Artificial Reefs as a Restoration Tool for Alaska's Coastal Waters

Final Report to

U.S. Fish and Wildlife Service, Alaska Coastal Program

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INTRODUCTION

Prince William Sound is an important region for commercial, subsistence, and recreational fish harvest. The city of Whittier, located at the head of Passage Canal in western Prince William Sound, is the primary gateway to the Sound and serves as a recreational destination for Anchorage residents and seasonal tourists. Whittier supports a variety of interests including commercial and sport fishing, kayaking, scuba diving, charters, and recreational boat use. Whittier is also a port destination for cargo vessels, cruise ships, recreational and commercial fishing vessels, and the Alaska Marine Highway system.

Economic growth and development in and around Whittier has resulted in increased localized pressures on coastal marine habitats. In addition, shoreline habitat is being altered by activities such as harbor expansion and development and sheet-pile dock construction. These development activities result in the degradation or loss of productive fish habitat primarily by the alteration or removal of existing habitat structure including natural rocky reefs and aquatic vegetation.

Currently, viable restoration options for mitigating habitat loss in Alaska's coastal waters are limited. At the same time, restoration methods applied in lower latitude marine habitats have not been explored in sub-Arctic marine ecosystems. Testing the efficacy of potential restoration tools in these ecosystems is necessary to determine effective enhancement and restoration options for Alaska's nearshore waters.

Artificial reefs (AR) are commonly deployed in temperate to tropical marine waters for the purpose of enhancing fish abundance, or restoring habitat following the degradation or loss of natural structure to anthropogenic or acute natural events (Miller 2002). Seaman (2000) defines AR as natural or man-made objects deployed on the seafloor with the effect of influencing biological and physical parameters in the marine environment. Modern AR applications use pre-planned reef designs that integrate biology and engineering to create specific features that mimic natural habitat. These artificial structures encourage settlement of plants and benthic invertebrates, and provide both shelter and a forage base for fish (Fabi et al. 2006; Hixon & Beets 1993). The addition of artificial structure increases habitat heterogeneity and available refuge for fish and mobile invertebrates by adding vertical relief and structural complexity (Jordan et al. 2005). These components have been demonstrated as important habitat parameters for demersal fish assemblages and are correlated with increased species richness and abundance (Perkol et al. 2006).

Although traditional AR applications have focused on enhancing fish abundance and total fish catch for recreational and commercial fisherman in coastal waters, recent evaluations of AR applications suggest that artificial structures may be utilized to compensate for structural damage to natural habitat and restore productivity where habitat is lost or destroyed (Pickering et al. 1998). In the United States, AR have been utilized in coastal waters of Gulf of Mexico, Atlantic, and Pacific states and are designated by National Marine Fisheries Service (NMFS) as essential fish habitat in the Gulf of Mexico and South Atlantic states.

The use of artificial reefs to mitigate natural habitat loss due to anthropogenic disturbance in Alaska's coastal waters requires an effective evaluation of AR performance relative to natural reef function in sub-Arctic waters. In May 2006, NMFS installed Alaska's first artificial reef in the marine waters by Whittier. Few studies have examined the effect of artificial structures in cold temperate marine systems, but available data suggests that addition of vertical structure in sub-Arctic waters positively affects abundance of demersal fish assemblages (Wilhelmsson et al. 2006). Additionally, research on temperate species of cod, rockfish, and flatfish has demonstrated association of these groups with high relief structures during phases of their early life history or throughout their life cycle (Cote et al. 2004; 1994; Gregory et al. 1997; Johnson et al. 2003).

Many commercially and recreationally important fish species including, Pacific halibut (*Hippoglossus stenolepsis*), lingcod (*Ophidon elongatus*), and several species of rockfish utilize nearshore habitats in the Prince William Sound. Increased shoreline development in Alaska's coastal communities may disrupt the function of productive sub-tidal communities that provide essential habitat for these and other species. Therefore, an evaluation of AR performance designed to address whether or not the objective of AR deployment is satisfied will inform natural resource managers seeking viable restoration options for Alaska's coastal waters.

Here I present the results of the first-year (2006) of a study designed to assess the efficacy of artificial reefs as a fish habitat enhancement tool with potential for future marine habitat restoration and enhancement projects in nearshore Alaskan waters. I document the marine community at the artificial reef and compare it to nearby rocky reefs and a hard bottom site.

OBJECTIVES & HYPOTHESES

(1) document the marine community at the artificial reef

a. describe spatially and temporally the plant assemblages colonizing the reef
b. document fish species diversity and abundance
c. determine if marine communities vary by reef structure (ball vs. pyramid)

(2) compare artificial reef and natural rocky reef community structures; and

(3) assess artificial reefs as a fish habitat enhancement and restoration tool.

