Ecological Assessment of the HMCS Yukon Artificial Reef off San Diego, CA (USA)

by

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EXECUTIVE SUMMARY

The San Diego Oceans Foundation sank the HMCS Yukon, a decommissioned Canadian destroyer escort (~112m long), off San Diego in 2000 as an artificial reef to support diving recreation, fishing, scientific research and education. The Foundation then developed and conducted a volunteer based monitoring program of the Reef to determine the colonization of marine life on the ship over time and to gauge its ecological effects. The monitoring program is still ongoing and the Foundation plans to continue the program indefinitely. Here, I report the results of the monitoring program four years after the establishment of the Reef.

The program consisted of volunteer divers conducting fish counts on permanently established transect lines and photographing quadrats attached to the hull and deck. No data were collected inside the vessel for safety reasons. The volunteer aspect of the program met with mixed success. The volunteer program was successful as a pilot program for implementing fish and invertebrate studies using trained volunteers. The results indicate that fish count data were consistent among the most experienced fish counters. However, because the study was voluntary, sampling effort was random. This was especially a problem for the photo quadrats, which were not conducted frequently enough over an adequate period to detect temporal patterns other than seasonal. Regular sampling frequency is recommended for the future.

The species composition of the fish community on the Yukon has changed significantly since the inception of the monitoring program. Many of the species that first colonized the ship were species whose ambits are large and which likely move among nearby artificial and natural habitats. Secondary colonization of the ship is ongoing and consists of fish that are residential and have recruited to the ship and species whose ambits are generally smaller than the early colonizers but whose abundances are variable.

Sheephead and boccacio, two species that are highly targeted by commercial and sports fishers, successfully recruit onto the Yukon. Blacksmith, a non-targeted species, also appear to successfully recruit on the ship. Therefore, the Yukon provides recruitment and nursery habitat for these species. In addition, Wreck Alley, the network of artificial reefs that the Yukon is part of, may have synergistic beneficial effects by increasing forage areas and by serving as stepping-stones for mobile species between natural habitats located to the north and south.

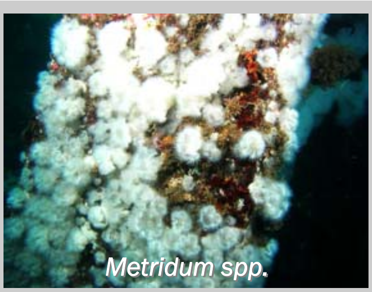
Comparisons to natural habitat in La Jolla indicate that the fish population on the Yukon is presently significantly less diverse. However, an increasing trend in species richness was observed which appears likely to continue at least over the short term. Therefore,


Juvenile boccacio


Terminal phase, sheephead

the fish community on the Yukon is still developing four years after reef establishment. The Yukon provides fish habitat that is a combination of deeper kelp-forest and canyon-rim habitat in southern California.

The fouling community on the Yukon is also still developing. There are presently abundant populations of the anenomes *Metridium* spp. and *Corynactis californica* over much of the ship. Comparisons of the fouling community, based on quadrat photos and my observations, with studies of other artificial reefs in southern California suggest that the fouling community on the Yukon is not yet successionally mature. This is evidenced by the lack of late successional-stage species such as gorgonians and turf algae. The algal community mainly consists of small stipitate kelps, flat bladed kelps, mats of filamentous diatoms, and recruits of two species of surface-canopy forming kelps (*Macrocystis pyrifera* and *Pelagophycus porra).* Although the ship supports these kelps, the Yukon does not appear to provide suitable substrate to support the development of a kelp forest because giant kelp cannot attach firmly to the hull. It is also apparent that anti-fouling paint is precluding colonization of both invertebrates and algae on some areas of the hull.



Metridium spp.

Corynactis californica

Due to limited resources, the Yukon monitoring program was not designed to address the issue of whether the Reef was beneficial for enhancing fish production over an area larger than the ship. The controversy over whether artificial reefs increase regional fish production or whether they lead to the concentration of fish into 'kill zones' and are therefore detrimental to fish on natural habitats is still the subject of much scientific debate. The role of the Yukon and the other artificial reefs in the area as enhancers or attractors is not known because no comprehensive studies have been conducted to specifically address this issue. Therefore, comprehensive studies of this artificial reef network are needed to determine whether these reefs are beneficial or harmful to natural populations.

BACKGROUND

Artificial Reefs

Fishers have used artificial reefs and other forms of habitat enhancement for centuries. The use of artificial reefs has increased tremendously in the last fifty years intended both as a means of mitigating human effects on marine ecosystems and as a means of disposal. As a tool for mitigation, artificial reefs are generally intended to mitigate overfishing and habitat degradation. Artificial reefs are also a by-product of other human activities not intended for mitigation such as shoreline development (jetties, piers, and breakwaters), energy production (e.g., oil rigs, cooling systems), waste disposal (armored sewer pipes, ships), and military conflict (shipwrecks).

Most artificial reefs have been established to enhance marine resources. However, while there is much evidence that artificial reefs can increase catch in the immediate vicinity

(Bohnsack et al. 1991), there is still much scientific debate over the utility of artificial reefs for the enhancement of regional fish production (e.g., Bohnsack 1989, Polovina 1991, Grossman et al. 1997). Central to this debate is the so-called 'production-attraction' controversy. This controversy is centered on the question whether artificial reefs actually increase regional production or whether they serve simply to redistribute fish via attraction thereby concentrating fish into 'kill zones'. It is likely that there is a continuum between these extremes, and every artificial reef lies somewhere along this continuum. The production/attraction debate is only relevant for mobile (non-residential) species for which redistribution is possible. There is ample evidence that artificial reefs support residential and sessile (attached) species (e.g., oil rigs, Wolfson et al. 1979, Love et al. 1999). Species most likely to benefit from artificial reefs are those having limited natural habitat (Pickering & Whitmarsh 1997). Therefore, the assumption that fish production is limited by resources provided by natural habitat underlies the motivation for most artificial reef development (Patton et al. 1985).

The Southern California Bight is presently dominated by sand relative to historical interglacial periods when sea level was up to ~100 meters lower and the proportion of rocky-hard bottom was much greater than it is today (Graham et al. 2002). Since most species of recreational and commercial interest are associated with hard bottoms in southern California, it is likely that natural habitat for many of these species is presently limited. Therefore, there is at least historical evidence that artificial reefs may be regionally beneficial in the Southern California Bight. Further evidence that artificial reefs may be beneficial in southern California is provided by a bight-wide habitat valuation study (Bond et al. 1999) in which shallow artificial reefs were second in habitat value only to kelp forests.

Effective enhancement of fish production in southern California utilizing artificial habitats is still in its infancy and should be approached using a staged process. First, studies testing whether artificial habitats could be regionally beneficial using scientifically defensible pilot programs are needed. Then, if artificial habitats appear beneficial, optimal designs for these habitats and networks of habitats must be developed. These efforts are already well underway in Japan in which a federally subsidized artificial habitat program is an integral component of an optimal resources management plan at the scale of the continental shelf (Nakamura 1985, Grove et al. 1994). The ultimate goal of this program is optimal 'farming' of the entire shelf. While not advocating such an approach in California, a better understanding of the ecological effects of artificial habitats is certainly needed.

Many artificial habitats have been established throughout southern California but their ecological effects are still poorly understood against the framework of the attraction/production controversy mainly because the resources to study artificial habitats are extremely limited. Simply put, there are presently not enough resources to support scientifically rigorous studies such as those advocated by e.g., Grossman et al. 1997, Carr & Hixon 1997, and Osenberg et al. 2002, to determine the ecological effects of artificial habitats. The present study of the HMCS Yukon is no exception.

In this report, I summarize the results of the monitoring program, make comparisons of the colonization of the Yukon to other artificial habitats in southern California, compare the diversity and species richness found on the Yukon to natural habitat located nearby, and discuss issues for future artificial habitat programs and studies off San Diego.

HMCS Yukon and Habitat Enhancement off San Diego

The HMCS Yukon is a decommissioned Canadian destroyer escort (~112m long with a beam of ~13m) that was 'intentionally' sunk on July 14, 2000 by the San Diego Oceans Foundation (SDOF) to create an artificial reef in waters ~30m deep off North Mission Beach in San Diego (Figs. 1, 2, and 3). The creation of the Yukon artificial reef was part of a larger complex of artificial reefs consisting of three smaller wrecks off Mission and Pacific Beaches. The smaller wrecks compose an underwater recreation area called the Mission Bay Artificial Reef (a.k.a., 'wreck alley'), a 512-acre underwater recreation area that was originally authorized in 1986. The Yukon is located in a second underwater recreation area, the San Diego Underwater Recreation Area (~450 acres), located immediately north of the Mission Bay Artificial Reef. The seafloor in both areas is owned by the City of San Diego and the artificial reefs are administered by the California Department of Fish and Game. No special protection exists for either underwater recreation area. Therefore all artificial reefs within them are subject to fishing.

The Yukon was prepared for sinking by the Artificial Reef Society of British Columbia and the San Diego Oceans Foundation. The vessel was cleaned of most contaminants (for details see the Environmental Impact Report). However, hull paint, including anti-fouling paint, was not removed because it was deemed that paint applied for more than five years did not pose a contamination risk (Environment Canada clean-up standards). Large holes, several meters wide, were cut into the side of the vessel so that divers could safely enter and exit the vessel. The Yukon was then towed to her reefing site and anchored for sinking. The Foundation planned to sink the ship using explosive charges, however, large seas swamped the vessel due to an unexpected southern swell and filled the hull with seawater. Because the Yukon took on too much seawater, she sank prematurely and lies on her port side rather than upright. The vessel is located at a depth of ~31 meters, and the shallowest part of the ship is her exposed starboard side which is ~17 meters deep.

Large access holes were cut throughout the ship to allow for current flow and to increase diver safety.

The Yukon was sunk as part of a habitat enhancement program initiated by SDOF. The Foundation developed a Master Plan for Habitat Enhancement (MPHE) for state waters off San Diego County in 1996 to "fulfill the desires of fishers, divers, and scientists for more places to explore, more fish to catch and specific sites reserved for habitat enhancement research" (EIR 1999). Four types of zones were proposed, (1) six kelp enhancement zones, (2) three research zones, (3) three deep-water economic zones, and (4) one shallow-water economic zone. The Foundation proposed six projects within the San Diego Underwater Recreation Area including the Yukon, and each project is limited to ~0.25 acres in area. To date, the Yukon is the only project completed within the Recreation Area. (EIR 1999).

Figure 2. Side-scan sonar image of the HMCS Yukon showing the vessel laying on its port side. The bow of the vessel is oriented northward.

The shelf off San Diego consists of sloping sandy plains and rocky habitat that support the two largest kelp forests in southern California. The southern edge of the La Jolla kelp forest is located ~2 km north of the Yukon, and the northern edge of the Pt. Loma kelp forest is ~6 km south (Figs. 1 and 2). Several other artificial habitats are located in the general vicinity between the La Jolla and Pt. Loma kelp forests. These consist of the three other reefed ships discussed above, debris piles of a demolished bridge, the remains of a Navy hydrographic station that was toppled by a storm in 1988, and quarry rock reefs established by the California Department of Fish and Game (Wilson et al. 1990). Due to the presence of all the artificial reefs between the kelp forests of San Diego, this area should be considered as an artificial reef network. Unfortunately, there has been no comprehensive study of the ecological effects of this network. The Fish & Game reefs have been followed over time (Bedford 1993) to determine colonization and species compositions, but these studies, as the present study, do not include studies of how these reefs might interact with other artificial and natural habitats located nearby.

Artificial Reef Monitoring Project: SDOF

Several months after the Yukon sank, the San Diego Oceans Foundation proposed a monitoring project (Artificial Reef Monitoring Project, ARMP) to investigate the ecological effects of sinking the Yukon and to determine its utility as an artificial reef. No monitoring plan was developed prior to the sinking and no monitoring projects were conducted on nearby artificial reefs and natural habitat. Therefore, the most appropriate method to determine the biological effects of sinking the Yukon, a before-after/control-impact study (BACI; e.g., Underwood 1992) was precluded. For future reference such studies are needed to better address the effects of establishing artificial reefs. The ARMP was developed strictly as a volunteer project to quantify changes to the fish and invertebrate communities on the Yukon over time.

