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COMPARISON OF CATCH AND RECREATIONAL ANGLERS FISHING ON ARTIFICIAL REEFS AND NATURAL SEABED IN GULF ST. VINCENT, SOUTH AUSTRALIA

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ABSTRACT

The ability of artificial reefs to enhance fishing success was evaluated in Gulf St. Vincent, South Australia. A 12-month creel survey provided data on the utilization, catch composition and catch rates of anglers fishing over artificial tire reefs and adjacent natural seabed sites. A low percentage of anglers (6.4%) fished on the artificial reefs, although the fishing intensity (angler-hours per unit area) was 92–171 times higher than for surrounding natural seabed areas. Effort was seasonably variable and significantly higher on weekends than weekdays. Catch rates of abundant taxa were compared between artificial and natural sites. Of 27 comparisons, 5 yielded significantly higher catch rates on artificial habitats and 9 on natural sites; the remainder were not significantly different. Artificial habitats showed enhanced catch rates of pelagic species while natural seabed favored demersal taxa. The artificial reefs yielded 7.5% of the total catch of the study area. Higher taxon richness was recorded for natural seabed areas than for artificial reefs (47 and 29 taxa respectively), with 18 taxa recorded as being unique to natural seabed areas. Shannon-Wiener diversity was significantly higher for all natural habitats when compared to artificial habitats, for both individual and pooled data, and showed a significant positive correlation with species richness.

One of the primary objectives of artificial habitat development and implementation has been the enhancement of fishing (Ambrose and Swarbrick, 1989; Milon, 1988, 1989; Stone et al., 1991), particularly recreational fishing around these structures (Radonski et al., 1985; Wilson, 1991). Enhancement of recreational fishing can conceivably be achieved in two ways. Firstly, artificial reefs can increase the total habitat available for the production of sought-after species, thereby increasing the total potential catch (Solonsky, 1985). Evaluation of this type of enhancement is possible where catch data are available before and after artificial reef deployment (Polovina and Sakai, 1989).

Secondly, artificial reefs may provide fishing locations that are superior to natural areas, by concentrating target species at abundances greater than those occurring naturally. This is often the aim of placing artificial habitats in areas of otherwise low productivity and devoid of natural topographic features. Recreational anglers in Florida recognized this aspect by giving a "better chance of harvesting fish" the highest importance rating when giving their reasons for choosing to fish on artificial reefs (Milon, 1989). Comparison of catch data from artificial habitats and adjacent natural seabed can be used to evaluate this method of fishing enhancement.

While many marine studies have compared artificial and natural reefs in terms of fish biomass, abundance, density and community composition (reviewed by Bohnsack and Sutherland, 1985; bibliography by Aiken, 1986; Alevizon and Gorham, 1989; Hueckel and Buckley, 1989; DeMartini et al., 1989), fewer have evaluated the enhanced fishing objective by comparing catch rates (Turner et al., 1969; Buchanan, 1973; Wickham et al., 1973; Crumpton and Wilbur, 1974, and Fast, 1974, both cited in Bohnsack and Sutherland, 1985; Milon, 1988; Buckley