H_1. Fish habitat is enhanced after deployment of artificial reefs; fish diversity and abundance at artificial reef sites is increased in comparison to natural hard bottom habitat.

H_2. Artificial reefs mimic the ecological structure and function of natural reefs such as rock outcroppings.

STUDY AREA

The study was conducted in Passage Canal, located in the northwest corner of Prince William Sound, near the port city of Whittier. Within Passage Canal, four study areas (Fig.1) were used to evaluate artificial reefs as an enhancement tool for nearshore fish habitat: artificial reef (Smitty's Cove), and three control sites: natural reef 1 (Bush Banks Pinnacle), natural reef 2 (rock slide), and natural hard bottom (Emerald Bay).

Site Name	Approximate Locations	Depth (m)
Artificial reef	60 46.73'N 148 39.87'W	12-20
Natural reef 1	60 47.88'N 148 36.65'W	15-22
Natural reef 2	60 48.24'N 148 39.47'W	11-17
Natural hard bottom	60 48.40'N 148 33.89'W	12-20

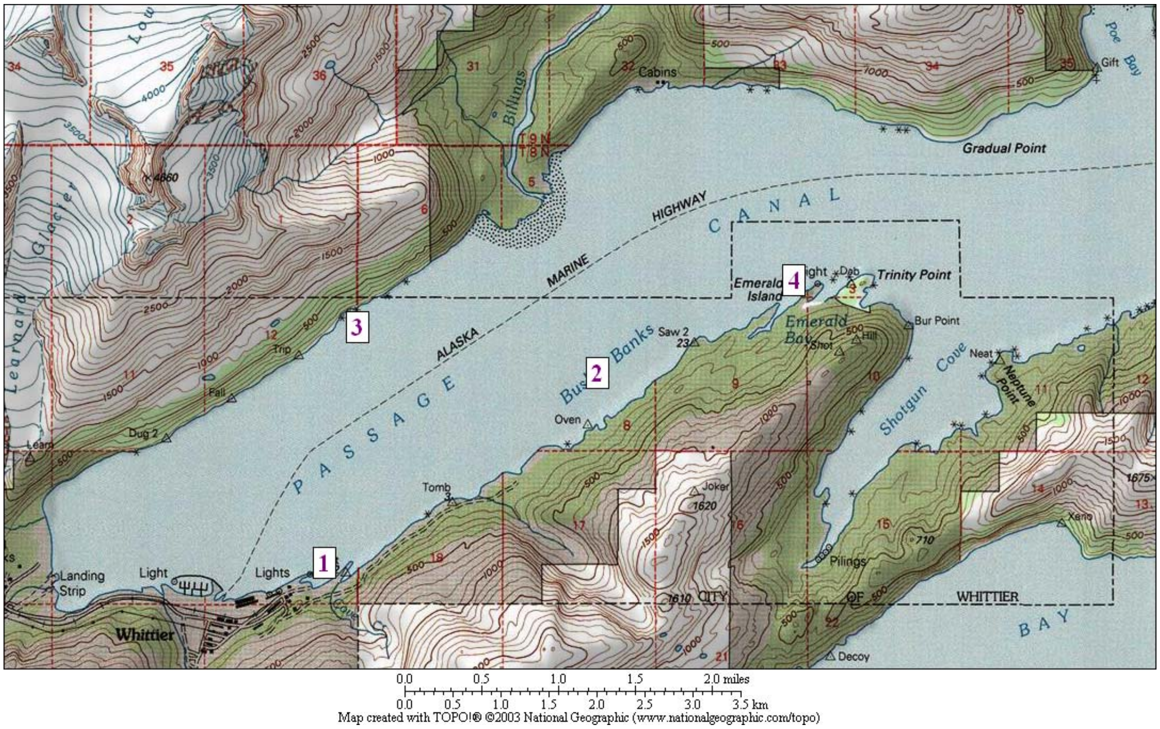

Fig. 1. Passage Canal study sites. **1)** artificial reef (Smitty's Cove), **2)** natural reef 1 (Bush Banks Pinnacle), **3)** natural reef 2 (Rock Slide), and **4)** natural hard bottom site (Emerald Bay).

The artificial reef installation at Smitty's Cove consists of two parallel rows, each containing three, circular reef plots (each ~10m diameter) consisting either of 1m high pyramid-shaped Fish Havens (30 pyramids/plot) or of 1m high spherical Reef Balls (30 balls/plot). The two rows are situated on a declining slope (12-20m depth) over a mixed soft and hard sediment substrate (Fig. 2).

