**Understanding the Capabilities of New Technologies and Methods**

**to Survey West Coast Groundfishes**

Estimating fish abundance using a manned submersible, an autonomous underwater vehicle, and acoustics coupled with a remotely operated vehicle in untrawlable habitats

Draft

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**Abstract**

**Introduction**

Surveys of west coast groundfishes are needed in high-relief rocky areas that are inaccessible to traditional net-based mobile fishing gear (e.g., bottom trawls). Several species, such as cowcod (*Sebastes levis*) and yelloweye (*S. ruberrimus*) rockfish, are strongly associated with these rocky habitats, have populations at various levels of depletion, and occupy habitats that have incurred substantial impacts (Love and Yoklavich 2006; Yoklavich et al. 2007). Now that much of the continental shelf and upper slope are closed to groundfishing, it is important to develop effective monitoring strategies for fish species living in these untrawlable habitats.

Non‐lethal survey methods, whether optical, acoustical, or some combination of both, are needed to adequately assess these vulnerable species while minimizing impact on the fishes and their habitat. To that end, we conducted a field study using three tools or techniques (i.e., a manned submersible [SUB]; a Seabed autonomous underwater vehicle [AUV]; and the collaborative optically assisted acoustical survey technique [COAST]) to survey groundfishes in complex rocky areas and to appraise resultant metrics of fish abundance, biomass, and diversity.

The specific objectives of this project using visual survey techniques from the SUB, AUV, and ROV were to (1) collect data on counts and sizes for several rockfish (*Sebastes*) species (both common and rare, large- and small-bodied, and semi-pelagic and highly demersal) and other taxa of interest (lingcod [*Ophiodon elongatus*], thornyheads [*Sebastolobus*], and Pacific hake [*Merluccius productus*]); (2) estimate densities (and associated precision) for these taxa; (3) estimate size composition for these species; (4) estimate abundance and biomass (and precision) for these taxa; and (5) estimate diversity of fish species within the study site. An additional objective was to couple the relative species and size compositions of fishes from the SUB? ROV? survey with fish densities estimated from an acoustics survey simultaneously conducted in the study area.

**Methods**

Study Area.

1. Underwater surveys of demersal fishes and habitats were conducted on two rocky seamounts (Footprint Bank and Piggy Bank) in the general vicinity of 33.9° N and 119°5 W off southern California (**Figure 1)**. The study site is located inside the State and Federal Footprint Marine Reserves, offshore of Santa Cruz Island, inside the Channel Islands National Marine Sanctuary. The Piggy Bank is about 30 km2 in area, ranging in depth from 275 to 900 meters; the Footprint Bank is about 10 km2 in area, ranging in depth from 80 to 500 meters. Our underwater visual surveys were planned to span from 400 m to the top of each seamount. Maps of high-resolution bathymetry and backscatter data from multibeam acoustic surveys of this area were available prior to our surveys (Dartnell et al. 2005). From those data we derived depth contours at 100-meter intervals and calculated the total area of each stratum using *ArcMap* 9.3: at Footprint 0-100 m (0.03 km2), 100-200 m (1.23 km2), 200-300 m (2.10 km2), and 300-400 m (2.78 km2) and at Piggy Bank 200-300 m (0.44 km2) and 300-400 m (1.73 km2).

2. Dates of surveys for each vehicle/technique (SUB, AUV, ROV, COAST):

a. SUB: 21-30 September 2011, using non-extractive transect methodologies and direct observations from the Nuytco *Dual Deepworker* SUB onboard the F/V *Velero IV*.

3. Survey methods and design.

a. SUB: A pilot operated the untethered SUB while an experienced scientist identified all fish species and estimated their total length (TL). Each transect was documented with two external high-definition (HD) color video cameras mounted at 45o on the starboard side of the SUB, one positioned in the same direction and field of view as the observer and the other camera located below the observer’s field of view to record fishes in the area closest to the SUB (that may not have been seen by the observer). The videotape was time-stamped and annotated in real-time by the scientist inside the SUB.

Dives were conducted during daytime (generally 0900-1700 h) over 10 days. Duration of dives ranged from 1.4 to 3.2 h (mean= 2.3 h, SE = 0.1). We tracked the SUB from the support vessel using a Linkquest *Tracklink 1500* ultra-short baseline (USBL) navigation system integrated with differential GPS and Fugro Pelagos *WinFrog* software; navigational data were time-stamped and recorded every 3 sec throughout each dive. The positioning system was linked to an ESRI *ArcMap* geographical information system (GIS), and a scientific navigator aboard the support vessel tracked the SUB in real time relative to bathymetry. The pilot and observer inside the SUB did not influence the direction of travel.