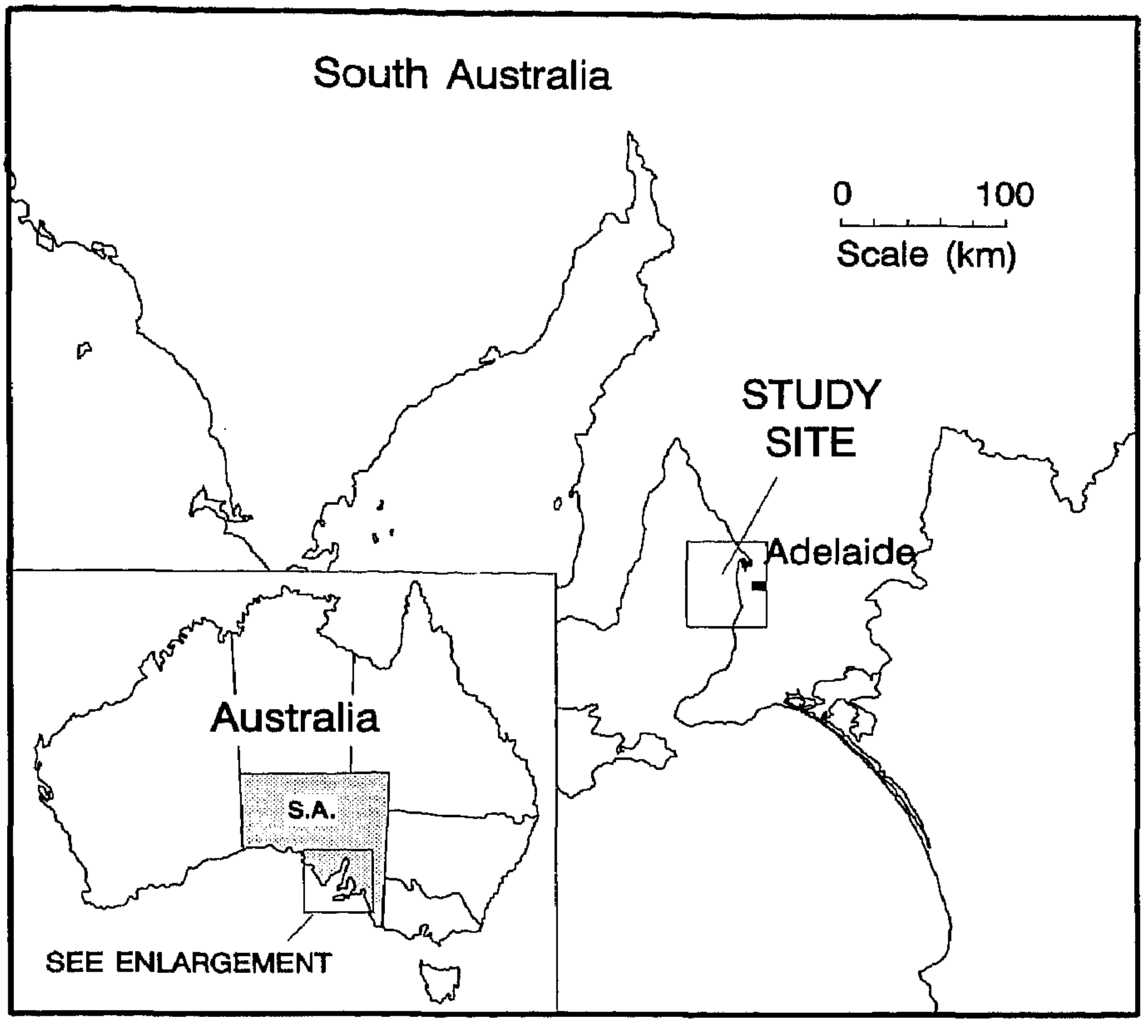

Figure 1. Location of study site in Gulf St. Vincent, South Australia.

et al., 1989; Feigenbaum et al., 1989a, 1989b). No comparative studies have been undertaken on Australian artificial reefs.

Artificial reef developments in the Australian region have recently been reviewed by Pollard (1989) and Branden et al. (1994), including descriptions of an extensive tire reef program in South Australia. Other accounts of this program can be found in Olsen et al. (1976) and Branden and Reimers (1987). The tire reefs were constructed of tetrahedron shaped modules of 28 tires, secured together and weighted down by concrete in the basal tires (Pollard, 1989). Individual modules stand approximately 1.8 meters high and 3 m^3 in volume.

Three of these tire reefs were placed in Gulf St. Vincent near Adelaide, South Australia (Fig. 1) in 1984, and are known as the Grange, Glenelg and Port Noarlunga tire reefs respectively (Table 1). Glenelg tire reef is supplemented by two 50-meter sunken vessels located approximately 800 meters away. Although fish and algal colonization have been studied on these tire reefs (Reimers and Branden, 1994), this is the first study to assess their effectiveness in terms of enhancement of recreational fishing.

The inshore waters of Gulf St. Vincent adjacent to Adelaide support about 38% of the recreational marine boat angling effort in South Australia (Philipson et al., 1986). This study seeks to quantify and compare the effort, catch rates and catch composition of this group of anglers on the artificial tire reefs and surrounding natural seabed over a 1-year period.