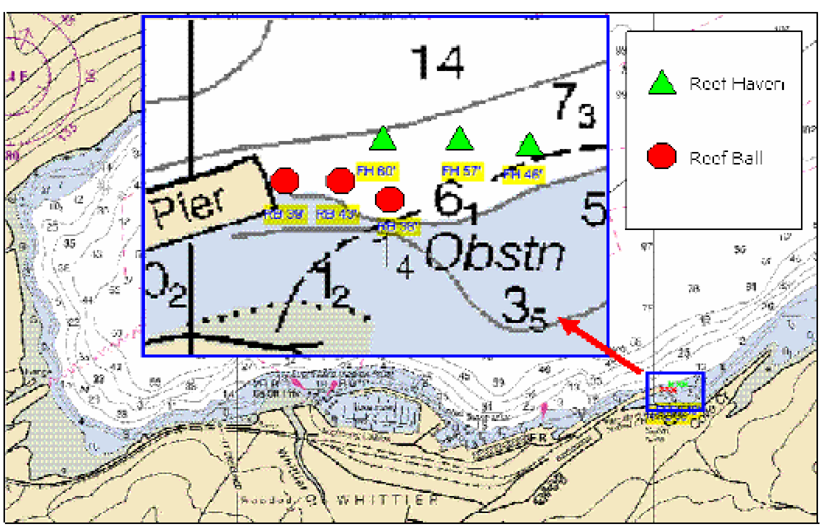

Fig 2. Location of artificial reef by structure type, Smitty's Cove, Whittier, Alaska.

Natural reef 1 at Bush Banks is a pinnacle that rises from the seafloor to a depth of 15-22m. The top of the pinnacle is approximately 100m diameter, and is characterized by a rocky substrate. Natural reef 2 is a rock slide site adjacent to the shoreline on a 45º declining slope. The substrate at the rock slide is composed entirely of boulders. The natural hard bottom control site at Emerald Bay is a cove with hydrographic, physical, and biological features similar to the Smitty's Cove site prior to deployment of the artificial reefs.

Methods

From June to September 2006, all sites were monitored once a month. Dive surveys described plant and fish communities. Non-dive surveys included fish traps for demersal fish, hook and line surveys for larger-bodied fish, and stationary-drop video cameras to validate dive results. At the artificial reef, each of the six circular reef plots (3 pyramid and 3 reef ball) were each sampled during monthly dive and non-dive surveys. At the two natural reef sites, I established one plot each at depths of 12m and at 18m (site #1) and 14m and 18m (site#2), and sampled each plot during monthly dive and non-dive surveys. At the natural hard bottom site I established one sampling plot at each of four depths: 12m, 16m, 18m, and 20m. The 12m, 16m, and 20m plots were sampled during non-dive surveys. Because of time constraints when SCUBA diving, for dive surveys only the 12m and 18m plots were sampled.

Dive surveys

At each plot, I randomly sampled three structures for macrophyte coverage. At the artificial reef site a structure was defined as either a reef ball or a reef pyramid. At both the base and the crest of each artificial or natural structure, a $0.1m^2$ quadrat was laid and a digital photo taken. Quadrat photos were overlaid with a grid to determine percent macrophyte coverage.

Also at each plot, a pair of divers swam a 30m long transect at approximately 1m above the substrate. At the circular reef plots, divers swam along the outside edge of the plot, whereas at the control sites divers swam in a straight line. For each transect, one diver used a video camcorder for filming. The second diver recorded on a slate all observations occurring within 1m on either side of the transect line.

In the laboratory, video footage from transects was viewed by "freezing" frames on a color monitor. Fish observations on the video were then compared with the second diver's slate observations. Because of poor lighting conditions and backscatter, video footage was of uneven quality. While slate observations were designed to validate the video footage, when compared the slate observations were more accurate. I therefore used the slate observation data, supplementing it with information from the video footage when necessary. Because dive surveys are biased towards more conspicuous fish species, I only used dive observations of pleuronectids (flatfish), scorpaenids (rockfish), and hexagrammids (greenlings and lingcod). I then quantified fish density as fish/m2 for each of these three species groups.

Non-dive surveys

At all plots, monthly non-dive surveys included hook and line, fish traps, and stationary videos. For hook and line surveys each plot was fished for 30 minutes by two anglers using bottom fishing tackle baited with herring. For trap surveys, three fish traps were deployed at each plot for 12 h. Trap surveys utilized semi-oval Memphis Net© designed mesh fish traps (trap dimensions: 26" x 19" x 9" with 6" door openings and ½" mesh). All fish caught were identified to species, measured, and released at the plot. Catch per unit effort (CPUE) was calculated as fish/angler hour (hook and line) or as fish/trap hour (trap surveys). For both fish trap surveys and hook and line surveys I calculated an average CPUE from all replicates at each major site.

