

CAN ARTIFICIAL REEFS ALTER USER PRESSURE ON ADJACENT NATURAL REEFS?

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ABSTRACT

We test the hypothesis that introducing an artificial reef into a natural reef environment by sinking a decommissioned ship will result in a win-win situation for the local environment (reduced user pressure), the local dive charter industry, and the larger local economy. Dive Shop logbooks combined with on-water observation was used to derive estimates of total use on both artificial and natural reefs surrounding the site where the SPIEGEL GROVE was sunk for 10-mo periods both before and after the ship was sunk. The results are consistent with this hypothesis. Following the deployment of the SPIEGEL GROVE (located off Key Largo Florida in the Florida Keys National Marine Sanctuary), recreational use of the surrounding natural reefs decreased, while local dive charter business increased, and the greater local economy grew in terms of both income and employment.

In June 2002, the retired navy ship USS SPIEGEL GROVE was sunk in the waters off of Key Largo in southern Florida and within the Florida Keys National Marine Sanctuary (FKNMS). At 510 ft, the SPIEGEL GROVE was at that time the largest vessel ever intentionally sunk for the purpose of creating an artificial reef within the FKNMS. This study aims to assess the economic and ecological impacts of the establishment of a new artificial reef by sinking a decommissioned ship. An understanding of the effects of sinking the SPIEGEL GROVE is important, as it will provide information to assist the FKNMS with its future decisions regarding the permitting of artificial reefs. There is a current moratorium on the permitting of new artificial reefs in the FKNMS, beyond the USS VANDENBERG, which will be deployed off of Key West.

The Key Largo Chamber of Commerce organized the sinking of the SPIEGEL GROVE to increase local SCUBA diving charter business and thus increase net tourism revenues in the local economy. As the number of divers visiting the area should be correlated with the quality and variety of local reef habitat, establishing a new artificial reef, particularly by sinking a ship of this size, would be expected to produce economic benefits for the dive industry through higher numbers of customers. Assuming that the increased numbers of divers represents some influx of new visitors to the area, as opposed to existing visitors substituting away from other activities, the resulting economic benefits for the dive charter industry should imply a net increase in the size of the aggregate local economy.

Above and beyond its economic impact, the establishment of an artificial reef impacts the surrounding marine ecosystems. These ecological impacts may be considered in two distinct categories: those stemming from the creation of new marine habitat and those stemming from changes in human impacts due to shifting recreational diving patterns. Assessing the ecological effects of habitat creation involves complex biological models and is beyond the scope of this study. The Reef Environmental Education Foundation (R.E.E.F.) in a separate monitoring effort is studying the ecological effects. However, in the present study we attempt to assess the ecological impacts from changes in recreational diving patterns resulting from the sinking of the SPIEGEL GROVE.

Proponents of sinking ships in the FKNMS hypothesize that the introduction of an artificial reef in a natural reef environment should reduce recreational use of the surrounding natural reefs, all else held constant, as divers and others shift a portion of their use from the natural reefs to the new artificial reef. Assuming that recreational use constitutes a negative pressure on natural reef ecosystems, shifting users from natural to artificial reefs yields an ecological benefit for the natural reefs. Of course, increasing numbers of users attracted to the area by the newly established artificial reef could offset the shift in recreation away from natural reefs, as most divers visiting the area would visit a variety of reef sites.

The research question was then whether the sinking of the SPIEGEL GROVE has resulted in positive net economic and ecological benefits for the Key Largo area. If the SPIEGEL GROVE has drawn new recreational users to the area and if these new users do not fully offset the expected shift away from natural reefs, then the introduction of this artificial reef should create a win-win situation for the local economy and ecology. Alternatively, negative ecological impacts may offset any economic gains. Examination of the SPIEGEL GROVE case study may help inform future decisions to establish artificial reefs under similar circumstances.

METHODS

In order to assess the economic and ecological impact of the SPIEGEL GROVE, we compared post-deployment conditions with the pre-deployment baseline conditions for a series of reefs located within 2 km of the SPIEGEL GROVE. The reefs in question lie several miles offshore and are accessible only by boat, which facilitated a simpler sampling methodology. In order to estimate total recreational reef use, two sources of information were used: dive logbooks from dive charter operations and on-water surveys of reef use collected at pre-determined reef sites on a stratified random sample of days. Both datasets were compiled for both the pre-deployment and the post-deployment period. The on-water data were used to extrapolate the dive charter logbook data to the population of all recreational users.