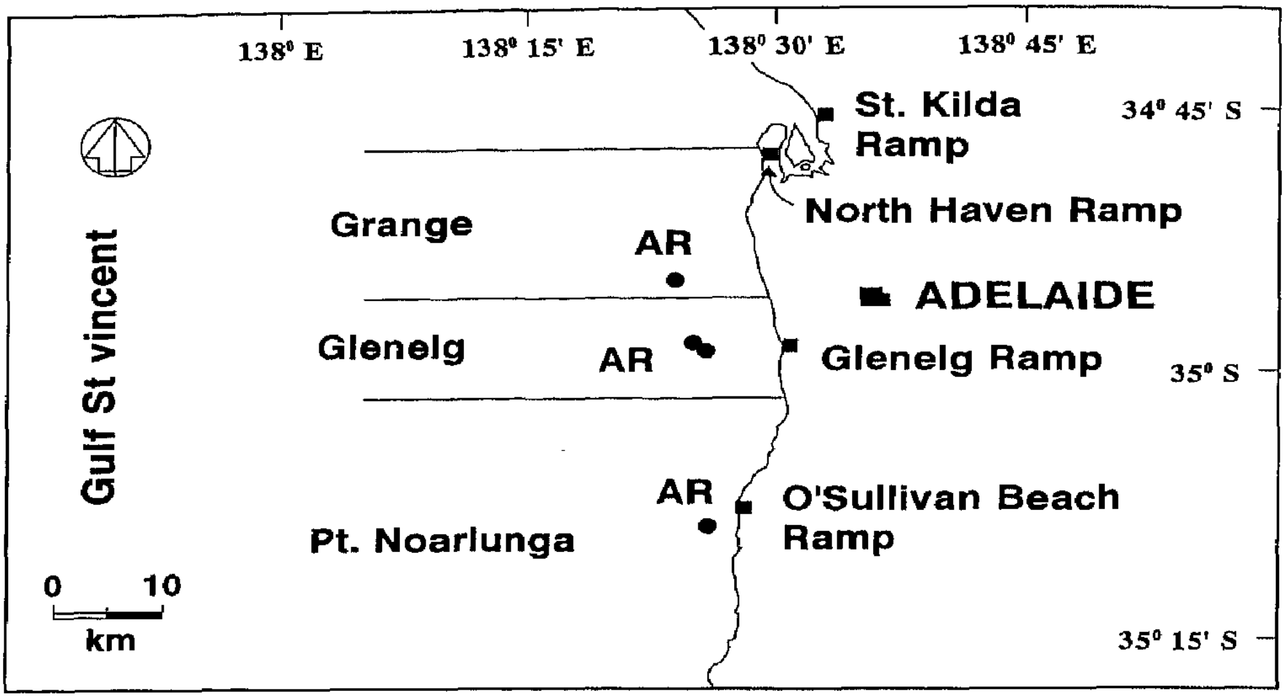

Figure 2. Details of study site showing location of artificial habitats (AR) within the creel survey sub-regions (Grange, Glenelg and Port Noarlunga). The locations of the four boat launching ramps used as data collection points are also shown.

Methods and Materials

Study Site.—Gulf St. Vincent is an inverse estuary of approximately 6.8×10^3 km^2 (Bye, 1976), lying between latitudes 34°10′S and 35°40′S. The study site consists of a section of the Gulf on the eastern coast, with a coastal length of approximately 105 kilometers and extending 15 kilometers to the sea (Fig. 2).

The seabed of Gulf St. Vincent has been described by Shepherd and Sprigg (1976). The northern region of the study site is dominated by *Posidonia australis* seagrass meadows in the inshore areas, with ascidian-scallop assemblages common offshore. The southern region has ascidian-scallop assemblages inshore, with bryozoan or hammer oyster (*Malleus meridianus*)-razorfish (*Pinna* sp.) assemblages offshore. The approximate area of these habitats within the present study site are ascidian-scallop (35%), seagrass meadows (25%), bryozoan (20%), oyster-razorfish (20%) and sand (5%). Low relief reefs of kunkarised shell beds occur irregularly throughout the study site.

Data Collection.—An access point creel survey was conducted from September, 1990 to August, 1991, with a total of 4,826 interviews being conducted on 41 sampling days. The methodology is described in detail elsewhere (McGlennon, 1992) but a brief summary is given here. The study site was divided into six sub-regions, three of which contain artificial tire reefs (Fig. 2). Only data for these three sub-regions have been included in this paper, and comparisons are made between the individual reef and the sub-region in which it is placed. As Port Noarlunga tire reef is located close to the boundary of regions 5 and 6 (McGlennon, 1992), data from these regions have been combined.

Four of the major boat launching facilities in Adelaide are located within the study site (Fig. 2), and served as the access points of data collection. Sampling was conducted on four randomly chosen days per month, stratified into 2 weekdays and 2 weekend-days. Interviews were conducted between 1200 and 1800 at each ramp on each day to maximize the number of interviews per sampling day. Anglers returning from their fishing trip provided data on their fishing location, fishing time and species and numbers retained.

Data Analysis.—Sampling days where no activity was recorded were not repeated, resulting in an unbalanced design for some analyses.

a) *Fishing Effort.*—Four temporal and spatial aspects of recreational fishing effort were analyzed: comparative use of each reef, relative use of each reef between different day-types (weekdays and weekend-days), seasonal trends in use of each reef and relative fishing intensity on the artificial and natural habitats.

As the number of anglers interviewed in each sub-region varied significantly, the analyses of fishing effort were made on data of the proportional use of each artificial reef and its surrounding

Table 1. Summary of habitat type, loccation and area of artificial habitats in Gulf St. Vincent near Adelaide, South Australia

Location	Habitat type	1) Latitude 2) Longitude	Area* (m^2)
Grange	tyre modules (1,200)	1) 34°55.1'S 2) 138°24'E	83,200
Glenelg	tyre modules (900)	1) 34°58.8'S 2) 138°26.4'E	78,000
	sunken vessels (2)	1) 34°58.4'S 2) 138°26.4'E	114,400
Port Noarlunga	tyre modules (650)	1) 35°05.2'S 2) 138°26.5'E	73,840

* Area includes enhanced fishing zone of 100 m around each habitat.

sub-region. The proportional data were transformed using an arcsine-type transformation recommended for data with small and large proportions (Eq. 14.5, Zar, 1984).

Fishing effort on each reef and the relative use of each reef on different day-types were analyzed with a two-factor (tire reef and day-type) Model I ANOVA, using a general linear model suitable for unbalanced designs (SAS Institute Inc., 1988). The data used were the means obtained from each of the 12 monthly samples of the creel survey. Seasonal trends in the monthly data were analyzed using a goodness-of-fit procedure, the log likelihood ratio (G statistic), to test whether proportional use was consistent throughout the year for each reef.