There were two components of the monitoring project, fish transects and photo quadrats. A fish tagging study was also initiated to determine the movement of fish among the other artificial reefs off Mission and Pacific Beaches and the Yukon, as well as nearby natural habitat, but was discontinued due to limited resources. Details of

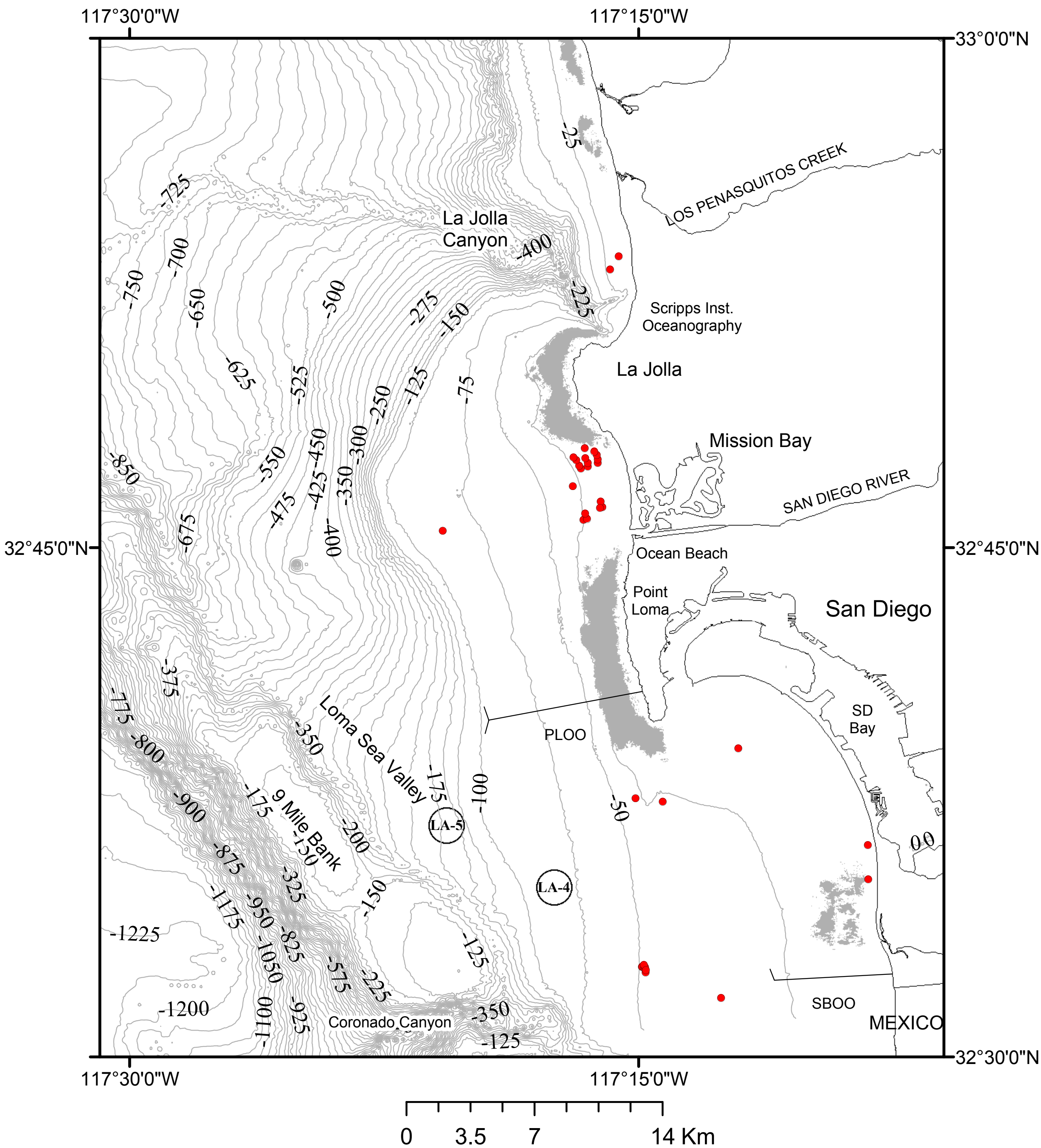


Figure 1. Coastal map of San Diego showing locations of some wrecks and artificial reefs (red dots). The locations of the dredge disposal sites LA-5 and LA-4 as well as the ocean outfalls off Pt. Loma (PLOO) and South Bay (SBOO) are indicated. Depth units are meters. The fullest extent of giant kelp (*Macrocystis pyrifera*) for the period 1967-2001 is indicated by gray shading. Canopy cover indicates the presence of hard bottom in shallow waters (<25m) off San Diego.

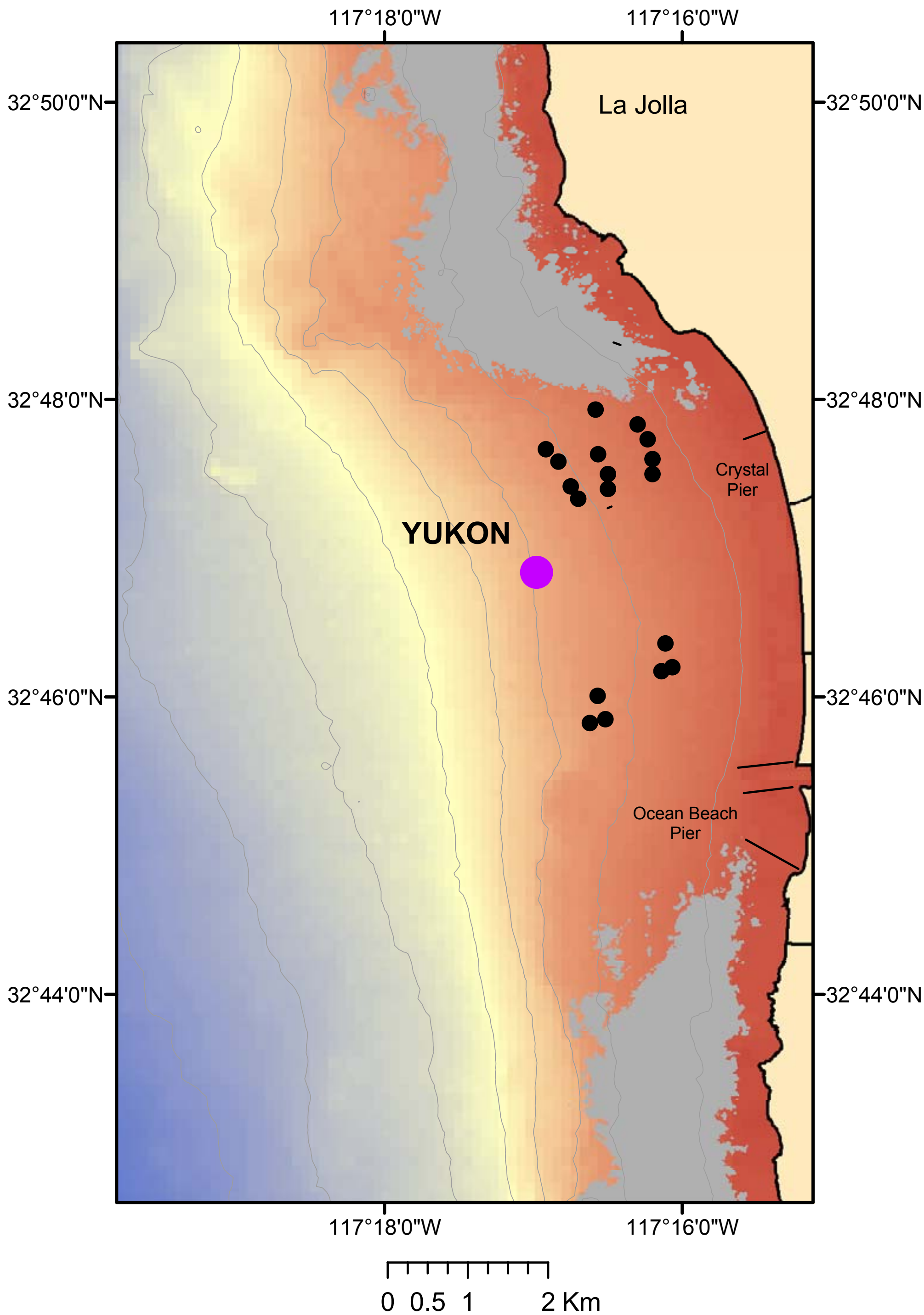


Figure 2. Map of coastal San Diego indicating the location of the HMCS Yukon. Black dots indicate other artificial reefs and wrecks in the area. Kelp is indicated by gray shading. Depth contours are in 10m intervals.

these components can be found at www.sdoceans.org/programs/arti_reef.php.

The primary purpose of this report is to summarize the results of the fish transect and photo quadrat monitoring programs. Secondary components include a discussion of the likely effects of the Yukon on the marine life in the general area, a discussion of the Yukon with regard to the attraction/production controversy, and recommendations for future monitoring and habitat enhancement programs.

METHODS

The use of volunteer observers has been successful in many fields. A few notable examples include astronomy and ornithology. The REEF fish survey project (http://www.reef.org/data/surveyproject.htm) is an example of a successful volunteer observer program in the field of marine ecology. Of primary importance to all these programs, is a core of well-trained observers. The Foundation established a rigorous training program through PADI entitled 'Yukon Research Diver' to ensure the SDOF volunteers were adequately trained and qualified (Fig. 4). Students learned core concepts and the mechanics of collecting transect data and photographing quadrats, species identification, and navigation on the sunken ship. Strict protocols enhanced the volunteer effort and the results show that volunteers can provide useful data.