Each dive included multiple 15-minute-long strip transects, which were located randomly (prior to the cruise) within the 100-m depth strata on each of the two seamounts (**Figure 1**). Large areas of soft sediment in the northeast section of the study site were excluded from the SUB sampling frame. Number of transects per stratum was based on optimal sample variances from past visual surveys in the study area, the area of each depth stratum, and the amount of time available for the entire survey. We performed a bootstrap analysis of coefficients of variation in density of various fish species and species richness estimated from similar SUB transects conducted in 2005 on Footprint seamount at depths < 200 m. We concluded that 15 transects produced optimal sample variances for the area within the 100-200 m depth stratum at Footprint, and applied that ratio (15 transects/1.23 km2) to determine the number of transects to be conducted within the other depth strata in the study area. We increased the number of transects within the <100 meter stratum based on relatively high density of fishes and species richness at that depth in the earlier survey of this area. Using *ArcMap* 9.3, the appropriate number of spatially random points were generated within each depth stratum to locate transects.

During a transect, we tried to maintain a constant distance within 2 m of the seafloor and a constant speed between 0.5 and 1.0 knots, depending on substratum type (i.e., generally slower speed in complex habitats). Those segments of a transect in which the seafloor was not clearly visible were excised and not considered as part of the 15-minute sample. The scientist estimated size of fishes using paired lasers (installed at 20 cm apart on either side of the main survey video camera) as a guide. The length of each transect was determined accurately using a Doppler velocity log and ring-laser gyrocompass attached to the outside of the submersible. Transect width of 2.5 m was estimated by the scientific observer with the aid of a hand-held sonar device, the submersible’s sonar, and a crossing laser set at 3 m from the observer when the submersible was 1 meter above the seafloor.

Video transects and associated audio annotations made by the observer inside the submersible were reviewed following the survey. Identification (to lowest possible taxon), counts, and total length (to nearest 5 cm) of fishes on or near (<2 m) the seafloor were entered into an existing MS Access relational database, along with data from navigation, CTD, and other information related to each dive. Seafloor substratum types were classified from the videotape, in order of decreasing particle size and vertical relief (as described in Greene et al. 1999): rock (R), boulder (B), cobble (C), and mud (M). A two-character code was used to quantify patches of uniform substratum type along each transect (as described in Yoklavich et al., 2000). The primary character in the code represented the substratum type that accounted for at least 50% of the patch, and the secondary character represented the substratum type accounting for at least 20% of the patch (e.g., CM represented a patch of at least 50% cobbles and at least 20% mud). The area of each substratum patch along a transect was estimated as the product of the transect width and the length of the patch.

b. AUV

c. ROV

[there will be considerable overlap with some parts of the methods/design, so we might be able to organize once everything is added to the document]

Data Analysis.

For each survey vehicle at each depth stratum and bank, we estimated total abundance (number of fishes) of each species and some taxonomic groups, and biomass of those species for which data on length-weight relationships were available (**Appendix 1**). We also calculated species diversity as total number of species (richness) in each stratum. To estimate total abundance, we first calculated the density of each species and group on each transect as:

where is the number of individuals counted within the transect, is the transect length, and is the transect width (2.5 meters). Mean density and variance was then calculated from transects in each depth stratum, and expanded to total abundance and variance by multiplying by the area of the depth stratum. Total abundance (*N*) and variance for each bank and the banks combined was estimated by summing abundance and variance for all depth strata. Coefficient of variation (CV) was calculated as:

To estimate total biomass () of species, we used the length-weight relationship:

where is total length, measured to the nearest 5 cm using reference lasers, and and are species-specific coefficients (Appendix 1). We substituted coefficients from closely related species for chameleon (*S. phillipsi)*, dwarf-red (*S. rufinanus)*, and pygmy (*S. wilsoni)* rockfishes and unidentified thornyheads and *Sebastomus*, because coefficients were unavailable for these taxa. We then calculated kg/100m2 for each taxon on each transect by summing the weights of individuals and dividing by the transect area. Mean kg/100m2 and variance were calculated from transects within each depth stratum, and expanded to total biomass and variance by multiplying by the area of the depth stratum. Total biomass and variance for each bank and the banks combined were estimated by summing biomass and variance for all depth strata. Coefficient of variation (CV) was calculated as:

**Results**

for each survey vehicle, we will need data on:

Effort:

Number of samples (transects or dives) per 100-m stratum

Length of sample

Amount of area sampled

Depth range sampled

Percentage of substratum types surveyed

Species composition (#species; excluding groups) per depth stratum

Metrics for Abundance/Biomass:

Overall list of unique taxa and total counts

Mean (SE) length for each species

Size distributions for select species (economically valuable? Those most amenable to visual surveys?)

Densities (mean, SE) by species (by bank)

Total abundance and CV for each species/taxon group on each Bank

Total biomass and CV for each species/taxon group on each Bank

Comparative Analyses Among Vehicles for:

Diversity

Densities

Size Distributions

Total Abundance

Total Biomass

**Discussion**

Assumptions of methods (for each tool/technique):

Detectability

Influence of vehicle on Fish behavior (attraction/avoidance)

Representative samples in the strata (randomly distributed)

Accurate measurements of fishes; transect length/width; total area

Issues with survey design

Perspective:

strengths/weaknesses of each vehicle

insights from evaluating results from the three tools in terms of surveys of Pacific coast rockfishes/other in untrawlable habitats (considering depths, substratum type, distribution of species (height off bottom, patchiness), distribution of habitats, other)