Fishing intensity was calculated by dividing the annual effort estimates (McGlennon, 1992) for each artificial reef or sub-region by its area (angler-hours·1,000 m^{-2}). The area of influence of an artificial habitat extends beyond its physical limits, giving rise to an enhanced fishing zone which is generally downcurrent of the habitat (Bohnsack and Sutherland, 1985). Because the tire reefs are subject to four tidal movements per day, as well as longshore currents, the enhanced fishing zone has been assumed to exist equally around the habitat and has been set at 100 meters (Bohnsack and Sutherland, 1985) (Table 1). Areas for the natural seabed sub-regions ranged from 158 km^2 to 476 km^2 (Table 1).

b) *Catch Rates.*—Catch rates (fish·angler-hour^{-1}) of the 12 most abundant taxa were compared between individual tire reefs and their surrounding sub-region, as spatial variation in catch rates existed between sub-regions for some species (McGlennon, 1992). The 12 taxa included 4 demersal teleosts, 5 pelagic/midwater teleosts, 1 cephalopod and 2 benthic decapod crustaceans, representing 98.8% of the recorded catch. As the distribution of catch rate data for each taxon was highly positively skewed, due to a large number of responses where catch = 0, the catch rates were analyzed using the non-parametric Kruskal-Wallis test (SAS Institute Inc., 1988), with the test statistic corrected for tied ranks (Eq. 11.31, Zar, 1984).

c) *Catch Composition.*—The diversity of species caught from each site was measured by calculating the Shannon-Wiener diversity index (H') and its components the species richness index (D) and the species evenness index (J) (Legendre and Legendre, 1983).

Shannon-Weiner diversity: $$H' = n \log n - \sum_{i=1}^{k} f_i \log f_i,$$

Species richness: $$D = s - 1/\log n, \quad \text{and}$$

Species evenness: $$J = H'/\log S,$$

where f_i is the frequency of each taxon, n is the total number of individuals and S is the number of taxa.

Values of H' were compared between 1) each artificial habitat and its surrounding natural sub-region and 2) the pooled data of three artificial habitats and three natural sub-regions by *t*-test (Zar, 1984).

RESULTS

Fishing Effort.—Mean monthly fishing effort varied significantly between the three artificial habitats ($F = 10.15$, $df = 2$, $P < 0.001$), ranging from 1.6% (±0.6 SE) at Port Noarlunga to 11.3% (±2.0 SE) at Glenelg (Table 2). Effort

Table 2. Summary of relative effort (x ± SE) by recreational anglers for three artificial habitats in Gulf St. Vincent, South Australia. Figures represent the proportion of effort expended on the artificial habitats compared to effort in the adjacent natural seabed area. Study areas are shown in Figure 2.

Location	Monthly effort (%)	Day-type effort (%) Weekday	Day-type effort (%) Weekend
Grange	6.2 ± 1.6	3.0 ± 4.4	5.9 ± 4.5
Glenelg	11.3 ± 2.0	4.1 ± 8.1	18.0 ± 9.2
Pt. Noarlunga	1.6 ± 0.6	0.9 ± 1.4	1.6 ± 2.8
Factor	**DF**	**F**	**Significance**
Location	2	10.15	P < 0.001
Day-type	1	16.03	P < 0.001
Location* Day-type	2	7.12	0.05 > P > 0.01

also varied significantly between day-types (F = 14.91, df = 1, $P < 0.001$), with weekend use consistently higher for all reefs (Table 2). However, an interaction effect between reef location and day-type was also statistically significant (F = 7.12, df = 2, $P < 0.001$), indicating that the relative use of these artificial reefs during the week and weekend varied with location (Table 2).

Comparisons of seasonal use of each reef showed statistically significant variation between months at all reefs (Grange: G = 538.9, $P < 0.001$; Glenelg: G = 374.0, $P < 0.001$; Port Noarlunga: G = 355.5, $P < 0.001$), indicating that temporal use varied substantially. However, the seasonal trends were not consistent between reefs and showed no pattern within reefs (Fig. 3). Fishing intensity was substantially higher for all artificial habitats than for their surrounding natural seabed sub-regions (Table 3), with comparative values of 92–171 times greater intensity.

Catch Rates.—Taxon-specific comparisons between each artificial reef and its surrounding natural seabed, for the 12 most abundant taxa, showed 14 significant differences (Table 4). Three teleosts recorded greater catch rates on artificial habitats; the demersal red mullet (*U. vlamingii*), and the two pelagic species, blue mackeral (*S. australasicus*), and trevally *Pseudocaranx* spp.). Both crustaceans (*P. pelagicus* and *O. australiensis*), the squid (*S. australis*), 2 demersal teleosts (*Haletta semifasciata* and Monacanthidae) and 1 pelagic teleost (*A. truttacea*) recorded greater catch rates from natural seabed.

However, the significance of some of these comparisons was site specific, with comparisons for the same taxa at other sites showing no difference. Absolute catches of some taxa were low at some sites (Table 5) and caution should be used in their interpretation.

