 18 n 5
additem %point%cov.pat exp_s-e 16 18 n 5
additem %point%cov.pat exp_e 16 18 n 5
additem %point%cov.pat exp_n-e 16 18 n 5
additem %point%cov.pat exp_n 16 18 n 5
additem %point%cov.pat exp_n-w 16 18 n 5
additem %point%cov.pat exp_tot 16 18 n 5
additem %point%cov.pat exp_avg 16 18 n 5
additem %point%cov.pat indx 12 12 n 5
sel %point%cov.pat
&type Calculating Wt_effective Fetch
/* there must be a space after '(' and before ')'
/* the calculations below calculate effective idw averaging 9 11.5 degree idws
calc wt_eff_s-e = ( a1-idw + a32-idw + a31-idw + a30-idw + a29-idw + a28-idw +
a27-idw + a26-idw + a25-idw ) / 9
calc wt_eff_s = ( a29-idw + a28-idw + a27-idw + a26-idw + a25-idw + a24-idw +
a23-idw + a22-idw + a21-idw ) / 9
calc wt_eff_s-w = ( a25-idw + a24-idw + a23-idw + a22-idw + a21-idw + a20-idw
+ a19-idw + a18-idw + a17-idw ) / 9
calc wt_eff_w = ( a21-idw + a20-idw + a19-idw + a18-idw + a17-idw + a16-idw +
a15-idw + a14-idw + a13-idw ) / 9
calc wt_eff_n-w = ( a17-idw + a16-idw + a15-idw + a14-idw + a13-idw + a12-idw
+ a11-idw + a10-idw + a9-idw ) / 9
calc wt_eff_n = ( a13-idw + a12-idw + a11-idw + a10-idw + a9-idw + a8-idw +
a7-idw + a6-idw + a5-idw ) / 9
calc wt_eff_n-e = ( a9-idw + a8-idw + a7-idw + a6-idw + a5-idw + a4-idw + a3-
idw + a2-idw + a1-idw ) / 9
calc wt_eff_e = ( a32-idw + a31-idw + a30-idw + a29-idw + a5-idw + a4-idw +
a3-idw + a2-idw + a1-idw ) / 9
calc wt_eff_tot = ( wt_eff_w + wt_eff_s-w + wt_eff_s + wt_eff_s-e + wt_eff_e
+ wt_eff_n-e + wt_eff_n + wt_eff_n-w )
calc wt_eff_avg = wt_eff_tot / 8
&type Calculating Exposure in each of the 8 compass directions
calc exp_w = ( %spd_w% * %dur_w% * wt_eff_w )
calc exp_s-w = ( %spd_s-w% * %dur_s-w% * wt_eff_s-w )
calc exp_s = ( %spd_s% * %dur_s% * wt_eff_s )
calc exp_s-e = ( %spd_s-e% * %dur_s-e% * wt_eff_s-e )
calc exp_e = ( %spd_e% * %dur_e% * wt_eff_e )
calc exp_n-e = ( %spd_n-e% * %dur_n-e% * wt_eff_n-e )
calc exp_n = ( %spd_n% * %dur_n% * wt_eff_n )
calc exp_n-w = ( %spd_n-w% * %dur_n-w% * wt_eff_n-w )
&type Calculating Total Exposure for each point (Sum of Exposure in each of
&type the 8 compass directions)

```

```

calc exp_tot = ( exp_w + exp_s-w + exp_s + exp_s-e + exp_e + exp_n-e + exp_n +
exp_n-w )
&type Calculating Mean Exposure for each point (Sum of Exposure in each of the
8 &type compass directions)
calc exp_avg = exp_tot / 8
/* the following produces a weighted exposure index without so many zeros
/* by dividing total exposure by max fetch in waterbody
calc indx = ( exp_tot / %dist% )
q
&messages &on
&type A point coverage will now be created with fetch, effective fetch,
&type exposure, and depth as point attributes named with the suffix "exp"
&type I need to comment out the part that needs %cover%a
intersect %point%cov %cover%a %point%exp point
&return
&routin makeshore
&type A new shoreline coverage based on the specified tide height will be
&type created to calculate fetch using grid. Areas within the body of
waterabove
&type specified tide height or "islands" will also be used to calculate fetch.
&type Grid, Tables, and ArcEdit commands will be used to redefine the
shoreline
&type and define the island boundaries based on the desired tidal height.
grid
%cover%lat = select(%bathy%, [quote value le %tide%])
%cover%a = gridpoly(%cover%lat)
q
tables
additem %cover%a.pat dissolver 4 5 n 0
sel %cover%a.pat
resel %cover%a-id gt 1
resel grid-code ne -9999
calc dissolver = 1
q
dissolve %cover%a %cover% dissolver poly
build %cover%
ae
ec %cover%a
de arcs
draw
ef poly
/* the following creates tidal 'island' coverage
sel all
resel grid-code = -9999
&IF [SHOW NUMBER SELECTED] > 0 &THEN put eraser
&ELSE
&type No islands detected at this water level
q
&return
&routin exit
&severity &error &ignore
&messages &on
&return &error An error has occurred.

```