The census of dive charter operations (42 operations) was compiled from the logbooks of those charter operations taking recreational users to the reef sites located in the study area. The majority (38 of 42) of dive charter operations provided complete logbook data for both the pre- and post-deployment periods. In general, the participating charter operations accounted for 80%–85% of total reef use by dive charter operations. The adjustment of the logbook numbers to include estimates of reef use by non-participant dive charter operations constitutes step one of the extrapolation process.

The on-water surveys were conducted at the individual reef sites (see Leeworthy and Stone, 2005 for a list of the sites), both natural and artificial, using techniques developed by Souter (1997a,b). These same stratified random sampling techniques were developed for use by NOAA to measure changes in no-take area use over time. Prior to data collection, a random sample of days was selected, and each day was assigned a reef site. Each reef site was sampled across seasons and on both weekdays and weekends. In the pre-deployment period, the 70 sample days spanned a 10-mo period from August 2001 to May 2002. The post-deployment sample covered the full year from August 2002 to July 2003, however the 10-mo pre-deployment period constrains the analysis. The full 12-mo sample consisted of 88 d of observation, 72 of which fell within the 10-mo period. See Leeworthy and Stone (2005) for details of the on-water sampling and estimation procedures.

Data from the on-water surveys were used to develop blow-up ratios of dive shop use to all use, which were then applied to the logbook numbers. This extrapolation was a two-step process whereby total dive charter reef use was estimated and then total recreational reef use including private boats, rental boats, and other charters (e.g., fishing charters) was estimated.

In order to improve the accuracy of the estimates, sample data were stratified by reef type (natural vs artificial), season (summer vs winter), and type of day (weekday vs weekend). Prior studies of visitor use in the Florida Keys (Leeworthy and Wiley, 1996a) identified summer as June–November and winter as December–May. The recreational reef users were also broken down into several categories: SCUBA divers, snorkelers, and others, including those fishing as well as those onboard, but not SCUBA diving, snorkeling, or fishing. Instead of developing a single blow-up ratio for all users, distinct ratios were developed for each user group by type of reef, season, and type of day.

After estimating the total reef use of all dive charter operations from the logbook numbers provided by participating dive charter operations (i.e., step 1 in extrapolation), we calculated the ratios of non-participant dive charter use to participant dive charter use and inflated the logbook numbers using these ratios. Dive charter operations, however, do not account for all recreational reef use, as access by private boats, rental boats, and other charters is also possible. So the next step was to develop a second set of ratios of non-dive charter use to dive charter use, which were applied in order to extrapolate the dive operation estimates of use to the population of all use. In both cases distinct ratios were developed for different user groups by type of reef, season, and type of day. Applying these ratios to the various user groups and summing the results yielded estimates of total recreational reef use in the Key Largo area. In the post-deployment period, recreational activity on the SPIEGEL GROVE was explicitly broken out as a subset of artificial reef use.

To estimate the economic impact of changing reef use patterns, we used ratios linking dives or boat outings to person-days of activity, for both artificial and natural reefs by county (Johns et al., 2003a). Using per person-day expenditure profiles for fishing and for SCUBA diving and/or snorkeling (Johns et al., 2003a), separate expenditure profiles were developed for residents and visitors. Data from the 1997 Monroe County Economic Censuses (U.S. Bureau of the Census, 1997) enabled the conversion of total recreational expenditures to local economic impact, again differentiating between residents and visitors. It is particularly important to have a county-specific model, owing to the isolated, tourism-based nature of the local economy (see Leeworthy and Wiley, 1996b). Only the direct economic impacts were estimated for residents of Monroe County since resident spending is local, meaning that the spending is derived from income earned by working in the local economy and is therefore part of the multiplier impact of basic or export industries (e.g., tourism or commercial fisheries) where new monies are injected into the local economy. For visitors, multipliers were used to capture indirect and induced effects, as their recreation expenditures represent an injection of external money into the local economy.

Using the models from Johns et al. (2003b), an estimate of the number of person-days, by activity, reef type, and residence status for both the pre- and post-deployment periods were multiplied by the corresponding expenditure profiles to arrive at the total expenditures associated with recreational reef use in the local economy. Expenditures were summed across activities, but kept stratified by reef type and residence status for the pre- and post-deployment periods. Total recreation expenditure estimates were then derived for sales/output, income, and employment effects separately for residents and visitors and compared between the pre- and post-deployment periods to gauge the impact of the sinking of the SPIEGEL GROVE.