Catch Composition.—The total number of taxa recorded from natural seabed fishing sub-regions (47) exceeded those from artificial habitats (29) (Table 5). No taxa were recorded exclusively from artificial habitats, while 18 taxa were only caught on natural seabed. However, most of these taxa were relatively rare (N < 20 individuals), with only the pelagic species snook, *Sphyraena novaehollandiae,* and barracouta, *Thyrsites atun,* exceeding 50 individuals.

Shannon-Wiener diversity values ranged from 0.81 to 0.94 for natural habitats, and from 0.77 to 0.80 for artificial habitats (Table 6). All comparisons of H′ between individual artificial habitats and adjacent natural seabed, and between pooled artificial habitats and natural seabed, showed significantly greater diversity in the catches from natural seabed (Table 6).

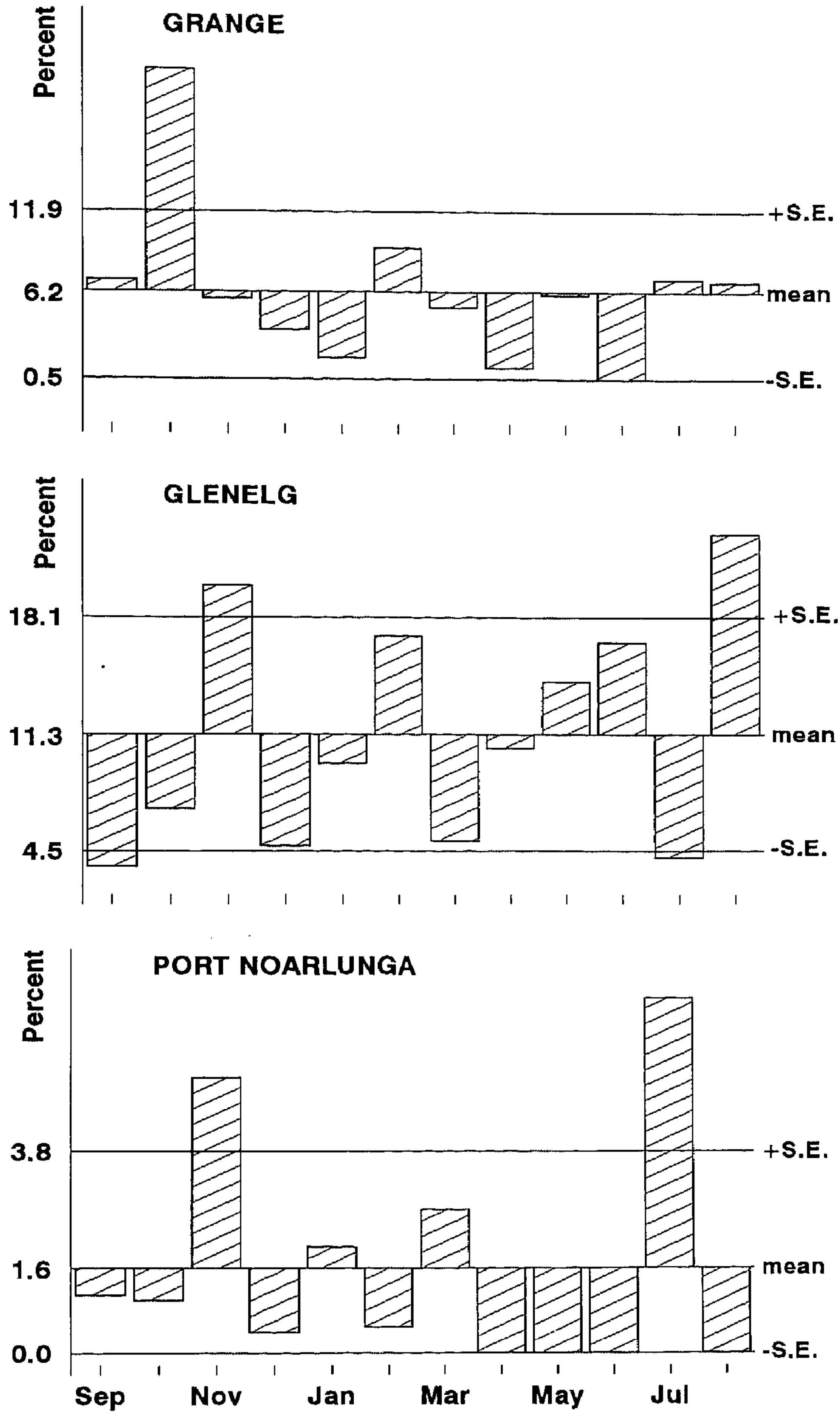

Figure 3. The proportional use (%) of each artificial habitat is shown as a deviation from the mean value for that site. Mean and standard error (SE) percentages are shown on the y-axis.

Table 3. Summary of comparative fishing pressure on each artificial habitat and the adjacent natural seabed. Values are annual estimates for the duration of the creel survey period, September 1990 to August 1991 (McGlennon and Evans, in press).

