ADAPTIVE SAMPLING IMPROVES ASSESSMENT OF MARINE RESERVES FOR FISHERIES

Kristen T. Honey, *khoney@stanford.edu*, Stanford University

Support from and thanks to Fiorenza Micheli (and Micheli Lab), Stephen Monismith (and EFML), Steve Palumbi, Alfred Spormann, Chelsea Wood, Steve Litvin, Malin Pinsky, and Chris Wilson at Hopkins Marine Station and Stanford University; University of Washington (Hilborn Lab); University of British Columbia (Carl Walters); Rod Fujita, Jerry Moxley, Chris Doerhoff, and Environmental Defense Fund

Profuse thanks to my dive buddy and Stanford research assistant, Tessa Pierce

Many thanks also to the Carr-Raimondi Lab (UCSC), especially Jared Figurski, Dan Malone, Olivia Cheriton, and the KOSINE team

Summer 2008 research was conducted under PISCO research permits in the Monterey Bay National Marine Sanctuary (KOSINE project), with generous PI sponsorship from Mark Carr

INTRODUCTION:

Physical conditions like swell are expected to affect the distribution and abundance of fish. In addition, SCUBA dive surveys may tend to occur in calm water. Hence, sampling could become biased and under- or over-count fish if swell effects are ignored. Biophysical links between local flow, swell conditions, and fish assemblages have important implications for the monitoring of fish populations and marine reserves, as well as the assessment of California's Marine Life Protection Act (MLPA).

PURPOSE AND HYPOTHESIS:

The project identified small-scale flow characteristics that can inform researchers about when to count fish to efficiently and accurately characterize populations and ecosystem conditions.

QUESTION ADDRESSED: How does kelp forest fish diversity vary along a swell exposure gradient and how does fish behavior, in response to swell, affect diver-based population estimates?

UNDERLYING HYPOTHESIS: An adaptive sampling procedure to monitor fish assemblages, while considering biophysical processes and swell conditions, will outperform (both, in experimental power and cost efficiency) a classical "fixed" sampling procedure that monitors fish at pre-determined times, irrespective of conditions.

METHODS:

During summer 2008, underwater moorings were placed along a natural swell gradient in kelp forests of southern Monterey Bay (see **Fig. 1**). Moorings monitored local swell with an Underwater Relative Swell Kinetics Instrument (URSKI), a new inexpensive technology developed by Jared Figurski and PISCO. URSKIs were located at 5-, 10-, 15-meter depths at three locations: Point Pinos (most exposed), Lover's Point, and Hopkins (least exposed). This 9-block sampling design generated an *in situ* index of relative swell intensity.

With URSKIs properly calibrated and logging swell data (local scale, 10-1000s m), SCUBA divers surveyed juvenile- and adult-fish-assemblage structure in rocky reefs within Monterey Bay marine reserves. PISCO-style fish surveys were conducted under a variety of swell conditions in mid-water and benthic transects (see **Table 1**). For all juvenile and adult fish, divers recorded species composition, location, density, and size structure (to the nearest cm). Divers completed an average of two dives (~6 transects) each day, 5 days a week, for 6 weeks.

FIGURE 1: Field Sites in Southern Monterey Bay

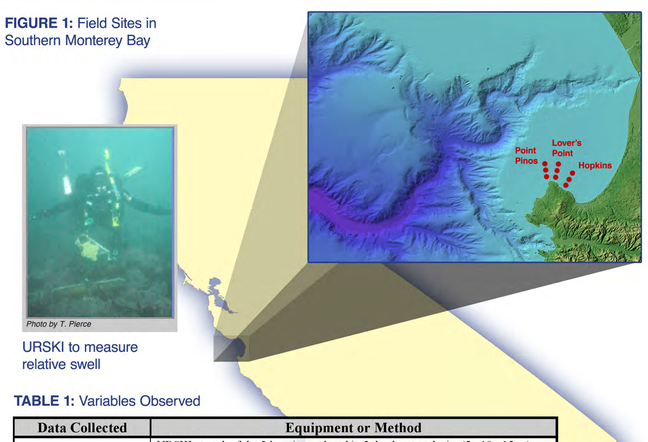


Photo by T. Pierce

URSKI to measure relative swell

TABLE 1: Variables Observed

Data Collected	Equipment or Method
Local-Scale Swell Conditions (XY acceleration, vectors summed)	URSKI at each of the 3 locations, placed in 3 depths at each site (5-, 10-, 15-m). • Accelerometer data logger, Onset HOBO pendant G #UA-006-64. • Housed within 5"-length, schedule-40 PVC pipe (protection, stability). • PVC housing attached to inverted plastic bottle (float), attached to 1-m cord tied at other end to steel I-beam anchor. • Floats filled with air, calibrated to others for standardization.
Local-Scale Fish Counts (species abundance, size, location)	SCUBA fish surveys with 30 x 2 x 2 m transects at the 9 sites. • Two transects at each depth. • PISCO fish survey and 2008 monitoring methods for marine reserves (www. piscoweb.org).