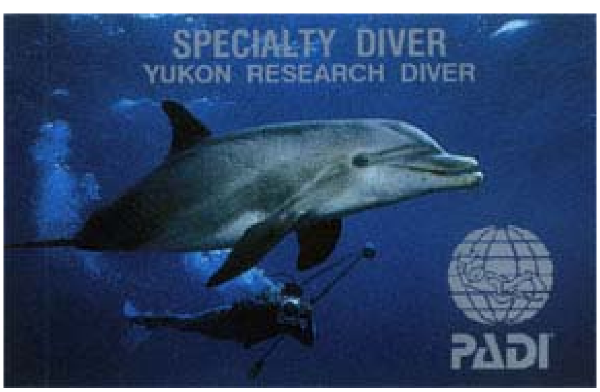


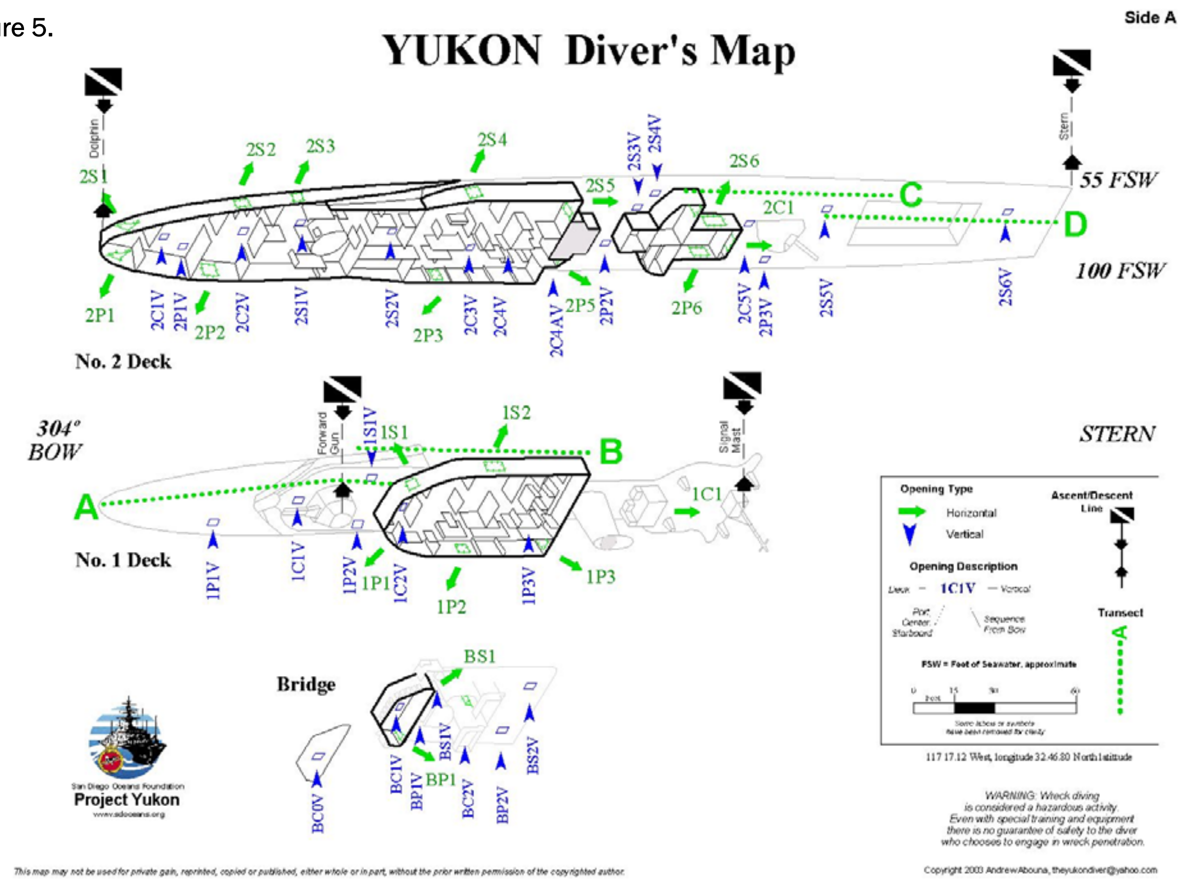
Figure 4. Yukon Research Diver Specialty Certification

Fish Transects

Because the ARMP was a volunteer project, the fish transect program was designed to be as simple as possible yet provide analyzable quantitative data. As such, some compromises were made such as pooling solitary rockfish species into one category because rockfish identification is difficult for some species. Also, size categories were limited to sub-legal and legal sizes for all but the wrasses (California sheephead and rock wrasse). The transect method was employed for fish counts rather than a roving diver technique, which is used in other volunteer fish counting programs, due to concerns that the roving diver technique would not provide data with adequate precision. The transect method was also chosen to facilitate comparisons of fish assemblages between the Yukon and natural habitat located nearby. Concomitant fish transect data were available for natural hard-bottom habitat in La Jolla from an unrelated project conducted by the Scripps Institution of Oceanography (Parnell et al., in press).

Four permanent wire rope transects (20 meters in length) were affixed to the Yukon so that divers could conduct fish counts. All transects are oriented horizontally (Fig. 5). Transect locations were chosen to include a range of habitat types. No data were collected inside the vessel for safety reasons. Transect lines were

Figure 5.



named *A-D.* Transect *A* is ~25 meters deep and runs from the bow to the base of the bridge. There is no overhead structure, but there are many crevices below the transect that are conducive habitat for rockfish and cryptic species (e.g., forward guns). Transect *A* lies to the side of the vertically oriented deck. Transect *B, ~ 20 meters deep, is located on the* starboard side of the bridge and runs the entire length of the bridge. The surface is flat with no overhead structure. There is some macroalgal cover underneath the transect. Transect *C* lies ~18 meters deep, and runs along the starboard side rail from abaft the middle of the ship to a point approximately three-quarters of the distance from the bow to the stern. Again, there are no overhead environments but there are large davits next to the line that provide shelter for fish. There is abundant macroalgal growth along this line. Transect *D, ~22 meters deep, is located in the* rear portion of the ship and lies along the vertically oriented deck. This transect is the furthest from the superstructure.

A web-based data entry form was provided at http://www.sdoceans.org/forms/armp_diverform.php for divers to enter their fish data. Fish counts on the Yukon began in late May of 2001, nearly eleven months after the Yukon sank and continue to the present. The frequency of fish counts was random because the program depended on volunteer divers of opportunity. No schedule of sampling with regard to season or conditions was developed. (However, monthly dive trips have since been established.) Divers were instructed not to count fish if visibility was less than ~3 meters. All fish counts were conducted during daylight hours. Other parameters recorded by the divers included the number of boats anchored on the Yukon, the number of other divers observed while underwater, visibility, surge, temperature, current, swimtime, and time of day.

<u>Photo Quadrats</u>

Photo quadrats were established to document the colonization of the ship by sessile invertebrates and macroalgae. PVC quadrats (square 0.25m^2) were affixed to the ship in a variety of locations to encompass a range of habitat types including vertical and horizontal surfaces as well as proximity to various structures on the ship. All quadrats were established on flat surfaces. An initial set of forty quadrats was attached in 2002 using splash-zone marine epoxy to attach the quadrats to the hull (Fig. 6). Unfortunately, all of these quadrats were dislodged within a few months.

Therefore, an alternative attachment method was used. A local commercial diving company (C&W Diving Services, Inc., San Diego) volunteered to weld metal tabs onto the ship to securely attach the PVC quadrats. Twenty-two quadrats were affixed to the Yukon in 2003 using this method. Three quadrats were attached to the vertically oriented deck amidships and the rest were distributed along the horizontally oriented starboard hull. Quadrat names were affixed to each quadrat for easy identification in the photographs. A volunteer diver (Jeff Hannigan) photographed the quadrats using a 35mm camera mounted on a custom made tripod (Appendix A). The film was then scanned at a resolution of 300 dpi for analysis.

Scanned images were enhanced and analyzed using ImageJ software. Organisms in the photo quadrats were also visually inspected *in situ* to aid identification of organisms photographed in the quadrats. The most common fouling organisms were identified to the lowest possible taxonomic level and included in the analysis. Taxa were either counted or measured for total area within a quadrat depending on which method was most precise for each taxa.

RESULTS

<u>Fish Counts</u>

A total of 160 fish counts were conducted along the transect lines from May 2001 through August 2004 by 13 volunteer divers. Nearly half of these transects were conducted by one diver, and nearly 80% were conducted by a total of only five divers (Fig. 7). Transects A and B had the most fish counts conducted, and only 12 counts were conducted along transect D (Fig. 8).

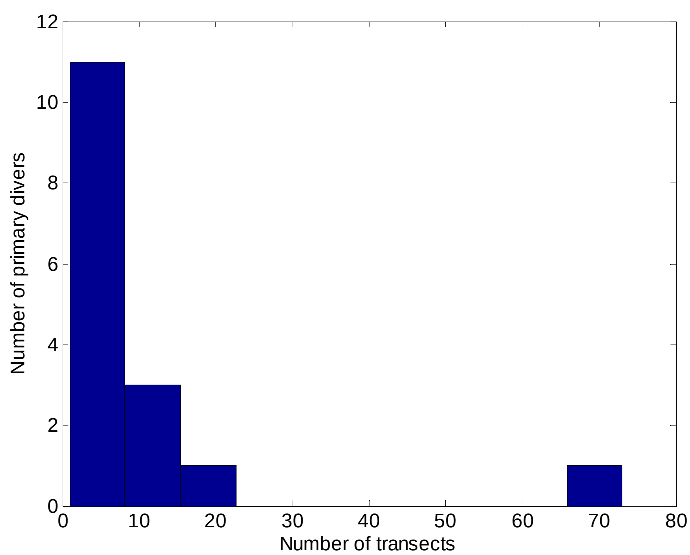


Figure 7. Histogram showing the number of transects conducted by all primary divers. There were 13 primary divers who conducted 160 total transects.

Fish counts first began on transect B in May of 2001, whereas fish counts did not begin on transects A and C until early 2002. Fish counts did not commence on transect D until October of 2002. Most fish counts were conducted during summer and fall, and the fewest were conducted in winter (Fig. 9). A timeline of fish surveys is provided in Figure 10.

One of the greatest concerns for the monitoring project was the accuracy and precision of the divers. This is a serious concern for professional research divers, and is of even greater concern for volunteer divers. This issue has been addressed in a rigorous study in Florida that was specifically designed to test the abilities of trained volunteer divers to record environmental parameters and to count fish (Halusky et al. 1994). The divers were able to successfully record most of the environmental parameters, but there were many problems with the fish counts that were attributed to insufficient training and variable levels of skill among the divers. The findings of Haluskey et al. were used in the design of the Foundation's ARMP. Even so, it was still important to gauge the magnitude of the variability among divers that reported data sampled from the Yukon.

The greatest proportion of variability among divers is likely due to variable levels of skill and their knowledge of the fish. Recall that nearly 80% of fish transects were conducted by only five divers and the remaining transects were conducted by eight other divers. Therefore, it is likely that the two groups differ in skill and knowledge due to experience and possibly motivation. A quick test of the results among these two groups is presented in Figure 11 in which the frequency distributions of total fish counts for the two groups are plotted as bar graphs. These graphs indicate that the proportion of less-experienced divers (those who conducted <10 fish counts) that counted <75 total fish was less than the proportion for the more experienced divers. A randomization test was used to determine if this difference was

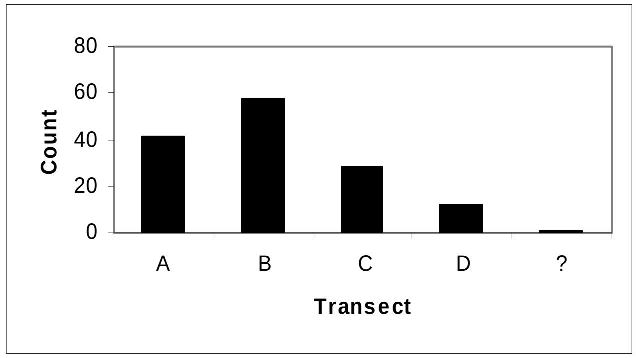


Figure 8. Histogram showing number of transects conducted on the four transect lines.

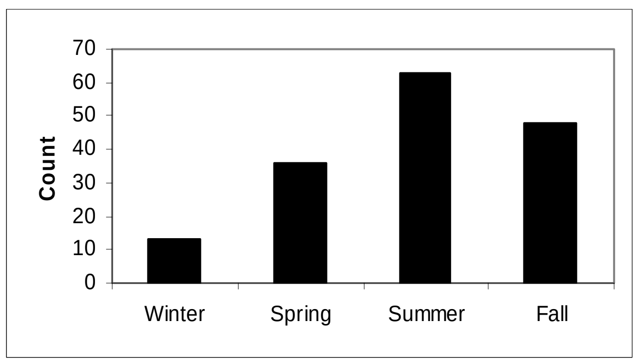


Figure 9. Distribution of surveys among seasons.

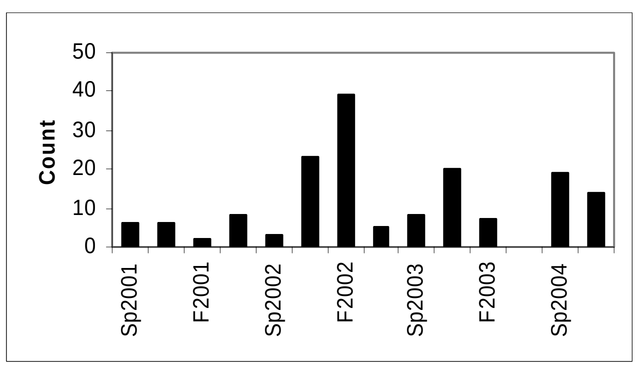


Figure 10. Timeline of fish surveys.

significant. The randomization test (Manly 1991) in which 5000 samples were generated from the data indicated that the probability that this was due to chance was less than 0.1%. This implies that the less experienced divers tended to overcount fish. And, the overcount was not due to the possibility that the less experienced divers preferentially counted different transects or conducted their counts during different seasons than the more experienced divers.