Each plot was videoed for 10 minutes using a Marine Video Splashcam© lowered into the water from the boat to a height of 0.5 - 2m above the substrate or artificial reef structure. Camera data is not available from September surveys due to camera malfunction. I used the drop camera data as an index of relative species richness. Fish such as pleuronectids (flatfish), scorpaenids (rockfish), and to a lesser degree the hexagrammids (greenlings and lingcod), are more likely to be enumerated during stationary camera surveys due to their more conspicuous use of habitat. Bathymasterids (ronquil) and cottids (sculpin) are less conspicuous to visual observation, particularly in habitats with high kelp coverage.

Results

Macroalgae colonization

On both reef ball and reef pyramid surfaces, macroalgae colonization was minimal during 2006 surveys. Turf brown algae (Class Bacillariophyceae, colonial diatoms) covered 4% of reef ball surfaces in June and 2% in July, but disappeared by August. Reef pyramid surfaces were 7% covered with Bacillariophyceae in June and 3% in July, then bare by August.

Substrate adjacent to the artificial reef structures did have well developed macroalgae communities dominated by *Agarum clathratum* (sieve kelp) and *Laminaria saccharina* (sugar kelp). Macrophyte coverage of the substrate surrounding reef pyramid plots varied from 30% at the shallowest plot (14m) to 10% at the deepest plot (19m), and coverage surrounding the reef ball plots varied from 60% at the shallowest plot (11m) to 20% at the deepest plot (14m). At the natural reef and natural hard bottom control sites, macrophyte communities were also dominated by *A. clathratum* and *L. saccharina* (Fig. 3). Macroalgae coverage and diversity decreased with depth and community composition was stable throughout the survey period.

Fish communities

The majority of fish collected during the survey period at all study sites belonged to six families: Scorpaenidae (rockfish), Gadidae (cod), Hexagrammidae (greenling), Cottidae (sculpin), Pleuronectidae (flatfish), and Bathymasteridae (ronquil; Table1). At all sites, low fish densities were observed throughout the survey period. Lowest fish densities were recorded in June with densities peaking during August and September surveys.

At both reef balls and reef pyramids the fish community was nearly identical. Rockfish were the most abundant family group observed during dive transects and drop camera surveys, followed by Hexagrammids (lingcod and whitespotted greenling *Hexagrammos stelleri*) in lower densities (Figs. 4 & 5). Although copper rockfish (*Sebastes caurinus*) and quillback rockfish (*S. maliger*) comprised the majority of rockfish observations for all sites, Puget Sound rockfish (*S. emphaeus*) and dusky rockfish (*S. ciliatus*) observations were unique to the artificial reef site. Flatfishes occurred at low to moderate frequencies at the artificial reefs in June and July with rock sole (*Pleuronectes bilineatus*) then Pacific halibut comprising the majority of observations.

