West Coast Ocean Forecast System (WCOFS) – Coastal Ocean Model Testbed (COMT)
Stakeholder Engagement Workshop Summary Report

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We held a 1.5 day workshop at Monterey Bay Aquarium Research Institute (MBARI) on 5-6 September 2019. The stakeholder engagement workshop was aimed at communicating project plans and receiving feedback on product utility and stakeholder needs. We focused on the central project themes (physics, fish, OAH, and HABs) to allow interaction between the technical team and stakeholders. We wanted to encourage broad participation of potential end-users and technical practitioners of WCOFS products from the entire West Coast since this project directly addresses end-user needs, provides explicit model developments that can lead to future products, and implicitly offers a wealth of other potential capabilities of interest to end-users through general WCOFS improvements. Day 1 was a joint exchange of stakeholder needs and metrics with the science and technical experts in the form of presentations and half a day of targeted breakout sessions; Day 2 focused on incorporating stakeholder feedback and generating recommendations for the project team. We invited 66 people from at least 5 different sectors, and 39 attended. Thanks to IOOS, we were able to fund the travel of 18 participants and cater the breakfast and lunches for all participants. We distributed a pre-conference questionnaire to all invitees as a Google Form on user needs that is summarized here.

Name	Program	Invited By	IOOS Region
Alex Kurapov	Oregon State	Team	CeNCOOS
Andrew DeVogelaere	MBNMS	Planning Committee	CeNCOOS
Andrew Moore	UCSC	Team	CeNCOOS
Andy Lanier	ODLCD	Jan	NANOOS
Becky Ota	CDFW	Henry	CeNCOOS
Carrie Culver	UCSB	Clarissa	SCCOOS
Casey Dennehey	Shorelands	Jan	NANOOS
Chris Edwards	UCSC	Team - Lead PI	CeNCOOS
Clarissa Anderson	SCCOOS	Team/Planning Committee	CeNCOOS
Corinne Gibble	CDFW OSPR	Clarissa	SCCOOS
Dale Robinson	UCSC/NOAA	Team	all West Coast
Dan Ayres	WDFW	Jan	NANOOS
Faycal Kessouri	SCCWRP	Clarissa	SCCOOS
George Robertson	OCSD	Clarissa	SCCOOS
Greg McGowen	CDFW OSPR	Clarissa	CeNCOOS
Henry Ruhl	CeNCOOS	Team/Planning Committee	CeNCOOS
Isaac Kaplan	NWFSC	Jan	NANOOS
James Doyle	NRL	Henry	CeNCOOS
Jan Newton	NANOOS	Team/Planning Committee	NANOOS
Jarrod Santora	UCSC	Henry	CeNCOOS

Jerome Feichter	UCSC	Team	CeNCOOS
Joe Schumacker	Quinault Indian Nation	Jan	NANOOS
Joe Tyburczy	HSU	Henry	CeNCOOS
Justine Kimball	OPC	Henry	CeNCOOS
Martha Sutula	SCCWRP	Clarissa	SCCOOS
Matt Hunter	ODFW	Jan	NANOOS
Megan Moriarty	CDFW OSPR/UCDavis	Clarissa	SCCOOS
Michael Jacox	SWFSC	Team	all West Coast
Noah Oppenheim	PCFFA	Clarissa	SCCOOS
Patrick Corcoran	OR Sea Grant/OSU	Jan	NANOOS
Raphael Kudela	UCSC	Team	CeNCOOS
Shauna Oh	CASG/UCSD	Clarissa	SCCOOS
Stephanie Brodie	NOAA SWFSC	Team	all West Coast
Stephen Wertz	CDFW	Henry	CeNCOOS
Toby Garfield	SWFSC	Planning Committee	SCCOOS
Tommy Moore	NWIFC	Planning Committee	NANOOS
Whitney Berry	OPC	Henry	CeNCOOS
Yi Chao	UCLA	Clarissa	SCCOOS

Breakout Session Reports:

Physics (Lead: Andrew DeVogelaere, MBNMS*)* – This group identified a very long list of use-cases. User needs were described for Lagrangian Particle Tracking capabilities (i.e. trajectory modeling) in order to: 1) determine where to position dead whales so that they drift away from beaches (National Marine Sanctuaries - NMS), 2) assess larval connectivity among Marine Protected Areas (state natural resource agencies and NMFS), 3) track the origin of invasive species (NMS, NERRS), stranded birds and mammals (NMS, NMFS, state fish and wildlife agencies), large marine debris (NMS), microplastics (NMS, EPA, state natural resource agencies); 4) predict entrainment areas for larval organisms near proposed desalination intakes (NMFS, desalination industry, state natural resource agencies); 5) locate lost shipping containers (shipping industry, NMS); 6) support US Coast Guard search and rescue operations, much as HFR and other model output are used in SAROPS; 7) predict oil spill trajectories, much as other models do now with HFR data assimilation into GNOME (state fish and wildlife departments – e.g. CA OSPR; NOAA OR&R, NMS). An important role for WCOFS was identified as aiding in the characterization of physical environments for optimal placement of physical structures in support of the Blue Economy. These would include proposed moorings for large ships, offshore wind energy infrastructure, and proposed or existing aquaculture siting. Commercial shipping could also be aided with modeled currents and wind in order to optimize ship traffic speed and fuel consumption. The Marathon representative stated that they would like to support instruments on their ships to improve modeling efforts. Use of WCOFS in an EcoCast-type model could also help minimize ship strikes on whales. Plume models around ports could inform ballast water zones in support of Marine Invasive Species Programs (MISP) by better

informing management schemes to match actual water characteristics related to invasive species survival and to facilitate dynamic management.

In terms of product development from WCOFS for ecosystems, a large topic of conversation was the sub-setting or "clipping" of model output to a select geographic area for curated data views tailored to user needs. These would be used to inform required NMS condition reports for California sanctuaries such as OCNMS, MBNMS, CBNMS, GFNMS, and CINMS where issues of kelp, abalone, sea star loss and sea urchin invasions plague northern California and are quickly expanding north and south. WCOFS and any coupled biogeochemical output would be extremely useful to understanding physical forcing on the environment with respect to many phenomena, including but not limited to, heat content in the upper ocean connected to marine heat waves, ocean acidification, and hypoxia. Analysis of these phenomena may require historical records and historical model reanalyses to determine their connection to extreme biological events, such as unusual mortality events of birds, mammals, and kelp. Hindcasting would also be necessary to assess the relative impact of MPAs vs. surrounding (reference) ocean conditions. Hypoxia predictions off the coast of WA would inform fishing operations, and fisherfolk are additionally interested in knowledge of subsurface currents for optimal net deployment. Better connection between nearshore and offshore models would help inform coastal sediment management (USGS, USACE).

Fish and Friends (Lead: Isaac Kaplan, NWFSC) – This group outlined **eight use-cases** for WCOFS related to fisheries applications. 1) The first was forecasting annual fishery catch and recruitment for Dungeness crab. This would require a coastwide model that predicts temperature, particle tracking, and other key variables with annual output. For Washington and Oregon this approach is already being developed by the J-SCOPE ROMS team (Siedlecki et al., http://www.nanoos.org/products/j-scope/home.php) to inform the annual decision regarding when to open the crabbing season, including tribal and state fisheries. Similar approaches could be developed coastwide, including for California and British Columbia crab fisheries. 2) The second use case concerns whale entanglement in crab pot gear, a major issue for the West Coast. WCOFS or the UCSC suite of models could be used for seasonal projections and historical hindcasts of SST, Chl-a, krill, anchovies, forage fish, and metrics of habitat compression for cool, recently upwelled water, all of which could be used to model whale distribution (habitat model) and then predict the probability of overlap with crab fishing areas. This would hopefully minimize spatial and seasonal closures of the crab fishery due to whale entanglement issues and might even influence the individual fisher choice of fishing location. 3) Searching for squid in real-time is a third use case whereby ROMS output from either the UCSC, Remote Sensing Solutions (Yi Chao), or WCOFS models would be used to create a simple product/map of temperature at 30-50m in near real-time or 1-3 days out. Squid fishermen already use bathymetry, tides, and mixing indices to find squid in real-time, but Del Mar Seafood has requested a subsurface temperature product. 4) Real-time or short-term forecasted maps of expected catch and bycatch would aid the Pacific whiting (hake) fishery, which is the #1 finfish in U.S. dollars. Chinook salmon is one key bycatch species that fishers must avoid. Predicted maps with the ratio of expected catch to bycatch could be developed for this fishery, similar to predictions from EcoCast for other fisheries (https://coastwatch.pfeg.noaa.gov/ecocast/). The J-SCOPE team and NOAA's Northwest Fisheries Science Center already forecasts seasonal distributions of whiting from the J-SCOPE ROMS seasonal predictions, and subsurface

information is important for this species. WCOFS could provide real-time or short-term forecasts, and this could also (potentially) be linked to spatial distribution of Chinook salmon.