RESULTS

LOCAL ENVIRONMENT/ECOLOGY (USER PRESSURE).—From the pre- to post- SPIEGEL GROVE deployment period, there was a 13.7% decrease in the total number of users (SCUBA divers, snorkelers, and others) on the surrounding natural reefs (Table 1). A 12.7% decrease in the share of recreational SCUBA diving use occurring on natural reefs representing 17,834 dives is in contrast to a 118.1% increase (34,100

Table 1. Net changes in total reef use following the deployment of the SPIEGEL GROVE.

Reef type	Absolute and percent change							
	Dives SCUBA	%	Dives snorkelers	%	All others	%	Total	%
Natural reefs	-17,834	-12.7	-26,072	-25.7	6,370	19.3	-37,537	-13.7
Artificial reefs	34,110	118.1	-18,786	245.1	14,162	271.2	67,059	160.5
Total	16,276	9.6	-7,286	-6.7	20,532	53.8	29,522	9.3

*This includes those who went out on charter or other boats, but who did not participate in any further activity, as well as those who participated in fishing.

dives) in the share of recreational SCUBA diving use occurring on artificial reefs. See Appendix 1 for more detailed and complete tables.

LOCAL DIVE CHARTER BUSINESS.—When considering the potential benefits to the dive charter industry, the absolute number of dives made by SCUBA divers and snorkelers and the number of other paying passengers onboard during those dives (those onboard but not snorkeling or diving) are the figures of interest because many customers participate in multiple dives and pricing is based on the number of dives on a trip. From the pre-deployment to the post-deployment period, the results show an increase of 6.5% or 9701 dives by SCUBA divers; a decline of 10.7% or 3094 dives by snorkelers; and an increase of 169 other paying passengers, or an 8.9% increase in business from these customers (Table 2). In total, there was an increase of 6776 in the number of dives with paying customers, or a 3.7% increase in business. See Appendix 1 for more detailed and complete tables.

LOCAL ECONOMY.—The net changes in total recreational expenditures from the pre- to the post-deployment period indicate that there was an increase of \$2.6 million in total recreational expenditures, which generated a total impact on sales/output of \$2.7 million, \$961.8 thousand in local income, and the creation of 68 new jobs (Table 3). As expected, visitors accounted for a much larger share of this growth than residents (90% vs 10%, respectively). For more detailed results and to see the breakdown by artificial and natural reefs, please see Appendix 1.

DISCUSSION

We hypothesized that introducing an artificial reef by sinking a decommissioned ship would benefit the local environment, the local dive charter industry, and the larger local economy. Results from this case study are consistent with this hypothesis. Following the deployment of the SPIEGEL GROVE, recreational use of the surrounding natural reefs decreased, while the local dive charter business increased and the greater local economy grew in terms of both income and employment.

There are several caveats that should be noted when considering these results. As mentioned in the methods section, the analysis was constrained by the pre-deploy-

Table 2. Net changes in dive charter operation business following the deployment of the SPIEGEL GROVE.

Reef type	Absolute and percent change (dive charters)							
	Dives SCUBA	%	Snorkelers	%	All	%	Total	%
Natural reefs	-18,170	-14.6	-6,780	-27.7	-125	-8.2	-25,075	-16.7
Artificial reefs	27,872	108.3	3,686	81.8	294	75.4	31,852	104.0
Total	9,701	6.5	-3,094	10.7	169	8.9	6,776	3.7

Table 3. Net economic impacts of the deployment of the SPIEGEL GROVE.

	Visitors*	Residents	Total
Expenditures	\$2,152,318	\$458,094	\$2,610,412
Sales/output	\$2,410,596	\$320,666	\$2,731,262
Income	\$874,435	\$87,349	\$961,784
Employment	62	6	68

* Visitor impacts include multiplier impacts and resident impacts do not.

ment logbook data to the 10-mo period excluding June and July. Since approximately 25% of recreational use on natural and artificial reefs in the FKNMS occurs during these months, this is a limitation of the study. If use patterns and the ratios of participating dive operation use to non-participating dive operation use and of dive charter use to non-dive charter use differ significantly during these months, as compared to the rest of the year, the conclusions could prove incorrect. Similarly, if the use patterns observed in the post-deployment period are attributable to the novelty of the SPIEGEL GROVE wreck, these patterns, and therefore the conclusions, may not hold true in the future.