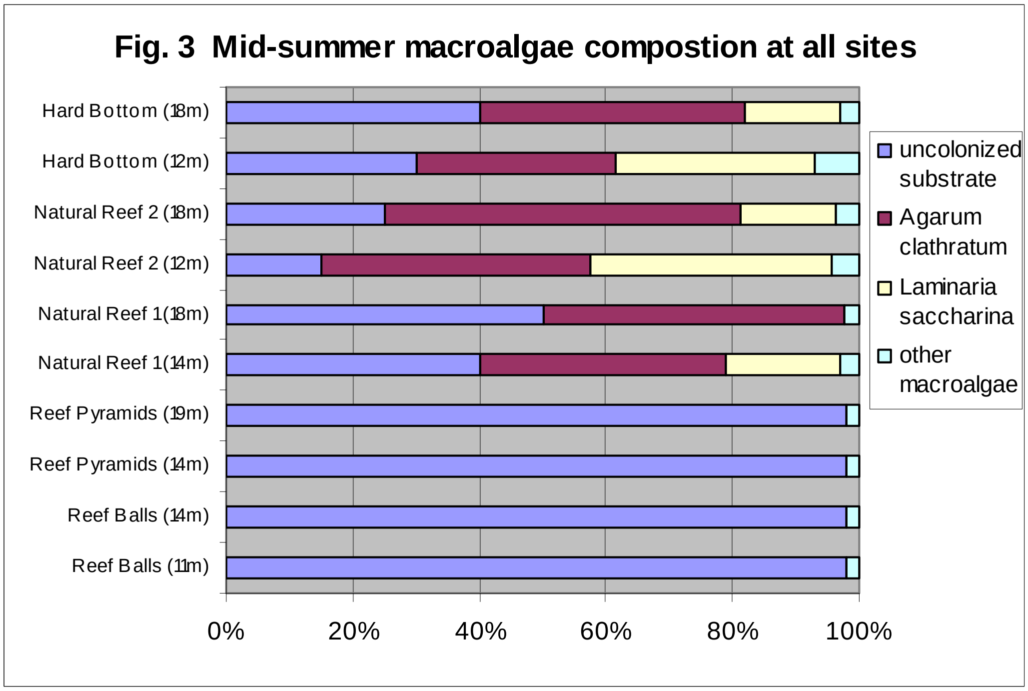

Fig. 3. Average percent (%) cover of macroalgae at control and artificial reef plots. July 2006, Whittier, Alaska.

At the natural reef sites, rockfish were the dominant group observed for all survey methods with copper and quillback rockfish occurring in equal densities (Figs. 4-7). Hexagrammids comprised the second most commonly observed family at the natural reef communities with whitespotted greenling then lingcod comprising the majority of those observations. Pacific halibut and rock soles were the most commonly associated flatfishes with the natural reefs, and were unique to the natural and artificial reef sites.

The natural hard bottom site yielded the lowest species richness of all sites. Interestingly, across all monthly fish trap surveys, this site consistently yielded the highest family diversity (4-6 families versus 1-3 families at all other sites; Fig. 6). Hexagrammids comprised a consistent majority of the fish observed for all survey methods at the hard bottom site with kelp greenlings representing the majority of those observations. Gadids, cottids, bathymasterids, and pleuronectids (yellowfin sole *P. asper*, only) occurred in lesser, but regular frequencies. All methods indicated very low frequencies of rockfish at the hard bottom site.

Table 1. Fish community compostion by site

Family	Species	Common name	Artificial reefs	Natural reefs	Hard bottom
Scorpaenidae	*Sebastes caurinus*	copper rockfish	x	x	x
	Sebastes maliger	quillback rockfish	x	x	
	Sebastes emphaeus	Puget Sound rockfish	x		
	Sebastes ciliatus	dusky rockfish	x		
Hexagrammidae	*Hexagrammos stelleri*	whitespotted greenling	x	x	x
	Hexagrammos decagrammus	kelp greenling	x	x	x
	Ophidon elongatus	lingcod	x	x	x
Pleuronectidae	*Hippoglossus stenolepis*	pacific halibut	x	x	
	Pleuronectes bilineatus	rock sole	x	x	
	Pleuronectes asper	yellowfin sole		x	x
Gadidae	*Microgadus proximus*	pacific tomcod	x		x
	Gadus macrocephalus	pacific cod	x		x
Cottidae	*Myoxocephalus polyacanthocephalus*	great sculpin	x	x	x
	Hemilepidotus hemilepidotus	red irish lord sculpin		x	x
Bathymasteridae	*Ronquilus jordani*	northern ronquil	x	x	x
	Bathymaster caeruleofasciatus	Alaskan ronquil	x	x	x