Location	Habitat	Hours (No.)	Intensity (h·1,000 m^{-2})	Ratio
Grange	Artificial	5,495	66.05	171.1
	Natural	91,187	0.39	
Glenelg	Artificial	11,064	57.51	92.8
	Natural	98,079	0.62	
Port Noarlunga	Artificial	1,352	18.31	100.6
	Natural	86,749	0.18	

Species richness values ranged from 8.36 to 11.15 for natural seabed catches, and from 6.0 to 8.47 for artificial habitats. Natural seabed values were invariably higher than those for the corresponding artificial habitats, for both individual and pooled data. Species evenness values, on the other hand, were consistently lower at natural seabed sites (range 0.51 to 0.56) than at artificial habitats (range 0.55 to 0.70).

Shannon-Wiener diversity showed a significant positive correlation with species richness ($r = 0.93$, $P < 0.001$) but was not significantly correlated with species evenness ($r = -0.32$, $0.5 > P > 0.02$).

Discussion

The South Australian metropolitan creel survey has allowed a comprehensive comparative analysis of recreational marine fishing catch and effort from artificial and natural reefs in eastern Gulf St. Vincent. Although the results would be a biased record of the actual community composition of both natural and artificial habitats (due to angler preferences and gear selectivity), they provide an excellent indicator of the effectiveness of these artificial habitats in enhancing fishing success.

Relative effort between the artificial habitats and surrounding natural seabed areas varied substantially between artificial reefs. The low usage rate of Port Noarlunga tire reef may be due to its low yield, particularly of King George whiting, *Sillaginodes punctata,* which is a primary target species for 63% of the anglers interviewed (McGlennon, 1992). Milon (1988) has reported anglers' preference for sites with higher average yields and greater variation in yield.

However, this does not explain the significant difference in proportional effort levels for the Grange and Glenelg artificial reefs, as their catch rates are similar for most target species. Further, both sites are located about five km from the nearest launching site, suggesting that travel cost and time are unlikely to be determining factors (cf. Milon, 1988; Bockstael et al., 1986, cited in Milon, 1989).

Other factors may contribute to the disparity in use between the Grange and Glenelg reefs. Grange tire reef is subject to the highest fishing intensity recorded in this study. This spatial concentration may set an upper limit on the number of anglers that can fish on the site before fishing success is adversely affected to the extent that other sites are chosen.

Additionally, the survey sub-region surrounding Grange tire reef contains at least one other large, well-known natural reef, whereas the sub-region around Glenelg contains smaller natural reefs that are not easy to locate for less expe-

Table 4. Mean catch rates (fish·anglerhour^{-1}) of the 12 most abundant taxa caught by recreational anglers from three artificial habitats (AR) and their adjacent natural seabed sub-regions (NR) in Gulf St. Vincent, South Australia. Catch rates were compared with the non-parametric Kruskal-Wallis test, corrected for the ties (H_c). The critical H value is approximated by $\chi^2_{(0.05,1)}$ = 3.841 (Zar, 1984). Significance levels; * $0.05 < P < 0.01$, ** $0.01 < P < 0.001$, *** $P < 0.001$, NS not significant, N/A no catch recorded.

	Grange				Glenelg				Pt. Noarlunga			
Taxon	AR	NR	H_c	Sig.	AR	NR	H_c	Sig.	AR	NR	H_c	Sig.
Teleostomi												
S. punctata	0.78	0.73	3.28	NS	0.76	0.84	2.22	NS	0.06†	0.44	5.14	**
A. georgianus	0.39	0.34	0.33	NS	0.19	0.23	0.08	NS	0.39	0.26	0.13	NS
H. melanochir	0.23	0.23	0.08	NS	0.40	0.23	3.56	NS	0.01†	0.08	2.25	NS
U. vlamingii	0.02	0.01	65.8	***	0.09	0.04	1.26	NS	0.03	0.04	1.62	NS
Haletta semifasciata	0.01†	0.04	7.12	**	0.01†	0.02	11.2	***	N/A	N/A		
Monacanthidae	0.16	0.09	1.69	NS	0.12	0.25	9.36	**	0.01†	0.15	5.75	*
A. truttaceus	0.00	0.01	0.65	NS	0.00	0.01	0.47	NS	0.07	0.07	17.0	***
S. australasicus	0.05	0.03	5.92	**	0.10	0.06	59.6	***	N/A	N/A		
Pseudocaranx spp.	0.06	0.05	20.0	***	0.09	0.01	59.0	***	N/A	N/A		
Cephalopoda												
S. australis	0.10	0.19	0.45	NS	0.11	0.12	4.28	*	0.08	0.11	0.92	NS
Decapoda												
P. pelagicus	0.04	0.04	12.4	***	N/A	N/A			N/A	N/A		
O. australiensis	N/A	N/A			N/A	N/A			0.01	0.03	4.29	*

† Indicates the number of fish recorded was less than 10 individuals for that habitat.