The results show a 9.3% increase in total reef use (measured in dives/trips) from the pre- to the post-deployment period. However, the results also show a decrease in snorkeling on the reefs. Because the data exclude snorkeling concessions and glass-bottom boats, this figure should not be interpreted as a decline in the absolute number of snorkelers on these reefs, but rather as a decline in the share of dive charter business accounted for by snorkelers. In other words, as dive charters concentrate their trips more on artificial reefs, which tend to be rather inaccessible to snorkelers, those interested in snorkeling are more likely to seek out snorkeling concessionaires. This means that the estimates of total recreational reef use may be biased downwards. However, if one assumes that snorkeling concessions capture the full decline in natural reef snorkeling on dive charter boats, the overall conclusions still hold.

In drawing the conclusion that the sinking of the SPIEGEL GROVE resulted in positive ecological benefits, only the effects of pressure from recreational use on natural reefs were considered, not the ecological effects of introducing new habitat in the form of an artificial reef. Given that decommissioned ships are thoroughly cleaned and all hazardous materials removed prior to sinking, it is difficult to imagine that the introduction of such an artificial reef could have negative ecological impacts. Still, the exclusion of habitat impacts from the analysis should be considered when interpreting the results. The ecological monitoring by R.E.E.F. for the FKNMS will give a more complete answer as to the ecological effects of the SPIEGEL GROVE.

The estimates of economic impact are based on models whose parameters were developed using data from the 1997 economic census. Attempts were made to update these models using 2002 economic census data; however, these data are not yet available from the U.S. Bureau of the Census. More recent numbers clearly would be desirable, but the impact on our estimates would be expected to be minor. It could be argued that we cannot attribute the increase in total use and the corresponding increases in dive business and the local economy to the SPIEGEL GROVE. However, review of the increase in total Monroe County sales revenue for the two 10-mo periods (State of Florida, Department of Revenue, 2003) reveals that revenue growth for the whole county actually declined from \$2.542 billion to \$2.515 billion, or 1.06%, while the total amount of sales/output increase due to total reef use estimated in the Key

Largo area of the county was 10.87%. Although not definitive evidence, we maintain that the majority of the increase can be attributed to the SPIEGEL GROVE.

It is important to note that the results of this study depend heavily upon the attributes of the local marine ecosystem, its individual reef sites, and the SPIEGEL GROVE reef site. Consequently, the conclusions may apply to other locations only inasmuch as those locations have similar attributes. The Key Largo area is a mature dive market with many different artificial and natural reefs. One would not expect large percentage increases in total use in such a mature market.

We were not able to estimate changes in net economic user value or consumer's surplus. In Johns et al. (2003a), it was found that the net economic user value per person-day was higher, on average, for natural reefs than for artificial reefs. However, one cannot simply apply the averages for the artificial reefs and natural reefs to assess the net economic gain or loss from the introduction of the SPIEGEL GROVE because economic theory would suggest that the observation that people chose to use the SPIEGEL GROVE rather than a natural reef indicates that the SPIEGEL GROVE was the highest valued alternative. What is needed is a model to estimate the value of recreational use of reef based on reef attributes, controlling for user characteristics. Such a model would yield estimates of economic user value that would allow for differentiating artificial and natural reefs with different attributes. Newness may be an attribute and the novelty of the SPIEGEL GROVE could wear off and user patterns could revert back to pre-deployment. To answer this question will require future monitoring.

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Appendix 1.

Reef use before and after the deployment of the SPIEGEL GROVE. *This includes those who went out on charter or other boats but who did not participate in any further activity, as well as those who participated in fishing.

Pre-deployment totals								
Reef Type	Dives SCUBA	%	Dives snorkelers	%	All others*	%	Total	%
Natural reefs	139,895	82.9	101,448	93.0	32,948	86.3	274,290	86.8
Artificial reefs	28,890	17.1	7,666	7.0	5,221	13.7	41,778	13.2
Total	168,785	100.0	109,114	100.0	38,169	100.0	316,068	100.0
Post-deployment totals								
Reef type	Dives SCUBA	%	Dives snorkelers	%	All others*	%	Total	%
Natural reefs	122,060	66.0	75,375	74.0	39,317	67.0	236,753	68.5
Artificial reefs	63,001	34.0	26,453	26.0	19,383	33.0	108,836	31.5
SPIEGEL GROVE	26,045	14.1	1,657	1.6	684	1.2	28,386	8.2
Total	185,061	100.0	101,828	100.0	58,700	100.0	345,589	100.0
Absolute and percent change								
Reef type	Dives SCUBA	%	Dives snorkelers	%	All others*	%	Total	%
Natural reefs	-17,834	-12.7	-26,072	-25.7	6,370	19.3	-37,537	-13.7
Artificial reefs	34,110	118.1	-18,786	245.1	14,162	271.2	67,059	160.5
Total	16,276	9.6	-7,286	-6.7	20,532	53.8	29,522	9.3

Dive charter reef use before and after the deployment of SPIEGEL GROVE. *This includes those who went out on charter or other boats, but who did not participate in any further activity, as well as those who participated in fishing.