Another test to gauge the relative precision among divers was to compare total fish counts among the more experienced divers. The ranges, medians, and quartiles of these divers relative to each other are shown in Figure 12. The experienced divers appear to be consistent among each other. An ANalysis Of VAriance (ANOVA) was performed on these data to determine if there was a global statistical difference among the divers (see Table 2). In this analysis the variability of total counts was partitioned into two components, one due to error (variability not accounted for) and the other due to the variability among divers. The results of the analysis indicate that it is highly probable (~85%) that the variability of total fish counted among divers was due to factors other than the divers. Therefore, the more experienced divers appeared to count fish similarly.

The results of pooling all the fish counts indicate that the most abundant fish were (in order of abundance) white surfperch, blacksmith, black surfperch, boccacio, vermillion rockfish, other rockfish, pile surfperch, black eyed gobies, barred sand bass, painted greenling, senorita, snubnose sculpin, and sheephead (Fig. 13, species names are listed in Table 1). Other

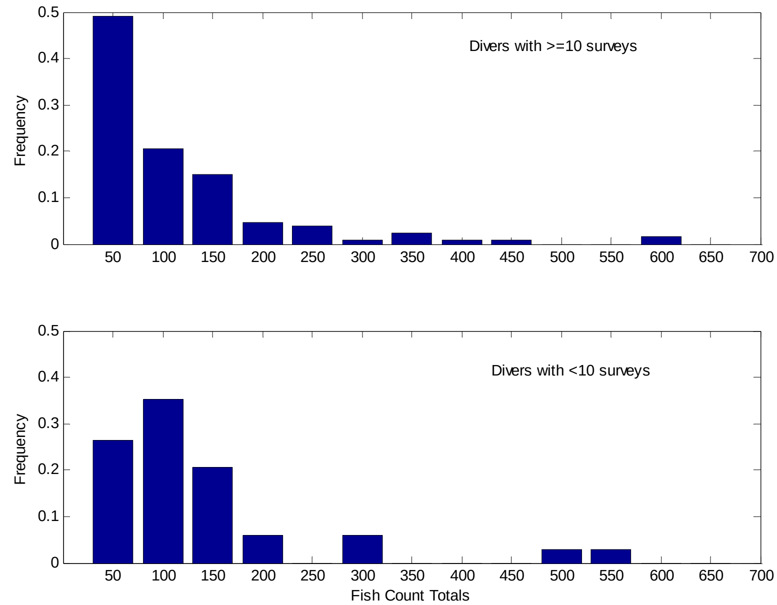


Figure 11. Frequency distribution of total fish counted on a transect for divers who conducted 10 or more surveys (top) and for divers who conducted less than 10 surveys (bottom).

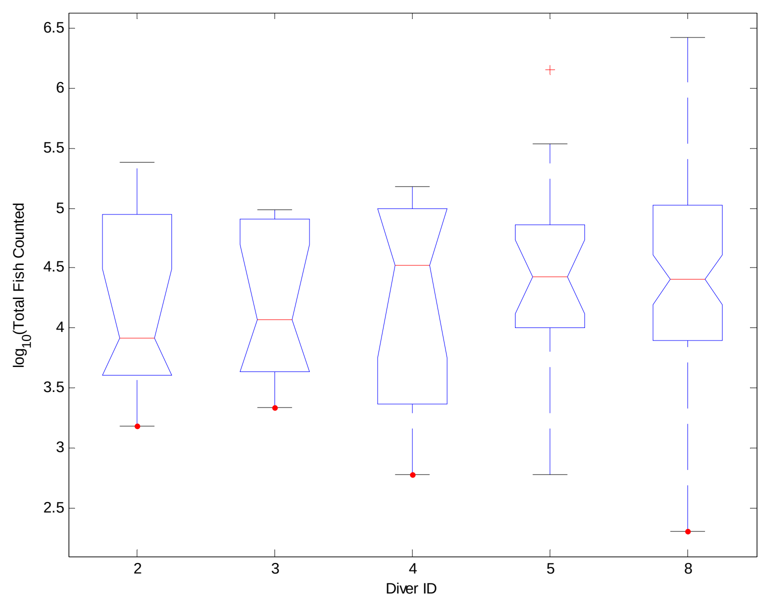


Figure 12. Results of inter-diver comparisons of total fish counts. Y-axis is log_{10} transformed total fish counts. X-axis is the diver ID number assigned to each diver. Plot shows comparisons among the 5 most experienced divers (those who conducted at least 10 fish surveys). Red lines indicate medians and notches indicate ranges of uncertainty around the medians. Upper and lower blue lines indicate lower and upper quartiles, whiskers indicate the range of the data, and red crosses indicates statistical outliers. The plot and the accompanying ANOVA (Table 1) indicate no differences among these divers.

Table 1. Common and scientific names of fish observed on the Yukon.

Family	Common Name	Scientific Name
Bothids	Speckled Sanddab	*Citharichthys stigmaeus*
	California Halibut	*Paralichthys californicus*
Clinids	Island Kelpfish	*Alloclinus holderi*
	Giant Kelpfish	*Heterostichus rostratus*
Cottids	Snubnose Sculpin	*Orthonopias triacis*
	Sculpin	*Scorpaena guttata*
	Cabezon	*Scorpaenichthys marmoratus*
		Unidentified sculpin
Embiotocids	Kelp Surfperch	*Brachyistius frenatus*
	Black Surfperch	*Embiotoca jacksoni*
	Rainbow Surfperch	*Hypsurus caryi*
	White Surfperch	*Phanerodon furcatus*
	Rubberlip Surfperch	*Rhacochilus toxotes*
	Pile Surfperch	*Rhacochilus vacca*
Gobiids	Blackeyed Goby	*Coryphopterus nicholsi*
Haemulids	Sargo	*Anisotremus davidsoni*
Hexagrammids	Lingcod	*Ophiodon elongatus*
	Painted Greenling	*Oxylebius pictus*
Labrids	Rock Wrasse	*Halichoeres semicinctus*
	Senorita	*Oxyjulis californica*
	California Sheephead	*Semicossyphus pulcher*
Malacanthids	Ocean Whitefish	*Caulolatilus princeps*
Percichthyids	Giant Sea Bass	*Stereolepis gigas*
Pomacentrids	Blacksmith	*Chromis punctipinnis*
	Garibaldi	*Hypsypops rubicundus*
Pleuronectids	C-O Sole	*Pleuronichthys coenosus*
Serranids	Broomtail Grouper	*Mycteroperca xenarcha*
	Kelp Bass	*Paralabrax clathratus*
	Barred Sand Bass	*Paralabrax nebulifer*
Scorpaenids	Kelp Rockfish	*Sebastes atrovirens*
	Brown Rockfish	*Sebastes auriculatus*
	Gopher Rockfish	*Sebastes carnatus*
	Copper Rockfish	*Sebastes caurinus*
	Calico Rockfish	*Sebastes dalli*
	Vermillion Rockfish	*Sebastes miniatus*
	Starry Rockfish	*Sebastes rosaceus*
	Olive Rockfish	*Sebastes serranoides*
	Boccacio	*Sebastes paucispinis*

species counted along the transects included

Table 2. ANOVA of the effect of diver (only experienced divers included, those who conducted 10 or more surveys and surveyed at least once each year) on total fish counts.

Source	SS	df	MS	F	Prob>F
Diver	1.0279	4	0.25698	0.34817	0.84487
Error	89.3085	121	0.73809		
Total	90.3364	125			

rainbow surfperch, cabezon, kelp bass, rubberlip surfperch, lingcod, sculpins, giant kelpfish, rock wrasse, corbina, and barred surfperch. There were anecdotal reports of an occasional sighting of a giant seabass, and twobroomtail groupers were observed inside the ship on several occasions. California halibut and speckled sanddabs have been commonly reported on the sand next to the ship and underneath the stern section of the vessel. Rockfish that I observed on the vessel over 3 dives in June of 2004 included gopher rockfish, calico rockfish, copper rockfish, vermillion rockfish, and brown rockfish. I also observed other species of fish that were not reported in the fish counts or the anecdotal accounts. These included island kelpfish, sargo, and kelp surfperch.

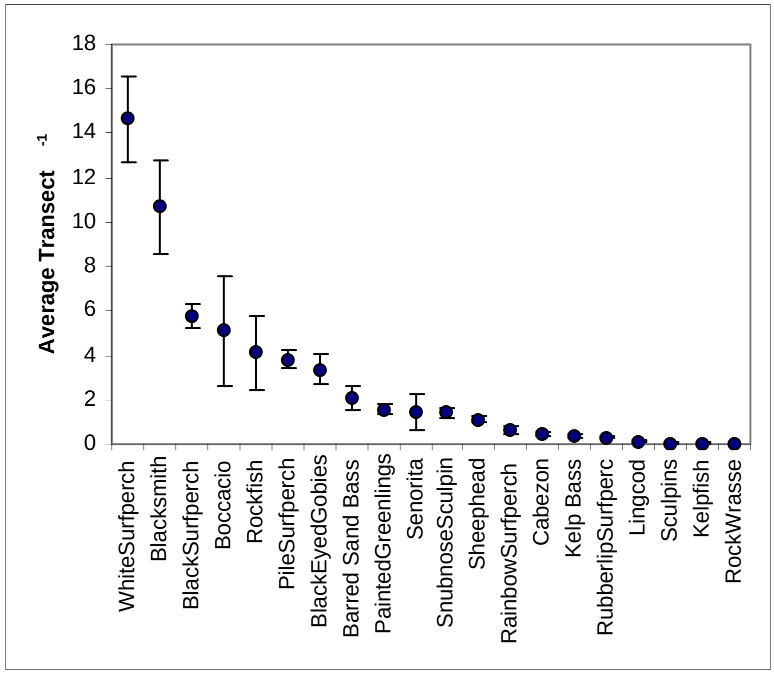


Figure 13. Average number of fish counted on all transects. Error bars are standard errors.

The fish count data were also tested for seasonal differences and for differences among transect lines. There appeared to be a strong seasonal component with more fish observed during summer and fall (Fig. 14). An analysis similar to ANOVA called a General Linear Model (GLM) test was conducted on total fish count data to determine if there were significant differences among seasons and transect lines. In this test, the variance of total fish counted was partitioned into season, transect line, the interaction between transect line and season, and error (variability not accounted for by these factors). Transect line D was not included in the

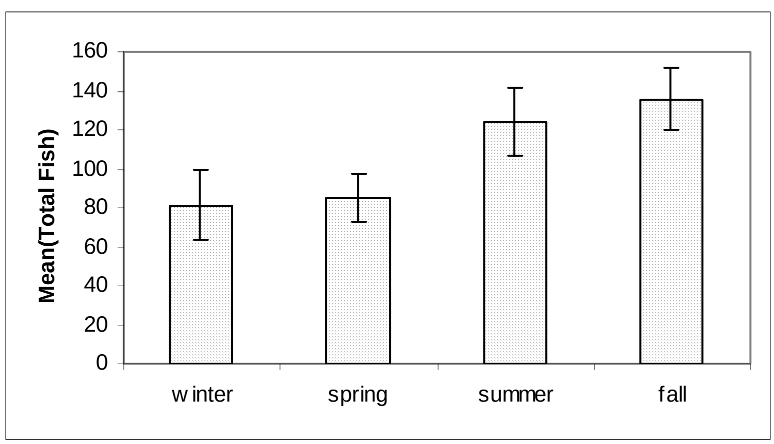


Figure 14. Seasonal averages and standard errors of total fish counted on transects A, B, and C. GLM analysis indicate that fish count totals were significantly different among seasons.

Table 3. Results of GLM analysis of effects of season and transect on log-transformed total fish counts. All data used for transects A, B, and C. Significant p-value is in boldface.