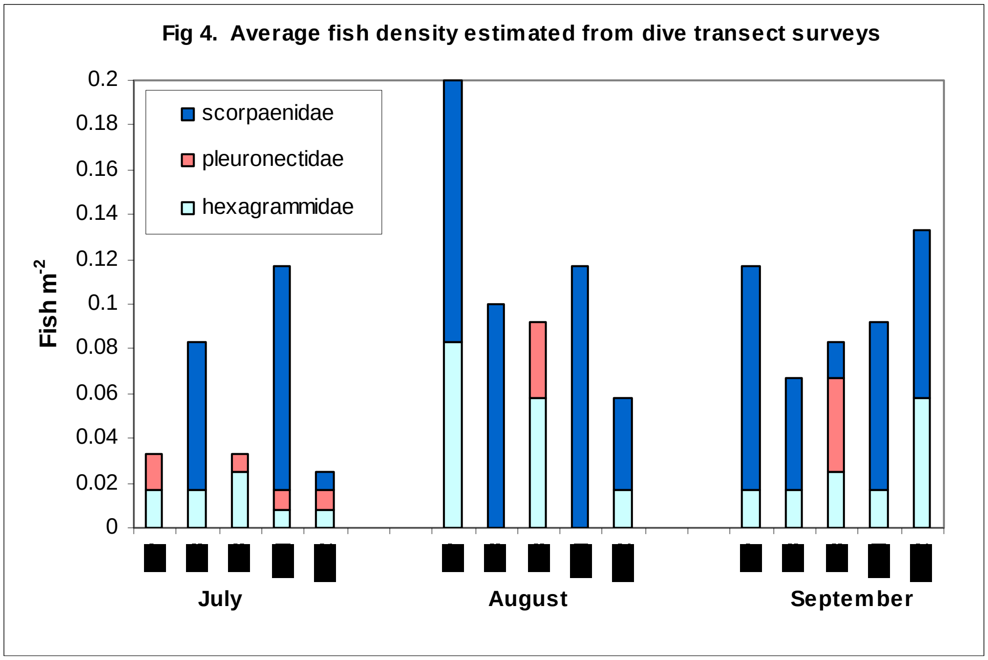

Fig. 4. Average fish density (fish/m^{-2}) by month and site estimated from dive transect surveys. 2006. Whittier, Alaska. RP= Reef Pyramid, RB= Reef Ball, HB= Hard Bottom, NR1= Natural Reef #1, NR2= Natural Reef #2.

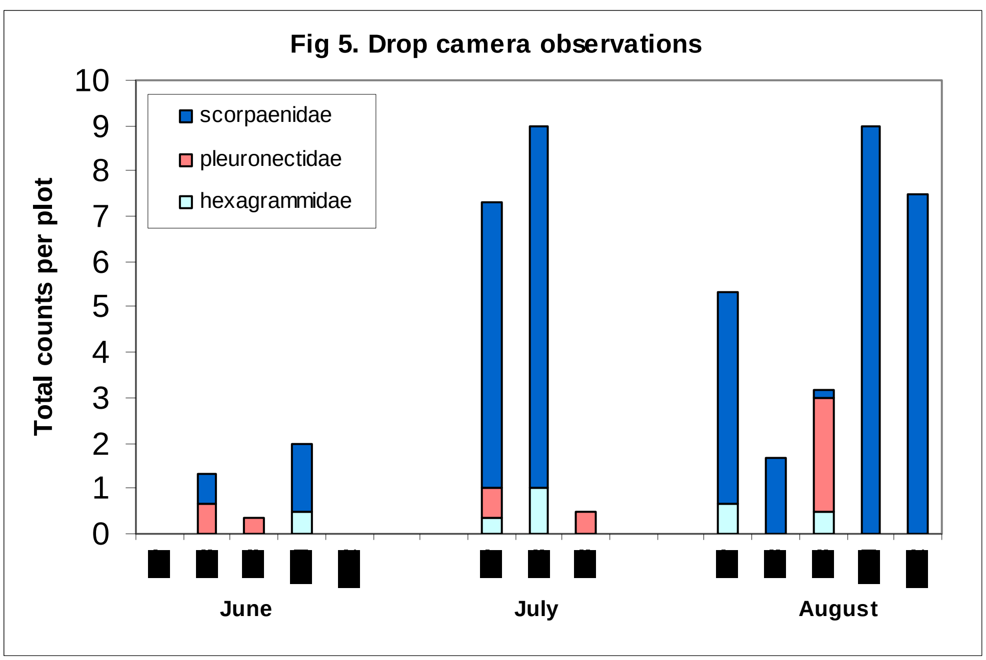

Fig. 5. Total fish observed during drop camera surveys by month and site. 2006. Whittier, Alaska. RP= Reef Pyramid, RB= Reef Ball, HB= Hard Bottom, NR1= Natural Reef #1, NR2= Natural Reef #2.