Table 5. Summary of taxa recorded in the catch of marine recreational anglers in eastern Gulf St. Vincent, South Australia. Values are the percentages of individuals caught on artificial and natural habitats, and the total number of individuals caught. * Signifies no catch recorded.

Taxon	Artificial habitat (%)	Natural seabed (%)	Number of fish
Elasmobranchii			
Triakidae			
Gummy shark			
Mustelus antarcticus	33.33	66.67	6
Carcharhinidae			
Bronze whaler shark			
Carcharhinus brachyurus	11.11	88.89	9
Sphyrnidae			
Hammerhead shark			
Sphyrna sp.	*	100.00	1
Heterodontidae			
Port Jackson shark			
Heterodontus portusjacksoni	5.26	94.74	19
Other	6.25	93.75	16
Teleostomi			
Arripidae			
Tommy ruff			
Arripis georgianus	5.92	94.08	8,788
Australian salmon			
Arripis truttacea	2.49	97.51	643
Berycidae			
Red Snapper			
Centroberyx gerrardi	*	100.00	2
Carangidae			
Silver trevally			
Pseudocaranax spp.	10.65	89.35	939
Yellow kingfish			
Seriola lalandi	*	100.00	9
Yellowtail scad			
Trachurus novaezelandiae	4.23	95.77	142
Centrolophidae			
Warehou			
Seriolella brama	3.23	96.77	31
Cheilodactylidae			
Magpie perch			
Cheilodactylus nigripes	*	100.00	3
Dusky morwong			
Dactylophora nigricans	15.38	84.62	26
Dinolestidae			
Long-finned pike			
Dinolestes lewini	*	100.00	18
Enoplosidae			
Old wife			
Enoplosus armatus	*	100.00	1
Gempylidae			
Barracouta			
Thyrsites atun	*	100.00	56
Gerridae			
Silverbelly lowfin			
Parequula melbournensis	*	100.00	21
Hemirhamphidae			
Sea garfish			
Hyporhamphus melanochir	10.79	89.21	6,247

Table 5. Continued

Taxon	Artificial habitat (%)	Natural seabed (%)	Number of fish
Kyphosidae			
Drummer			
Kyphosus sydneyanus	25,00	75.00	4
Labridae	16.67	83.33	6
Mugilidae	6.25	93.75	80
Mullidae			
Red mullet			
Upeneichthys lineatus	10.47	89.53	850
Odacidae			
Weedy whiting			
Haletta semifasciata	2.28	97.78	569
Ophidiidae			
Ling			
Genypterus spp.	*	100.00	2
Pempheridae			
Bullseye			
Pempheris spp.	*	100.00	6
Platycephalidae			
Flathead			
Platycephalus spp.	6.54	93.46	321
Plesiopidae			
Blue devil			
Paraplesiops meleagris	*	100.00	6
Pleuronectidae			
Greenback flounder			
Rhombosolea tapirina	*	100.00	10
Plotosidae			
Estuary catfish			
Cnidoglanis macrocephalus	*	100.00	1
Pomacentridae			
Scalyfin			
Parma victoriae	*	100.00	1
Scombridae			
Blue mackeral			
Scomber australasicus	11.10	88.90	1,658
Scorpididae			
Sweep			
Scorpis sp.	8.82	91.18	34
Sillaginidae			
King George whiting			
Sillaginodes punctata	7.25	92.75	19,175
Silver whiting			
Sillago spp.†	0.52	99.48	577
Sparidae			
Bream			
Acanthopagrus butcheri	*	100.00	10
Snapper			
Pagrus auratus	5.55	94.45	36
Sphyraenidae			
Snook			
Sphyraena novaehollandiae	*	100.00	230
Tetraodontidae	33.33	66.67	3
Terapontidae			
Striped perch			
Pelates octolineatus	3.79	96.21	132
Zeidae			
Silver dory			
Cyttus australis	*	100.00	1
Other	6.25	93.75	80

Table 5. Continued

Taxon	Artificial habitat (%)	Natural seabed (%)	Number of fish
Decapoda			
Portunidae			
Blue swimmer crab *Portunus pelagicus*	5.63	94.37	480
Sand crab *Ovalipes australiensis*	0.28	99.72	352
Cephalopoda			
Lologinidae			
Southern calamary *Sepioteuthis australis*	4.79	95.21	3,509
Sepiidae			
Cuttlefish *Sepia apalma*	7.32	92.68	41
Octopodidae	*	100.00	2

† *Sillago* sp. consists of two species (*Sillago schomburgkii* and *S. bassensis*) which are often confused by anglers. The data have therefore been pooled.

rienced anglers. Milon (1988) reports that, all other factors being equal, preference is shown for natural habitat. The lower proportional use of Grange tire reef may therefore be due to maximal spatial concentration of anglers in addition to ready access to a nearby natural reef.

Relative use also varied between months of the year and days of the week. However, seasonal variation was not consistent between reefs and showed no discernible pattern within reefs, and factors influencing seasonal use have not been determined by this study. The higher relative use of all artificial reefs by weekend anglers than weekday anglers may be due to their ease of location for less experienced anglers, as the reefs were generally marked by surface buoys.