Source	df	Seq SS	Adj SS	Adj MS	F	Prob>F
Transect	2	0.5225	0.1196	0.0598	0.46	0.633
Season	3	1.4233	1.5868	0.5289	4.06	**0.009**
Transect*Season	6	1.2867	1.2867	0.2145	1.64	0.140
Error	130	16.9551	16.9551	0.1304		
Total	141	20.1877				

analysis because so few counts were conducted on it. The results (Table 3) indicate that total fish counts differed significantly among seasons but not among transects.

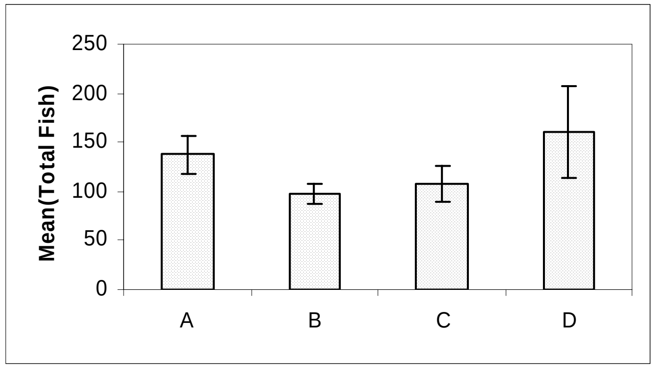


Figure 15. Averages of total fish counts among transect lines. Note that only 12 transects were conducted along transect D. Error bars are standard errors. GLM analysis indicates that fish counts were not significantly different among transect lines.

Differences in species assemblages among transects were analyzed using the multivariate ANalysis Of SIMilarities (ANOSIM). Data from all transects were used in the analysis. The results indicate no differences among the transects when all are included (global test), however, significant differences were observed between lines C and D, and between lines A and D. Closer inspection of these differences reveal that these differences were due to the under-sampling of transect D, which was disproportionately sampled during summer and fall when fish were significantly more abundant. Therefore these differences are likely not real and one can conclude that there were no significant differences among the transect lines for fish assemblages.

Seasonal differences in species assemblages were also tested using ANOSIM. The results indicate that the species assemblages were not significantly different among seasons when all seasons were included in the analysis. However, a significant difference was observed in species assemblages between spring and fall (0.1%). Another multivariate analysis was conducted to explore the significant differences in the species assemblages between fall and spring using SIMilarity PERcentages (SIMPER). This analysis tests for what species contribute the most dissimilarity among groups (in this case seasons). The results indicate that most of the dissimilarity that was observed between fall and spring was due to differences in the abundance of white surfperch, blacksmith, black surfperch, pile surfperch, and barred sand bass (species percent contributions to dissimilarity: 18.45%, 15.73%, 8.88%, 8.41%, and 5.48% respectively). Mean abundances for these species in fall and spring are plotted in Figure 16. White surfperch, blacksmith, black surfperch are more abundant in the fall, and pile surfperch and barred sand bass are more abundant in the spring.It is well known that the rate at which organisms arrive and colonize artificial reefs varies among

Table 4. Trends of fish species observed along transects. Primary colonizers were observed within the first year of the monitoring program (by the second year of the sinking). Later arrivals were species first observed later. X denotes whether species appeared to be decreasing, increasing, or highly variable through time.

	Decreasing	Increasing	Highly Variable
Primary Colonizers			
Black Surfperch	X		
Pile Surfperch	X		
Blacksmith			X
Barred Sand Bass	X		
Sculpin		X	
Sheephead		X	
Cabezon			X
Later Arrivals			
White Surfperch	-	X	
Painted Greenling	-	X	
Black Eyed Goby	-	X	
Kelp Bass	-	X	
Boccacio	-		X
Rainbow Surfperch	-		X
Rockfish	-		X
Lingcod	-		X

species, and that species abundances, biomass (weight of all living organisms combined), species richness (number of species), and diversity (measure of the number of species balanced by how evenly the animals are distributed among species) increase through time until they reach a maximum. Therefore, an important aspect of any artificial reef study must include an evaluation of these parameters over time. Unfortunately, in the case of the Yukon, data were not acquired immediately after it sank. Therefore, the initial colonization of the ship is not known. The development of the fish community on the Yukon as observed on the transect lines is summarized in Table 4. Fish that were observed within the first year of the monitoring program (within the second year after sinking) included black surfperch, pile surfperch, blacksmith, barred sand bass, sculpin, sheephead, and cabezon. Of these species, black surfperch, pile surfperch, and barred sand bass appear to be declining in abundance, while sculpin and sheephead are increasing. Blacksmith and cabezon show no clear trends as their abundances are highly variable over time. Species that were first observed after the first year of the monitoring program

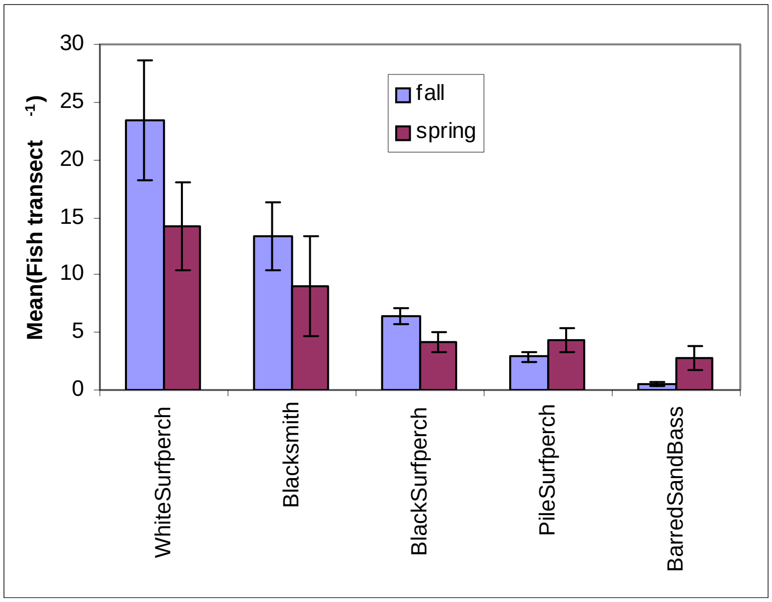


Figure 16. Mean species abundances (per transect) for species that contributed the biggest differences in species assemblages between fall and spring.

included white surfperch, painted greenling, black eyed gobies, kelp bass, boccacio, rainbow surfperch, vermillion rockfish, other rockfish, and lingcod. Of these, white surfperch, painted greenling, black eyed gobies, and kelp bass appear to be increasing while the remaining species are highly variable. The other species observed on the Yukon were observed too rarely to gauge their trends over time.

The average of total fish abundances (all species pooled by season; Fig. 17) over time have been highly variable with annual peaks in the time series but no clear trend. However, there appears to be a very gradual trend of increasing average species richness per transect (Fig. 18). The diversity of the fish community appears to also be increasing somewhat (Fig. 19) but there was a seemingly anomalous global maximum that was observed early on in the time series during the fall of 2001. Annual fish data were analyzed using Multi-Dimensional Scaling (MDS) to determine if the fish assemblage on the Yukon changed over time (Fig. 20). MDS is a way of graphically representing the similarity of samples in two (present case) or three dimensions. Every sample consists of the counts of twenty species of fish. Therefore each sample exists within a 20 dimensional space. However, it is impossible to visualize this 20 dimensional space. MDS analysis reduces the number of dimensions from twenty to two. The distance among the points represents their similarity in this arbitrary two-dimensional view. Inspection of Figure 17 reveals that there is a marked change from 2001 to 2003 and 2004. Therefore the fish assemblage on the Yukon appears to have changed considerably over time. An ANOSIM, which tests for global and

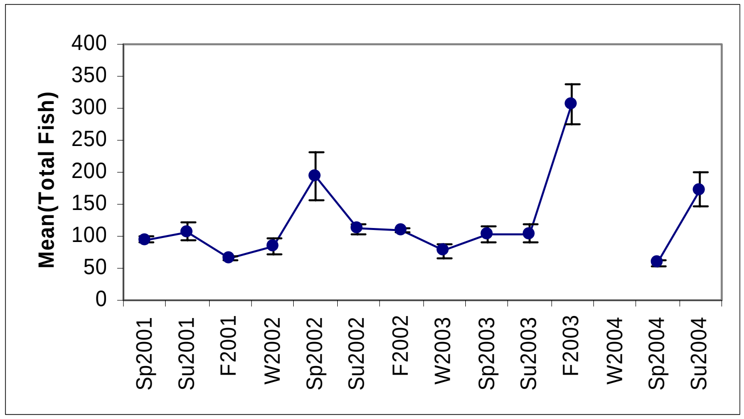


Figure 17. Time series of total fish counted on transects A, B, and C. Error bars are standard errors.

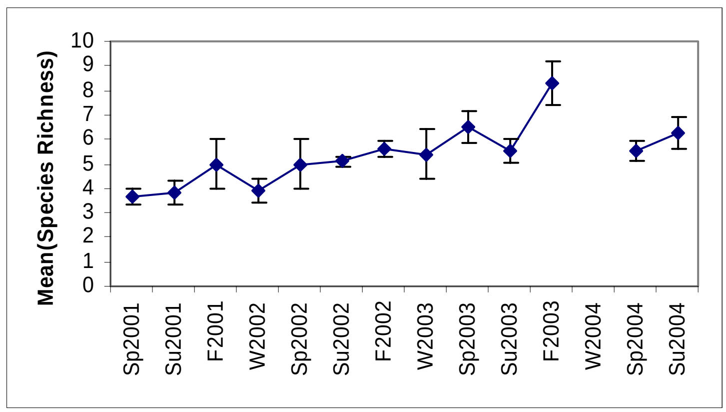


Figure 18. Time series of average fish species richness per transect on transects A, B, and C. Error bars are standard errors.

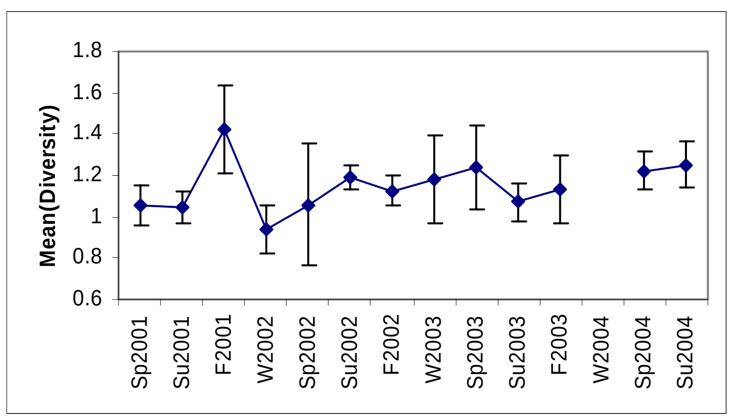


Figure 19. Time series of average fish diversity (Shannon's H'). Error bars are standard errors.

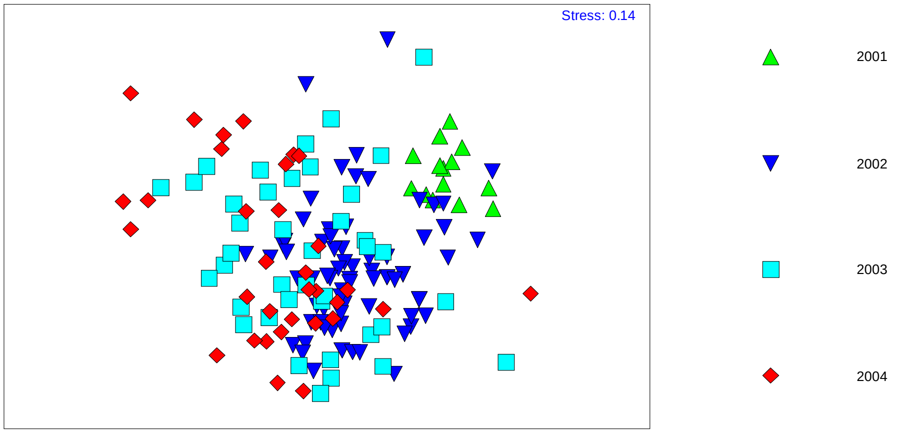


Figure 20. MDS plot of Yukon fish surveys on transects A and B comparing data for 2001-2004. Results indicate that the fish assemblage has changed over time. ANOSIM values indicate a global significant different among years and that the assemblage of 2001 was significantly different ($p<0.001$) from 2003 and 2004. The fish ssemblages of 2003 and 2004 were not significantly different.

pairwise differences among years, was run on the same data. The results indicate that there is a global significant difference among years (.1%), and in particular 2001 is significantly different from 2003 and 2004 (0.3% and 0.1%, respectively), whereas 2003 and 2004 are not significantly different (10.2%). This suggests that the fish assemblage was initially very different, composed only of the early colonizers listed above, and that the assemblage had become stable by 2003.