Future products from WCOFS or extant regional models in the West Coast could include: 5) dashboards curated for a given species or fishery issue, 6) expansion of EcoCast (and forced by WCOFS) to include more of the open Pacific Ocean (Hawaii) to cover longline fisheries for albacore and Bluefin tuna and whale migration routes, 7) expansion of sardine/anchovy modeling already underway with J-SCOPE ROMS using the proposed WCOFS-NEMURO coupling to represent sardine/anchovy response through inclusion of individually based models (IBMs, Fiechter et al. *Prog. in Ocean.* (2015)) and of oxygen habitat models (a la Curtis Deutsch) 8) use of WCOFS or other ocean models to inform the salmon prediction that is already underway via "stoplight" forecasts of the timing of return of open coast Chinook and Coho. The breakout group wanted to emphasize that hindcasts from WCOFS or another regional model are required for many of the applications they discussed and that quantifying uncertainty is crucial since as we produce predictions of organisms at higher trophic positions in the food web, the distance in modeling space from the physical predictions is large, hence greater uncertainty/less skill in those predictions. Finally, it behooves us to consider the ethical consequences of ecological forecasting (Hobday et al. 2019).

Harmful Algal Blooms (Lead: Clarissa Anderson, SCCOOS) – This group identified **three use-cases** pertaining to HABs: 1) HAB monitoring officials and managers tasked with resource allocation (state depts of fish and wildlife, state public health departments, NMFS) identified a need for tracking the precise interstate trajectories or *Pseudo-nitzschia* blooms, their impacts, and improvement of lead times for warnings, e.g. shellfish toxicity. WCOFS would cover the entire West Coast domain, which would be critical for broad representation of HABs and facilitate better planning in border regions. Required lead times for models or expert opinions are desired out to a 14-day horizon. 2) Complexity in food web interactions and surface to benthic coupling makes it very hard to accurately predict which parts of the food web will be most impacted by a given HAB event and how long those impacts will persist. Thus, creative solutions are necessary to deliver warnings to natural resource/wildlife managers to a) evaluate ocean models for persistence in features and any ancillary stranding info or observations that might indicate that a hot spot is forming and allow managers to adaptively sample, b) exploit the current model capabilities to provide quarterly analyses that generate a prognosis for near-term (seasonal) future conditions and HAB likelihood, c) continue to build out our mechanistic understanding of food webs for true predictability in the next 10 years in BGC/ecosystem models such as NEMURO. 3) Stakeholders representing fishery and shellfish growing interests identified the need to predict nearshore impacts of HABs on aquaculture and fisheries since many of the economic impacts of HABs are associated with environments in the very nearshore zone where most ROMS model predictions (WCOFS included) are extremely limiting or inaccurate. Three solutions exist: a) dynamic downscaling of ROMS to <30m horizontal resolution, b) "coupling" of coastal models with estuarine models, either through supply of boundary conditions or initial conditions where appropriate, and c) new data collection at sites of interest to better understand dynamics and trends and tune downscaled models.

Ocean Acidification and Hypoxia (Lead: Tommy Moore, Northwest Indian Fisheries Commission-NWIFC) – Rather than specific use-cases, this group focused their discussion on thresholds and indicators, model reanalysis, and forecasting/long-term modeling needs. Thresholds for pH, O2, and other derived parameters like aragonite saturation state (omega) will need to be species-specific and distinguished as either chronic or acute. Phenomena associated with OAH must be described in terms of horizontal and vertical extent and temporal duration, especially as related to vulnerable periods in a species' life history. Habitat compression modeling and source attribution are areas likely to be most heavily impacted by a coupled WCOFS-NEMURO model. Model reanalysis/hindcasting was identified as a key product for evaluating OAH impacts, particularly for evaluating susceptible areas, long-term trends, and generating seasonal habitat maps for establishing baselines and trajectories. Forecasting (real-time) and long-term (projection) modeling needs would be applicable to event response, adaptive management, and assistance to fisherfolk. Policymakers will likely require seasonal and annual forecasts, rather than real-time forecasts. Long-term climate scenario models are required for enacting policy that regulating OAH. Downscaled models focusing on high priority areas such as bays, estuaries, and marine canyons are essential.

Miscellaneous points that pertain to all the discussions were that 1) observations to support models are crucial, 2) economic valuation of data and model output will allow us to understand economic benefits of model predictions to stakeholders, and 3) source attribution could be an important outcome of modeling efforts for tackling current challenges and charting future research.

Next Steps

We are continuing to populate a living document with **Use Cases and Model Requirements**.

Due to the enthusiasm of workshop participants, we will be organizing targeted webinars with stakeholders who could not attend to ensure that staff members at the various agencies represented can better understand the suite of ecological models currently served by the West Coast IOOS Regional Associations and the opportunities offered by WCOFS.