Only one other study could be found which has compared relative fishing effort between natural and artificial reefs. Buchanan (1973) recorded 35% of total angler-hours in his South Carolina study site were expended at one artificial reef, representing a fishing intensity of 14,000 times that for the adjacent natural seabed. Fishing intensity should, however, be dealt with cautiously. The comparison assumes that fishing pressure on the natural seabed is evenly distributed over the study site. This is often not the case, with fishing concentrated in a

Table 6. Summary of species diversity (H′), species evenness (J), and species richness (D), values for the recreational catches from artificial habitats and associated natural seabed sub-regions in Gulf St. Vincent. The *t*-statistics compare the species diversity of paired artificial and natural habitats, with significance levels the same as in Table 4.

Habitat	Reef type	H′	Sig. H′	J	D
Grange	Natural	0.81	**	0.52	8.36
	Artificial	0.77		0.58	6.25
Glenelg	Natural	0.81	*	0.51	8.62
	Artificial	0.77		0.57	6.77
Port Noarlunga	Natural	0.94	*	0.56	11.15
	Artificial	0.78		0.70	6.00
Pooled	Natural	0.87	***	0.51	10.51
	Artificial	0.80		0.55	8.47

number of sites where target species aggregate. The assumption therefore tends to overestimate the disparity in relative fishing pressures.

The catch rate comparisons of the present study yielded a surprising result. It was reasonable to assume a priori that species with a functional relationship with seabed reefs would have exhibited higher catch rates at the artificial habitats, rather than the natural seabed which is generally of low-relief. However, four out of six significant results in favor of artificial habitats were for two pelagic species, the scombrid *S. australasicus* and the carangid *Pseudocaranx* spp.

These species are carnivorous, feeding on zooplankton and small fish, and the advantage of the artificial habitats to them may therefore lie in the attraction of baitfish/prey species. Other interpretations should not be overlooked, however. For example, Beets (1989) found that carangids were most often associated with FADs, with or without seabed reefs, rather than seabed reefs alone. It is possible that the marker buoys and chains of the tire reefs act as FADs for these species.

The group of taxa recording higher catch rates on natural seabed areas include many with a functional relationship to seagrasses, including the two crustaceans, the squid and the teleost taxa *Haletta semifasciata* and sub-adult *A. truttacea*, and these would not necessarily be expected to show affinity for tire reefs. Much work remains to be done on the functional ecology of these reefs and their associated fauna.

Catch rate comparisons showed, therefore, that the effectiveness of artificial habitats, in terms of fishing enhancement, is species specific. Deployment decisions, including whether to proceed or not, and design features such as siting, size and structure, must consider the ecological requirements of the species that the habitat is intended to attract. An understanding of the relationship between the physical influence of the artificial reef and the associated biota (Bohnsack and Sutherland, 1985; Baynes and Szmant, 1989) is necessary to maximize fishery related objectives.

Other studies have compared catch rates on seabed artificial reefs. Turner et al. (1969), from limited data, recorded artificial reef fishing success at 2–3 times that of natural reefs. Beets (1989) conducted trolling over experimental reefs and recorded a significantly greater number of strikes and fish caught (5 and 2–3 times respectively) than that recorded from a control transect. Fiegenbaum et al. (1989a) recorded significantly higher CPUE ($kg{\cdot}rod{\cdot}h^{-1}$) for 2 of 3 artificial reefs compared to control sites. However, no significant differences in catch rates were recorded by Buchanan (1973) for recreational catches of demersal or pelagic species in South Carolina, or for commercial hook and line fishermen in Japan by Kanamori (1991).

The present study revealed a highly significant positive correlation between species diversity and richness. The greater diversity recorded from natural habitats is therefore a result of changes in catch composition rather than changes in the distribution of individuals per species. Legendre and Legendre (1983) have related the number of species with the number of niches available, enabling a further relationship to be formed between species diversity and diversity of the environment. It is intuitively reasonable, therefore, to expect greater diversity and richness from the natural seabed sub-regions which encompass seagrass meadows, bare sand, natural reefs and other varying habitats, than from the relatively homogeneous habitat provided by the tire reefs.

However, the greater species richness added little in terms of fishing enhancement as the occurrence of the major species, at least when ranked, was similar between associated natural and artificial habitats. Additionally, many of the species unique to natural habitats are of low eating or sportfishing value, and were caught in low numbers. The disparate fishing pressure between artificial and natural habitats may have contributed to the lower species richness recorded from artificial habitats, as some of the species recorded as unique to natural habitat have also been reported in divers' observations on the tire reefs (K. L. Branden, pers. obs.).

In conclusion, the artificial habitats of Gulf St. Vincent provide fishing sites that are intensively utilized by recreational boat anglers, appealing particularly to weekend anglers. Their effectiveness in enhancing fishing success is species specific and varies with location. The artificial habitats produce a catch composition of lower species diversity and richness than natural seabed sub-regions, although the relative abundance of major species is similar. The interaction of tire reefs with fish communities warrants additional study in order to further establish their functional and ecological roles.

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