An important factor in determining if an artificial reef might be increasing the local production of fish is the observation that fish are recruiting onto the reef. This was not possible for most species in this study because juvenile fish for these species are difficult to identify (especially by volunteer divers), or they recruit to cryptic habitat (hiding places) on the ship where they are not likely to be observed during the fish counts. However, young of the year (YOY) boccacio and sheephead were observed on the Yukon along the transect lines and in other areas of the ship. Therefore, these species appear to be successfully recruiting on the Yukon. Volunteers also frequently noted juvenile blacksmith and white surfperch indicating these species also likely recruit onto the Yukon.

To gauge the utility of artificial reefs, it is also important to determine how species assemblages and densities on artificial reefs compare to natural habitat nearby. Fortunately, fish transect data from natural habitat in La Jolla were available from a different project (Parnell et al. *in press).* The southern margin of the La Jolla kelp forest is ~2.5 km from the Yukon and extends nearly 8.5 km northward to La Jolla Bay (Fig. 1). Fish transects were conducted during the spring, summer, and fall in 2002 and 2003 throughout the La Jolla kelp forest. Fish counts in the kelp forest were conducted along 30 meter-long transects but were otherwise the same as those on the Yukon. Therefore, the La Jolla counts, multiplied by a factor of two-thirds, are directly comparable to the counts conducted on the Yukon. Fish counts were also conducted in the La Jolla Submarine Canyon (Fig. 1) using a Remotely Operated Vehicle (ROV) as part of the

La Jolla project. These counts were conducted between depths of 50 and 150 meters in 2003. These counts are not directly comparable to those on the Yukon because they were not conducted along transect lines. But the ROV counts provide a useful qualitative analog of fish assemblages near canyon heads for comparisons with fish observed on the Yukon. Both the submarine canyon and the Yukon are high relief habitats.

The transect data in La Jolla enabled direct quantitative comparisons for species common to both La Jolla and the Yukon. For fished species, these included sheephead, kelp bass, barred sand bass, total rockfish (excluding vermillion and boccacio), sculpin, cabezon, and lingcod. Detailed analyses of the habitat where fish counts were conducted in La Jolla enabled the discrimination of different microhabitats within the kelp forest. Comparisons of fish between the Yukon and La Jolla were therefore conducted for the habitat most similar to the Yukon; high-relief deeper habitat within the La Jolla kelp forest. The results are shown in Figure 21. The La Jolla kelp bed appears to be better habitat for kelp bass, barred sand bass, total rockfish (excluding vermillion and boccacio), and sculpin. The Yukon appears to be better habitat for cabezon and lingcod. Sheephead appear to exhibit roughly equal affinity to both habitats. The relative affinities of these species for these different habitats may change through time as the fish assemblages on both will likely change with time. An MDS of fish transect data collected on the Yukon and in La Jolla is shown in Figure 22, where it is obvious that the fish assemblages in these habitats are mainly distinct with slight overlap (ANOSIM difference 0.1%).

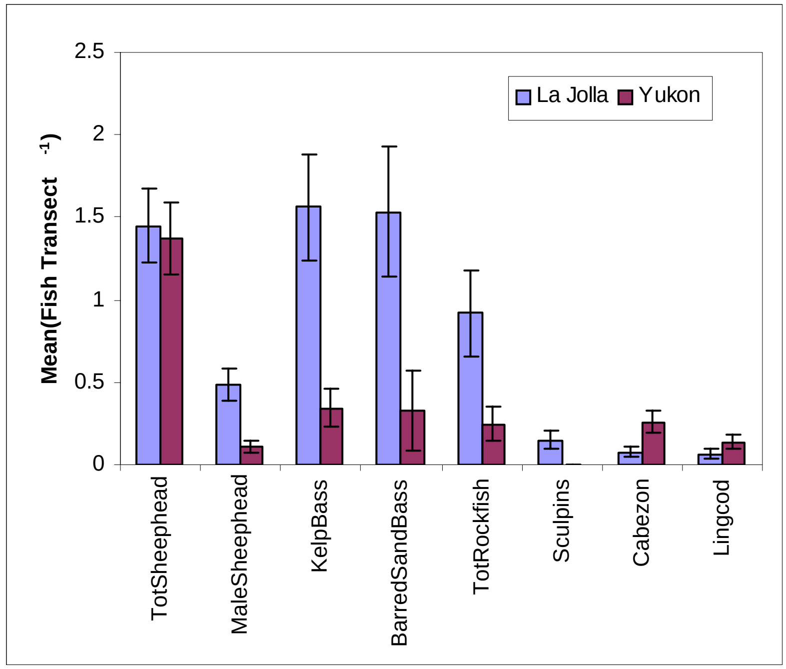


Figure 21. Comparisons of average targeted fish abundances on the Yukon with similar those of the most similar habitat in the La Jolla kelp forest. Error bars are standard errors.

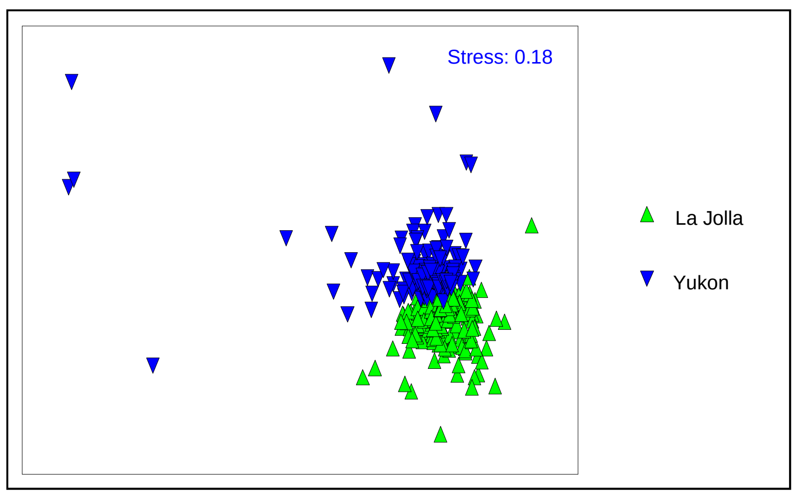


Figure 22. MDS plot of fish survey transects conducted in La Jolla over hard-bottom and the HMCS Yukon. The plot indicates that the fish assemblages in the two habitats are different.

The diversity (Shannon's H') of all non-cryptic fish in the high-relief kelp habitat in La Jolla is significantly greater than that of the Yukon (two sample t-test, $p<0.0001$). The average diversity in La Jolla was 2.001 (std=0.352) and was 1.16

(std=0.378) on the Yukon. The 95% confident interval in the difference of diversity between La Jolla and the Yukon were 0.722 and 0.966. These results are highly significant. The kelp forest appears to be nearly twice as diverse as the Yukon for fish. (N.B., winter counts on the Yukon were excluded from the analysis because no counts were conducted in La Jolla during winter). However, the Yukon appears to be favorable habitat for vermillion rockfish and boccacio, both of which are only very rarely observed in the kelp forests. These species are much more commonly observed in La Jolla Canyon. Therefore, the Yukon appears to represent habitat that is a combination of the deeper high-relief habitat in kelp forests and the high-relief habitat associated with submarine canyon rims in southern California.

The fish data were also examined for possible effects due to the presence of other divers on the Yukon, visibility, surge, and current using best subsets regression and multiple regression analysis. The results indicate that the number of other divers and visibility accounted for a significant proportion of the variability of total fish counted (11.4%). The p-value for divers was 0.002 and the value for visibility was 0.001. The global regression p-value was <0.0001, and the regression equation was {fish = 85.6 - 15.7 divers + 13.0 viz}. Therefore, fish counts were positively affected by visibility and negatively affected by the presence of other divers. While not significant, surge and current, when included in the full regression model, had negative effects on fish counts.

Photo Quadrats

Sampling frequency was also random for the photo quadrats. A total of 45 quadrat photos were taken between April 7, 2003 and May 31, 2004 of permanently attached quadrats. These dates represent the period beginning 33 months and ending 47 months after the Yukon sank. Therefore, the colonization of the ship during the first 33 months was not documented. Quadrats were photographed for a maximum period of ~14 months which precluded meaningful interannual comparisons.

The distribution of sampling among quadrats is presented in Figure 23. Individual quadrats were photographed 1-4 times. Taxa included in the analysis are listed in Table 7. Since the time series were short, quadrats were only analyzed for differences among vertical and horizontal orientations (slope angle) and for seasonality. Slope angle is an important determinant of fouling community structure on natural and artificial surfaces (e.g., Glasby & Connell 2001). Some of the horizontal quadrats were positioned over areas of the hull that still had active anti-fouling paint (see Fig. 24). Also, some horizontal quadrats generally appeared to be disturbed by divers as fin scuff marks were apparent in many of the photos. A statistical comparison (Mann-Whitney test) of horizontal quadrats not affected

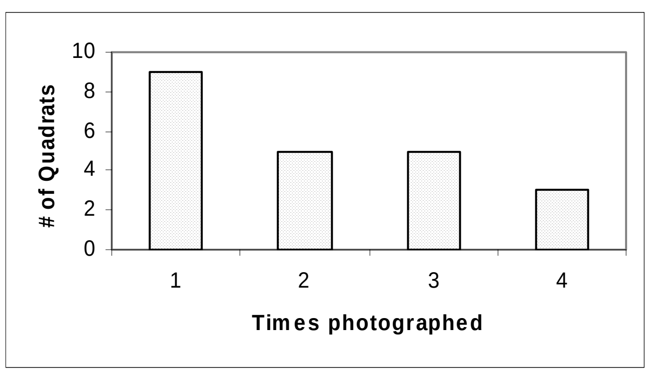


Figure 23. Distribution of photographs taken among the photo quadrats.

Table 5. Invertebrates observed on the HMCS Yukon.