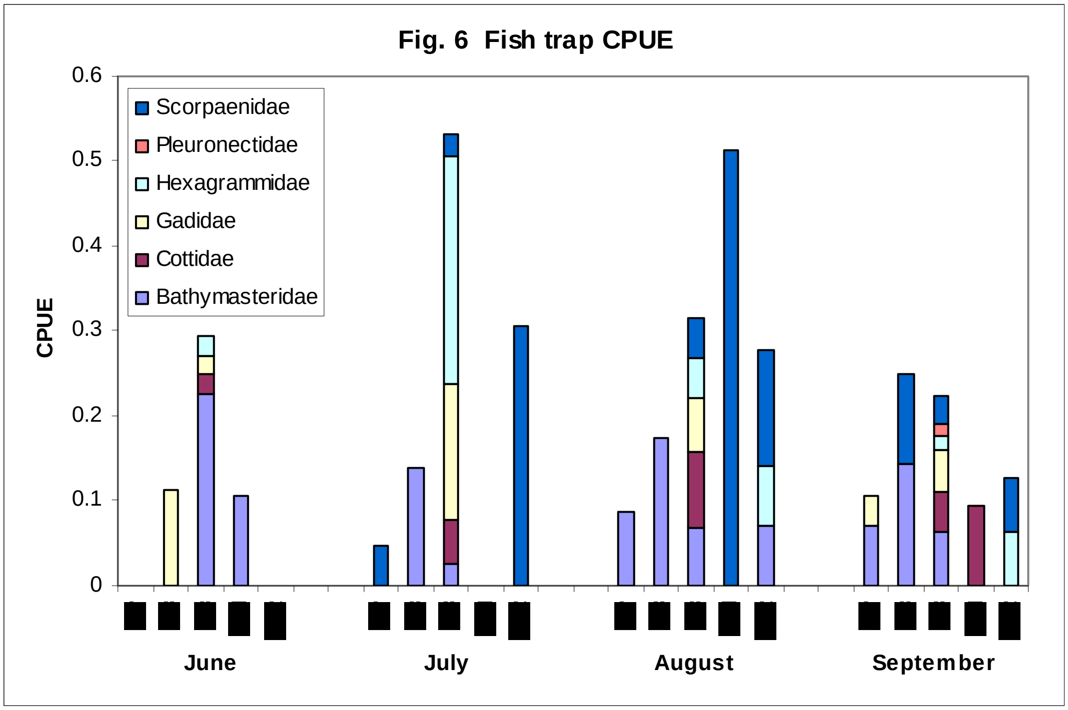

Fig. 6. Fish trap catch-per-unit effort (CPUE) by month and site. CPUE is expressed as fish/trap hour.2006, Whittier, Alaska. RP= Reef Pyramid, RB= Reef Ball, HB= Hard Bottom, NR1= Natural Reef #1, NR2= Natural Reef #2.

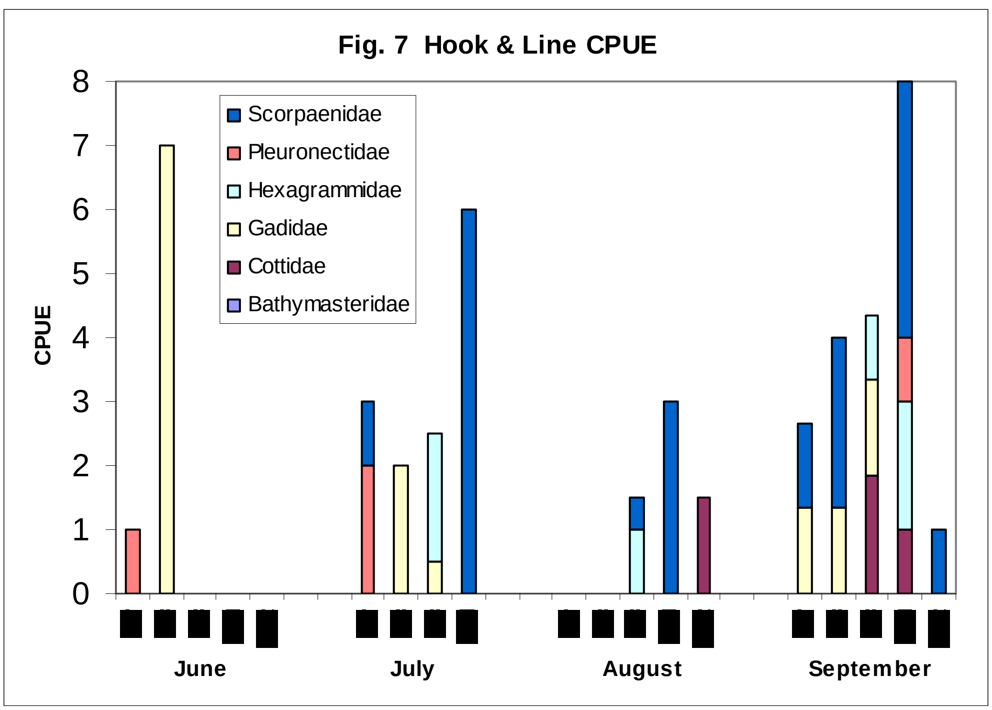

Fig. 7. Hook & line catch-per-unit effort (CPUE) by month and site. CPUE is expressed as fish/angler hour. 2006, Whittier, Alaska. RP= Reef Pyramid, RB= Reef Ball, HB= Hard Bottom, NR1= Natural Reef #1, NR2= Natural Reef #2.

DISCUSSION

Artificial reefs function as both fish habitat enhancement and restoration tools in lower temperate to tropical latitudes worldwide. However, limited data is available on the function of artificial reefs (AR) in sub-arctic marine environments. Most literature describes a successful metric of AR success as one that evaluates AR community development and function relative to productive natural communities such as rocky reefs. This report summarizes the colonization events between June and September 2006 following the May 2006 deployment of Alaska's first artificial reef at Smitty's Cove by Whittier.