RESULTS:

Approximately 150 fish transects were completed in August and September 2008; 118 transects satisfied PISCO's data-collection and quality standards. The total fish count exceeded 1,200 individuals and included 26 different species from 16 genera. Given the high degree of ecosystem variability (see **Fig. 2**), correlations between swell conditions and fish require additional data for statistical significance ($p < .05$) (see On-Going Research).

For both benthic and mid-water counts, species assemblages demonstrated associations with specific swell conditions:

- **Fewer fish were observed in low swell.**
- **Rockfish observations increased under medium swell.**
- **Surfperch observations increased under large swell.**

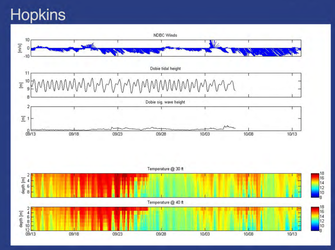
1

Cumulative Distribution Function

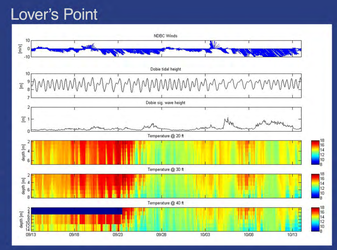
0

low — URSKI Index of Swell — high

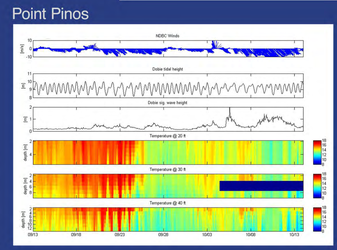
Hopkins



Lover's Point



Point Pinos



MEDIUM-SWELL RESULTS:

MEDIUM SWELL = Daily swell conditions fall within the middle third of the study's observed range (maximum of range's lower third to minimum of the upper third, across the 2.5 month study period).

Divers observed fish, including rockfish, more frequently during medium swell than other conditions.

Conditions observed: 66 / 118 surveys = 56%
Most often observed at: Lover's and 10-m sites (see **Fig. 1**)
Fish counted: 792 individuals; average 12 fish per dive
26 species; 10 *Sebastes* spp.
16 genera

CONCLUSIONS:

This pilot study offers insight into how ocean swell conditions affect fish at a local scale. During periods of low and high swell, SCUBA divers observed fewer fish, thereby underestimating some known resident populations like nearshore rockfish. Recommendations for sampling are preliminary, but project results are informing us when to count fish.

The implication for PISCO and marine monitoring programs is that SCUBA divers conduct fish surveys in medium swell, when feasible, and appropriately calibrate other counts (see **Fig. 3**). Optimal survey designs must include adaptive techniques to account for and correct for potential biases from biophysical interactions between local hydrodynamics and fish assemblages.

ON-GOING RESEARCH:

During summer 2009, fieldwork will be expanded with multiple dive teams and sophisticated automated technology (*e.g.*, cameras, wave gauges, thermistor chains, and ADCPs deployed with Stanford's Environmental Fluid Mechanics Laboratory, Hopkins, and PISCO). Future research is possible through generous support from Stanford and the Packard Foundation (Hopkins Marine Life Observatory grant).

Funding: Financial support from the Stanford Graduate Fellowship in Science and Engineering; Emmett Interdisciplinary Program in Environment and Resources (E-IPER, Stanford University); and Hopkins Marine Life Observatory grant (David and Lucile Packard Foundation).

Why count fish if they're not there?

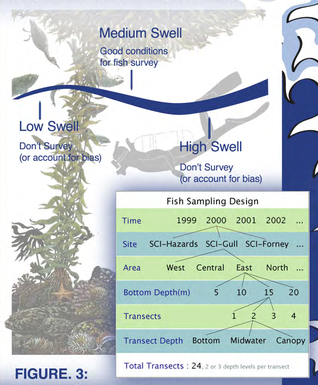


FIGURE. 3: Adaptive Sampling Design

Image sources: PISCO, Monterey Bay Aquarium