Group	Common Name	Scientific Name
Brachiopods	Lamp Shell	*Terebratalia transversa*
Bivalves	Rock scallop	*Crassedoma giganteum*
		Mytilus californianus
Bryozoans	Moss Animal	*Bugula* spp.
	Southern Staghorn Bryozoan	*Diaperoecia californica*
		Membranipora membranacea
	Lacy Bryozoan	*Phidolopora labiata*
	Elephant Ear Tunicate	*Polyclinum planum*
		Schizoporella unicornis
		Tricellaria occidentalis
	unidentified erect bryozoan	*Crisulipora occidentalis?*
Cnidarians	Ostrich Plume Hydroid	*Aglaophenia struthionides*
	Orange Cup Coral	*Balanophyllia elegans*
	Strawberry Anenome	*Cornynactis californica*
	White Plumed Anenome	*Metridium giganteum*
	Elegant Anenome	*Metridium senile*
	Hydroid	*Obelia* sp.
	Tube Anenome	*Pachycerianthus fimbriatus*
	Hydroid	*Plumularia* spp.
	Anenome	*Urticina* spp.
Crustaceans	Giant Acorn Barnacle	*Balanus nubilus*
	Yellow Crab	*Cancery anthonyi*
		Loxorhynchus crispatus
	Sheep Crab	*Loxorhynchus grandis*
		Membranobalanus orcutti
	Spined Kelp Crab	*Pugettia dalli*
	Red Barnacle	*Tetraclita rubescens*
Echinoderms	Bat Star	*Asterina miniata*
	Spiny Sand Star	*Astropectin verrilli*
	California Sea Cucumber	*Parastichopus californicus*
		Pisaster brevispinus
	Giant Blue Spined Start	*Pisaster giganteus*
		Pisaster ochraceus
	Sunflower Star	*Pycnopodia helianthoides*
	Red Urchin	*Strongylocentrotus franciscanus*
	Purple Urchin	*Strongylocentrotus purpuratus*
Gastropods		*Anisodoris nobilis*
		Hermissenda crassicornis
	Kellet's Whelk	*Kelletia kelletii*
	Ida's Mitre	*Mitra Idae*
		Polycera tricolor
	Scaled Worm Shell	*Serpulorbis squamigerus*
Polychaetes	Fragile Tube Worm	*Salmacina tribranchiata*
		Serpula vermicularis
	Christmas Tree Worm	*Spirobranchus spinosus*
		Spirorbis sp.
Porifera	Red Volcano Sponge	*Acarnus erithacus*
		Aplysina fistularis
	Boring Sponge	*Cliona celata*
	Boring sponge	*Cliona celata*
	Gray Puffbal Sponge	*Craniella* sp.
	Bread crumb sponge	*Halichondria panicea*
		Haliclona sp.
	Cobalt Sponge	*Hymenamphiastra cyanocrypta*
	Spiny Vase Sponge	*Leucandra heathi*
	Urn Sponge	*Leucilla nuttingi*
	Gray Moon Sponge	*Spheciospongia confoederata*
		Spheciospongia confoederata
	Orange Puffball Sponge	*Tehthy aurantia*
Tunicates		*Archidistoma molle*
		Archidistoma psammion
	Light Bulb Tunicate	*Clavelina hunstmani*
		Didemnum spp.
		Euherdmania claviformis
	Stalked Tunicate	*Styela montereyensis*

Table 6. Algae observed on the HMCS Yukon.

Group	Common Name	Scientific Name
Red Algae		*Corallina* spp.
		Cryptopleura spp.
		Lithophyllum spp.
		Lithothamnion spp.
	Rainbow-leaf	*Mazzaella splendens*
		Rhodymenia spp.
Brown Algae		*Agarum fimbriatum*
		Desmerestia ligulata
		Dictyopteris undulata
		Dictyota binghamiae
	Forked Kelp	*Egregia menziesii*
		Laminaria farlowii
	Giant Kelp	*Macrocystis pyrifera*
		Pachydictyon coriaceum
		Pelagophycus porra
		Pterygophora californica

Table 7. Algal and invertebrate taxa analyzed in photo quadrats and the method used to analyze each group (count v. area).

Name	Count/Area	Description
Agarum	Count	*Agarum fimbriatum* (blade alga)
AlgalRecruits	Count	algal recruits too small to identify
Eisenia	Count	*Eisenia arborea* (stipitate alga)
Laminaria	Count	*Laminaria farlowii* (blade alga)
Macrocystis	Count	*Macrocystis pyrifera* (giant kelp)
Pelagophycus	Count	*Pelagophycus porra* (surface canopy forming alga)
Pterygophora	Count	*Pterygophora californica* (stipitate alga)
Rhodymenia	Count	*Rhodymenia* spp. (red algae)
Corynactis	Count	*Corynactis californica* (anenome)
Hermissenda	Count	*Hermissenda crassicornis* (nudibranch)
Styela	Count	*Styela montereyensis* (stalked tunicate)
Tubes	Count	calcareous tubes (gastropods and polychates)
CC	Area	crustose coralline algae (red calcareous algae)
Filament Mat	Area	green/grey mat consisting of filamentous diatoms inhabited by gam-arid amphipods (some in tubes), ostracods, harpacticoid copepods
Foliose Red	Area	foliose red algae
Archidistoma	Area	*Archidistoma psammion* (encrusting colonial tunicate)
Bugula	Area	*Bugula* spp. (fluffy erect bryozoan)
EncBryoSp1	Area	unidentified red encrusting bryozoan
ErectBryoSp1	Area	unidentified erect bryozoan (possibly *Crisulipora occidentalis*)
Halichondria	Area	*Halichondria panicea* (yellow encrusting sponge)
Hydroids	Area	mainly *Plumularia* spp.
Salmacina	Area	*Salmacina tribranchiata* (colonial tubed polychaete)
BareSpace	Area	no growth (either antifouling paint, diver disturbance, or fish grazing)

by anti-fouling paint or scuffing reveals significantly more bare space ($p<0.03$) on horizontal quadrats. Dominant taxonomic compositions of the horizontal and vertical quadrats are graphed in Figures 25-29. Horizontal quadrats were generally dominated by algae, *Corynactis californica, Archidistoma psammion,* and gastropod and polychaete tubes. Vertical quadrats were dominated by *C. californica, Styela montereyensis, Salmacina tribranchiata, and Bugula* spp. The multivariate test ANOSIM was used to statistically compare the taxonomic compositions of vertical and horizontal quadrats. The result indicates that taxonomic compositions of vertical and horizontal quadrats were significantly different (0.2%). The largest contribution to this difference (analyzed using SIMPER) included *Bugula* spp., *Salmacina tribranchiata, Corynactis californica,* and polychaete and gastropod tubes, all of which were more abundant in vertical quadrats, and foliose red algae, *Laminaria farlowii, algal recruits, erect bryozoan sp. 1, and hydroids, which were* more abundant in horizontal quadrats (see Fig. 30). There were also significant seasonal effects observed in the horizontal quadrats ($p=0.02$; N.B., there were too few vertical quadrats photographed among seasons to be statistically tested). The seasonal

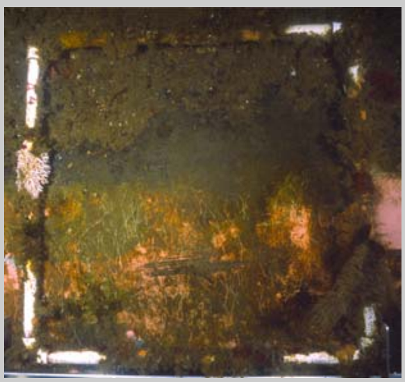


Figure 24. Photo of horizontal quadrat over area still affected by anti-fouling paint (lower two-thirds of quadrat). The affected areas are mainly only colonized by filmentous diatoms and hydroids.

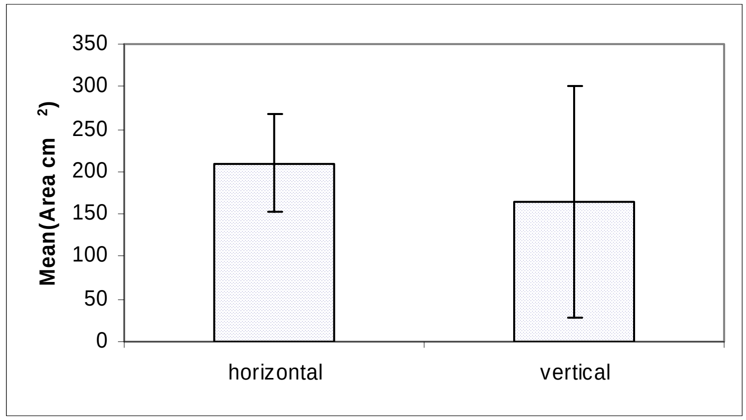


Figure 25. Average of bare space on horizontal and vertical quadrats. Quadrats affected by anti-fouling paint were not included. Error bars are standard errors.

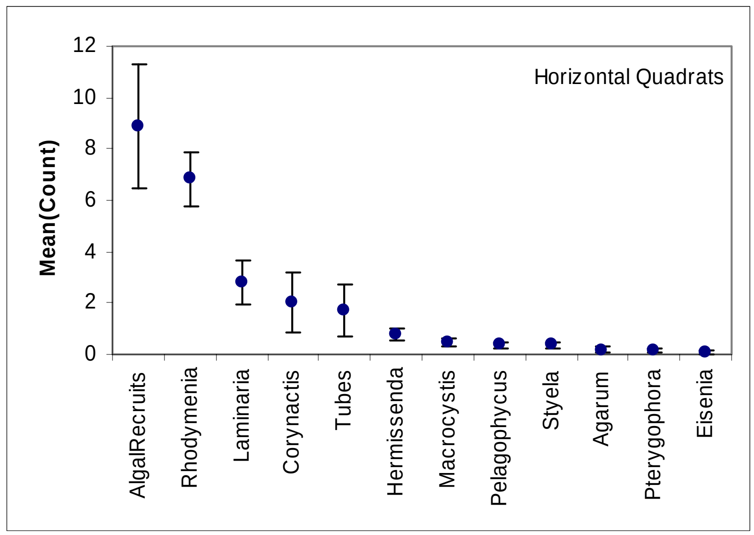


Figure 26. Average counts of each taxon for horizontally oriented

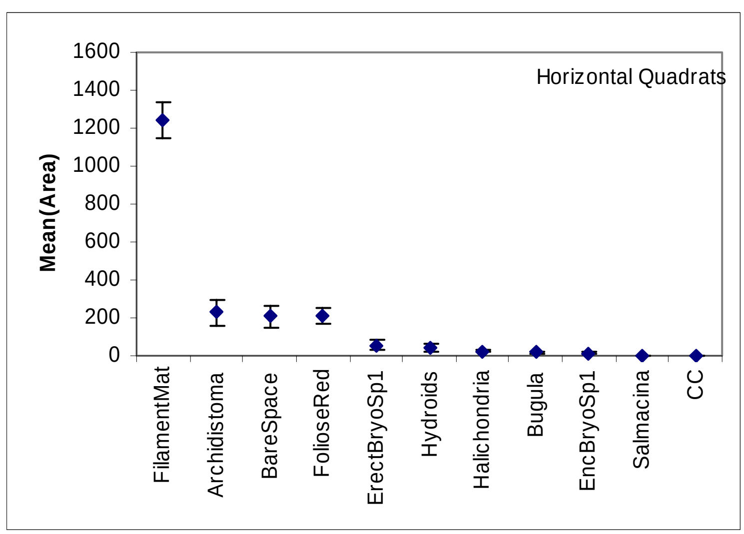


Figure 27. Average area of each (cm^2) taxon for horizontally oriented quadrats

variation was greatest for *Archidistoma psammion, algal recruits, Bugula* spp., and filamentous mat, which were more abundant during summer, and foliose red algae and hydroids, which were more abundant during winter (Fig 31). (N.B., It was not possible to test for seasonal and orientation effects in a simultaneous 2-way ANOSIM because there were too few replicates among seasons for the vertical quadrats.)

Another seasonal difference that was observed in the photos but was not easily quantifiable, was the degree of epiphytic cover on macroalgae. Hydroid and bryozoan cover was noticeably greater in the winter photos than in the summer photos. The degree of hydroid and bryozoan cover observed on brown algal recruits on the Yukon was much greater than that typically observed in natural habitat and may be an important cause of mortality for algal recruits on the Yukon.

Extensive turnover of brown macroalgae, with the exception of *Laminaria farlowii and Agarum fimbriatum, was also observed in* the quadrats that were photographed over the entire 14-month period. There was extensive recruitment of *Macrocystis pyrifera, Pterygophora californica, Pelagophycus porra* (an annual kelp) in many of the horizontal quadrats. However, most recruits were gone within six months. The most likely source of mortality for *M. pyrifera* and *P. porra* is holdfast dislodgement from the smooth metal surface of the hull. Very little tension is required to detach these kelps from the hull (Parnell pers. obs.).