Pre-deployment totals								
Reef type	Dives SCUBA	%	Dives snorkelers	%	All others*	%	Total	%
Natural reefs	124,388	82.9	24,498	84.5	1,517	79.6	150,403	86.8
Artificial reefs	25,744	17.1	4,504	15.5	389	20.4	30,638	13.2
Total	150,132	100.0	29,002	100.0	1,906	100.0	181,041	100.0
Post-deployment totals								
Reef type	Dives SCUBA	%	Dives snorkelers	%	All others*	%	Total	%
Natural reefs	106,218	66.5	17,718	68.4	1,392	67.1	125,328	68.5
Artificial reefs	53,616	33.5	8,190	31.6	683	32.9	62,489	31.5
SPIEGEL GROVE	21,888	13.7	295	1.1	138	6.7	22,321	8.2
Total	159,834	100.0	25,908	100.0	2,075	100.0	187,817	100.0
Absolute and percent change (dive charters)								
Reef type	Dives SCUBA	%	Dives snorkelers	%	All others*	%	Total	%
Natural reefs	-18,170	-14.6	-6,780	-27.7	-125	-8.2	-25,075	-16.7
Artificial reefs	27,872	108.3	3,686	81.8	294	75.4	31,852	104.0
Total	9,701	6.5	-3,094	-10.7	169	8.9	6,776	3.7

Appendix 1. Continued.

Monroe county economic impact of recreational natural reef use before and after sinking of the SPIEGEL GROVE.

	Pre-deployment		
	Visitors	Residents	Total
Expenditures	\$17,335,332	\$1,992,737	\$19,328,068
Sales/output	\$19,415,571	\$1,394,916	\$20,810,487
Income	\$7,215,954	\$398,141	\$7,614,095
Employment	512	30	542
	Post-deployment		
	Visitors	Residents	Total
Expenditures	\$14,853,943	\$1,826,422	\$16,680,365
Sales/output	\$16,636,416	\$1,278,496	\$17,914,912
Income	\$6,161,575	\$362,613	\$6,524,188
Employment	437	27	464
	Net		
	Visitors	Residents	Total
Expenditures	-\$2,481,388	-\$166,314	-\$2,647,703
Sales/output	-\$2,779,155	-\$166,420	-\$2,895,575
Income	-\$1,054,379	-\$35,528	-\$1,089,908
Employment	-75	-3	-78

Monroe county economic impact of recreational artificial reef use before and after sinking of the SPIEGEL GROVE.

	Pre-deployment		
	Visitors	Residents	Total
Expenditures	\$3,712,577	\$213,249	\$3,925,825
Sales/output	\$4,158,086	\$149,274	\$4,307,360
Income	\$1,564,478	\$41,625	\$1,606,103
Employment	111	3	114
	Post-deployment		
	Visitors	Residents	Total
Expenditures	\$8,346,283	\$837,657	\$9,183,940
Sales/output	\$9,347,837	\$586,360	\$9,934,197
Income	\$3,493,292	\$164,503	\$3,657,795
Employment	248	12	260
	Net		
	Visitors	Residents	Total
Expenditures	\$4,633,707	\$624,408	\$5,258,115
Sales/output	\$5,189,751	\$437,086	\$5,626,837
Income	\$1,928,814	\$122,877	\$2,051,691
Employment	137	9	146

Appendix 1. Continued.

Monroe county economic impact of total recreational reef use before and after sinking of the SPIEGEL GROVE.

	Pre-deployment		
	Visitors	Residents	Total
Expenditures	\$21,047,909	\$2,205,985	\$23,253,894
Sales/output	\$23,573,658	\$1,544,190	\$25,117,847
Income	\$8,780,432	\$439,766	\$9,220,199
Employment	623	33	656
	Post-deployment		
	Visitors	Residents	Total
Expenditures	\$23,200,227	\$2,664,079	\$25,864,306
Sales/output	\$25,984,254	\$1,864,855	\$27,849,109
Income	\$9,654,867	\$527,115	\$10,181,982
Employment	685	39	724
	Net		
	Visitors	Residents	Total
Expenditures	\$2,152,318	\$458,094	\$2,610,412
Sales/output	\$2,410,596	\$320,666	\$2,731,262
Income	\$874,435	\$87,349	\$961,784
Employment	62	6	68