Although high variability exists in the data set due to observed low densities, the results demonstrate distinct fish communities between the low relief natural hard bottom site (NHB) and high relief natural and artificial reef sites. The data indicate a habitat preference by rockfish for sites with high relief, especially sites with high relief structure colonized by kelp. Highest rockfish densities were observed at natural reef sites where high relief features attracted a community dominated by *S. caurinus* and *S. maliger*. More intriguing, however, is the occurrence of Puget Sound rockfish and dusky rockfish at the artificial reefs, but not at the natural reef sites. According to a Whittier divemaster with more than 1,000 dives in Passage Canal, neither Puget Sound rockfish, dusky rockfish, nor Pacific halibut occurred in Smitty's Cove prior to the reef's deployment (J. Vandergriff, pers. commun.). This indicates that at least initially, the artificial reef is attracting a more diverse fish community.

At the artificial reef sites, dive transects and drop camera surveys indicate that rockfish densities are relatively moderate to high whereas fish trap data reflect a relatively low to moderate densities. The absence of kelp coverage at the artificial reefs may partially explain the varying results between visual and non-visual survey methods. Visual census data is biased toward individuals with conspicuous habitat utilization (i.e. fish not utilizing kelp coverage). Rockfish utilizing artificial reef sites were more visible due to the absence of kelp. These discrepancies suggest that visual surveys at natural reef sites may underestimate rockfish density whereas densities at the artificial reef sites may be more accurate due to a higher probability of a fish being viewed and counted.

Another factor explaining the dissimilarity between fish trap and visual census data could be the presence of the seastar *Pycnopodia helianthoides*. This seastar was recorded in high densities at all sites during fish trap surveys, with highest densities recorded at the artificial reefs. Its presence in ~75% of all fish traps suggests the likelihood of interference with catch rates due to the tendency of this large-bodied seastar to become caught in trap openings. The absence of larger-bodied fish such as rockfish, rock sole, and sculpins and the higher frequency of smaller fish such as ronquils and Pacific tomcods (*Microgadus proximus*) in trap sets may be explained by *Pycnopodia* interference.

Prior to artificial reef deployment, hydrographic features and substrate features at both the reef ball site and reef pyramid site were similar. These similarities and the close proximity of the sites yielded similar fish community compositions for the 2006 surveys. More recently, second year (2007) surveys have observed a dense macrophyte community dominated by *Agarum clathratum* colonizing the reef ball surfaces and a high density of post-larval shrimp utilizing it as nursery habitat (B. Reynolds, unpub. data). At the reef pyramids during this same 2007 period, a less dense macrophyte community dominated by *L. saccharina* was observed, indicating that the two reef structure types may colonize different types of macrophytes or at different rates.

Surveys at the natural reef sites in 2006 and 2007 noted use of *A. clathratum* as shrimp nursery habitat. These observations suggest that at the artificial reef site macrophyte colonization will subsequently lead to an increased forage base (ie. juvenile shrimp) for reef-associated fish species. A study of variability in rockfish utilization of artificial reef and natural reef sites in temperate Pacific waters noted differing initial densities becoming more similar following succession of macrophyte communities (Danner et al. 1994). Danner's study implies the importance of monitoring temporal changes in community structure when determining artificial reef success.

One impact that this study cannot quantify is the impact of recreational fishers on the study sites. For example, the August hook and line surveys at the artificial reef site yielded no fish. This survey period coincided with increased localized fishing pressure by recreational fishers targeting coho salmon along the coast of Passage Canal. Rockfish, and to a lesser degree lingcod utilized the artificial reef habitats and both are highly sought after by recreational fishers. Because rockfish and lingcod are relatively sedentary and inhabit nearshore, hi-relief habitats that are easily identifiable on nautical charts to fishers, both are prone to overfishing (Matthews 1990, 1992).

Overall, the data suggest similarities between artificial reef and natural reef community structure. The continuation of surveys describing the spatial and temporal changes in biological communities following artificial reef deployment will determine if similarity or convergence in similarity with natural reef communities is occurring and provide valuable information for viable restoration options in Alaska's coastal waters.

Public Outreach

- Reynolds, B. "Artificial Reefs as a Restoration Tool for Alaska's Coastal Waters" Presentation. Marine Science graduate student body at Dauphin Island Sea Lab, University of South Alabama.
- Reynolds, B. 2007. Surveying Alaska's first artificial reef system. Breakwater 2:1,3. (newsletter of Prince William Sound Science Center).

Project Partners

- Prince William Sound Science Center, Cordova, Alaska
- Dauphin Island Sea Lab, University of South Alabama
- NOAA Restoration Center
- NMFS Habitat Conservation Division (Anchorage field office).
- U.S. Fish and Wildlife Service, Alaska Coastal Program

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