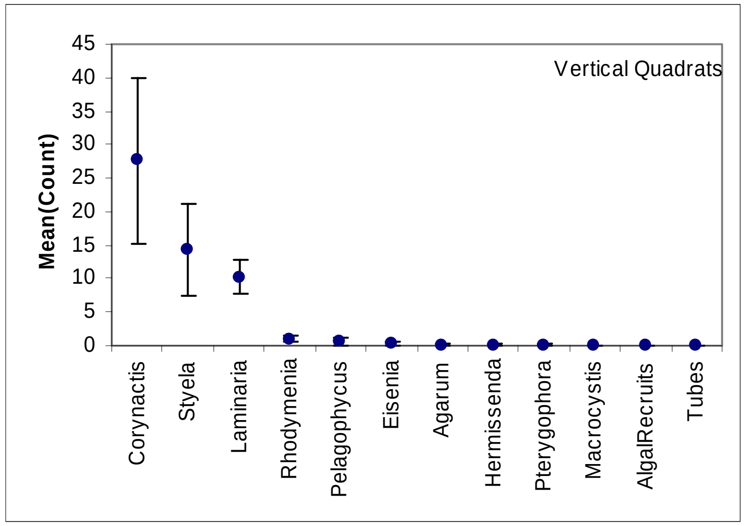


Figure 25. Average counts of each taxon for vertically oriented quadrats.

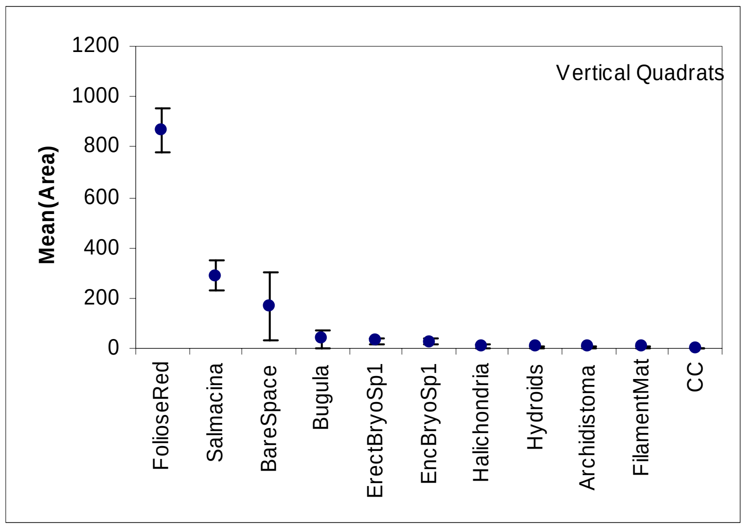


Figure 26. Average area of each (cm^2) taxon for vertically oriented quadrats.

DISCUSSION

Artificial Reef Monitoring Project

The purpose of the Yukon Artificial Reef Monitoring Project (ARMP) is twofold. The first is education and public outreach, both important components of the Foundation's mission. In this regard, the ARMP has been successful since several hundred divers in San Diego County have attended training sessions and seminars in which the state of California's marine resources have been highlighted. To some extent, the ARMP also brought together the diving community of San Diego by networking with dive clubs and organizations and through local diving websites and listservers such as Divebums

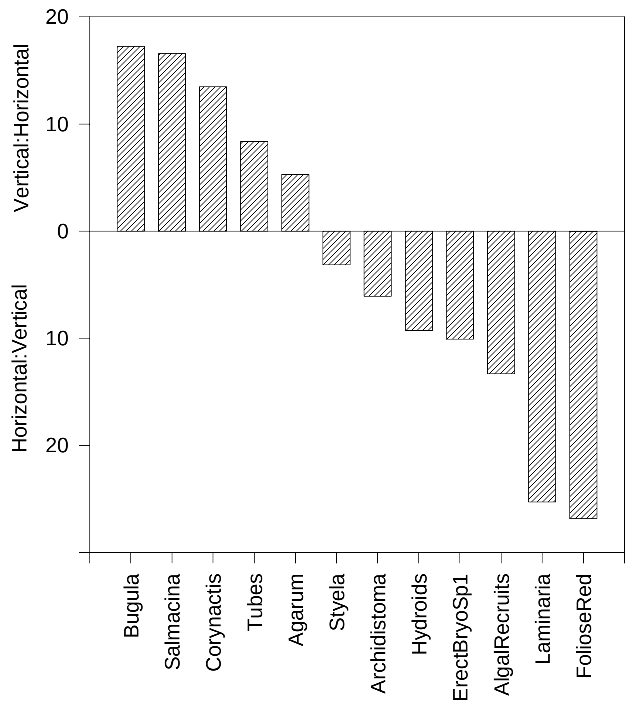


Figure 30. Ratios of taxa (average of counts or area) found on vertical quadrats relative those of horizontal quadrats. Values above abscissa indicate taxa that are more abundant in vertical quadrats and values below abscissa indicate taxa more abundant in horizontal quadrats. Only those taxa that were significantly different between horizontal and vertical quadrats (Mann-Whitney) are included in graph.

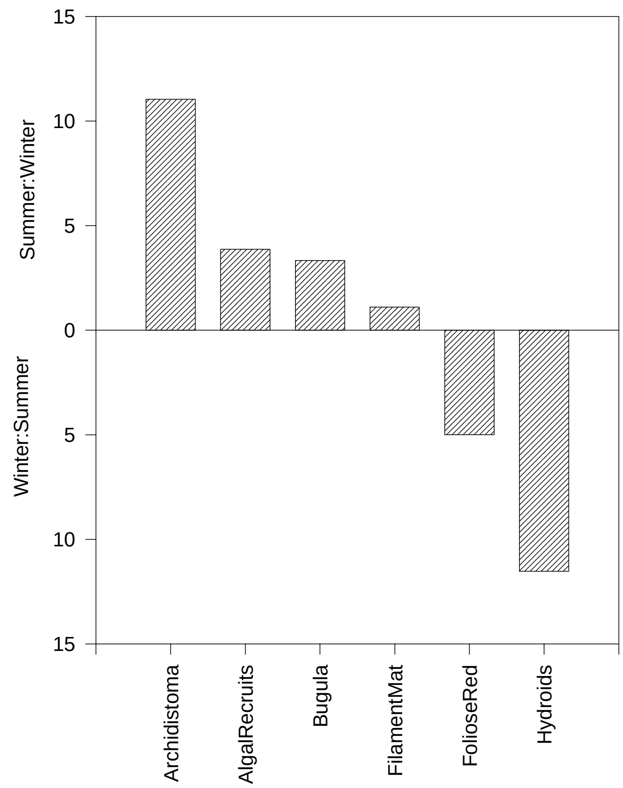


Figure 31. Graph showing seasonal differences observed in the photo quadrats. Ratios of taxa relative to season (winter or summer) are plotted for horizontal quadrats.

(http://www/divebums.com). The second goal was to monitor the Yukon to assess its biological community over time and to gauge its ecological effects. This component of the project has only been partially successful mainly due to the lack of resources to support a comprehensive research program. The results of the fish counts demonstrated that well-trained and experienced volunteer divers are quite useful. However, a much more rigorous and comprehensive program is needed in the future to determine the regional effects of establishing so many artificial reefs off San Diego.

Findings

The results of the fish transects demonstrated that the composition of the fish assemblage on the Yukon has changed significantly since the Yukon sank and that the rate of change appears to be slowing since the assemblages of 2003 and 2004 were similar. There was immediate attraction of barred sand bass, sculpin, and cabezon from other habitat, and there was secondary attraction of kelp bass, several species of rockfish, and lingcod. It is obvious these individuals migrated from elsewhere since they were too old to have recruited on the ship. This is cause for concern because fishing has been observed several times on the Yukon including episodes of fishing by commercial passenger fishing vessels after which the population of barred sand bass, a slowly maturing species, appeared noticeably depleted (N. Morris, pers. obs.).

Fish movements between artificial and natural habitat in Monterey (Matthews 1985) indicate that several species of targeted fish migrated up to ~1.6 km from natural to artificial habitat, and that artificial habitat is subjected to greater fishing effort due to its small size and well known location. The results of Matthews and observations collected as part of the ARMP indicate that the Yukon may concentrate some targeted species. The fish tagging study that was begun on the Yukon but was discontinued due to limited resources would likely have helped to address this issue. The presence of numerous other artificial habitats in the area is an additional complication. Are these artificial reefs also concentrating fish that recruited onto natural habitat? Or, does the network of reefs serve as the basis of a large forage area for some species thereby possibly enhancing fish production? Does the network of artificial habitats provide a migration corridor between natural rocky habitat to the north and south? Clearly, the regional effects of these artificial habitats are presently poorly understood and should be comprehensively studied especially if artificial reefs are proposed for this area in the future. These studies should include the entire network of artificial reefs and natural habitat in La Jolla and Pt. Loma. These studies should also include the determination of fishing effort on the Yukon, the other artificial reefs, and natural habitat to partition the temporal variability of fish counts into fishing mortality, natural mortality, and migration.

The Yukon is likely beneficial for some species of fish. The development of a fish assemblage on the Yukon consisting of many residential species (e.g., sheephead, kelp bass, and some species of rockfish) is evidence that the Reef may benefit natural fish production for these species by redirecting fishing effort from natural habitat and through reproductive output. The Yukon is also likely beneficial for bocaccio, a seriously depleted species, because it appears to provide important recruitment and nursery habitat for this species.

The Yukon provides habitat for fish that appears to be a combination of submarine canyon rim habitat and deeper high-relief kelp forest habitat. Despite this, the diversity of the Yukon is approximately half that of natural kelp habitat nearby. Part of the reason for this is that the fish assemblage on the Yukon is still developing. However, any assumptions that the Yukon may provide better fish habitat than natural reefs due to its high profile may be incorrect. The results of a comprehensive study of fish habitat structure throughout the Southern California Bight indicated that while vertical relief is very important habitat for many species of fish, fish abundances appear to saturate at a vertical relief of ~0.75m (Patton et al. 1985). Therefore, there may not be any advantage of high relief artificial structures such as the Yukon relative to low relief artificial habitat such as the quarry rock reefs of Pacific and Mission Beaches. While, it was not possible to quantitatively determine if the fish assemblages on the Yukon and the quarry rock reefs (Bedford 1993) were similar, the species compositions were similar.

In summary, the Yukon appears to attract some species of non-residential fish. The Reef appears to be beneficial to some species as it provides recruitment and nursery habitat, and provides habitat for residential reef obligate species. The latter likely redirects some fishing effort away from natural habitats and increases regional reproductive output. However, the contribution of reproductive output for residential obligate species is likely small relative to that of fish living on abundant natural habitat nearby. The same argument can be made for the Yukon's contribution to the abundances of reef obligate species (see Ambrose & Swarbrick 1989). However, all these conclusions are based on consideration of the Yukon in isolation. The network of artificial reefs that the Yukon is part of may have synergistic beneficial effects. The network might be beneficial to natural populations by increasing forage area and by serving as stepping-stones for mobile species between natural habitats located to the north and south.

The succession of fouling communities on artificial reefs in southern California has been previously well reported (e.g., Aseltine-Neilson et al. 1999). Although the Yukon provides much more vertical relief than most artificial reefs, comparisons of these studies to the Yukon provide an invaluable means of determining the maturity of the fouling community on the Yukon. Future study of the other high-relief artificial reefs off Mission and Pacific Beaches (NEL Tower wreckage, and the wrecks Ruby E, El Rey, and Shooter), which date back to the mid 1980s, would be of further value in this regard. The composition of the fouling community is important to the fish community because the fouling community provides an important source of habitat and food. The results of this study indicate that the fouling community on the Yukon is not yet mature because some late successional stage species such as gorgonians have not yet colonized the ship.

The algal community on the Yukon appears highly disturbed. While many species of kelps recruit onto the ship, there is high mortality due to fouling by hydroids and bryozoans, and because the larger kelps do not appear to be able to firmly attach to the hull. The oldest giant kelp plants (*Macrocystis pyrifera) observed on* the Yukon were in the 4-stipe stage and therefore less than six months old. The other canopy forming kelp in southern California, *Pelagophycus porra,* does not appear able to stay attached beyond a length of a couple of meters. Therefore a kelp forest will not develop on the Yukon unless there is intervention in the form of affixing different substrate to the upper surface of the wreck. Even with such intervention, a kelp forest might not develop on the reef because extensive fouling by bryozoans may lead to incidental kelp overgrazing by fishes such as senoritas and kelp surfperch that feed on the bryozoans (Bernstein & Yung 1979).

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ARTIFICIAL REEF MONITORING PROJECT

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