**The Alaska Ocean Observing System**

**Ocean Acidification Workshop II: Scoping the Approach and Priorities for Ocean Acidification Monitoring Activities in Alaska**

**DRAFT Workshop Minutes (Carol Janzen, AOOS, revised May 12, 2016)**

8:00 – 9:00 Breakfast

9:00 Welcome Molly McCammon

Agenda and Workshop Goals Carol Janzen

Round-Table Introductions

**Jeremy Mathis Presentation: 09:20**

Jeremy Mathis provided a comprehensive overview of NOA OAP (Ocean Acidification Program) and the Alaska OA research plan and aimed at covering where we are, what we have done, and where are we going with respect to OA efforts. The Federal Ocean Acidification Research and Monitoring (FOARAM) ACT of 2009 was established to foster, direct and coordinate a series of OA activities, including:

1. Interdisciplinary research to improve understanding of OA;
2. Establish long-term monitoring;
3. Research and identify and develop adaptation strategies for conservation;
4. Education;
5. National public outreach;
6. Coordination of OA monitoring and impacts research with other appropriate international ocean science bodies.

Total NOAA OA funding in 2015 amounted to about $8.5 million, and the projected spending for 2016 is $10 Million to cover entire United States for OA. This includes locations along the east coast, coastal bays, the west coast, and of course, the Alaskan coastline.

Alaska has an equal amount of ocean as the entire lower 48 contiguous states, yet each region is splitting assets. Alaska doesn’t have equal resources. There is a shellfish inspired OA program on west coast. It has grown out from there.

A question was raised about are regions that have less of an OA concern, and whether all the available OA funding was going to be split equally amongst states, regardless of their OA concerns. An additional question inquired how much funding is coming from other sources. Jeremy answered that NSF had $10-15 million to spend per year on OA programs to kick start the efforts. In 2015, this initial funding ended. There has been a $40 million investment thus far, but there is nothing in a dedicated RFP for OA from NSF anymore. People will have to send new NSF proposals and compete with all the rest of the scientific research proposals.

AOOS has contributed $750K thus far into OA efforts in Alaska. NPRB has made a $450K commitment. There has been some money from BOEM and other groups on an ad hoc basis. Outside of NOAA, there is no current dedicated funding for research and monitoring of OA.

NSF and NASA put out proposal RFPs with OA components, and EPA is starting up some OA initiatives, as is USGS. About $1 million dollars from each agency is projected for the entire US.

NOAA has put together a workplan for the regions, and submitted this to the OAP. The workplans have been reviewed and resources allocated based on what the needs are. Mike Sigler in Juneau and others authored the plan -- the NOAA Alaska OA Research Plan – which includes:

* + Crab research;
  + Fish research;
  + Coral Research, which will shift from mineralogy catalog and risk assessment of Alaska corals and sponges to studying physiological effects of OA on corals held in the lab;
  + Modeling research and bioeconomic models of crab species (Mike Dalton);
  + Ocean Monitoring will continue on two moorings (Gulf of Alaska Bering Sea) and at hatchery observations in the Gulf of Alaska. There will also be survey cruises every 4 years (2015 will be in Gulf of Alaska; 2019 will be in the Bering Sea or the Arctic).

The State funding situation was promising, but less so in recent months. Alaska in 2012 provided a $2.7 million proposal to build an OA network. These funds started the Ocean Acidification Research Center (OARC), at the University of Alaska, Fairbanks. Leverage support from a number of agencies was used to conduct broad-scale monitoring around Alaska. This effort funded 5 moorings:

M2 (Bering Strait/Sea)

Gak1,

Kodiak,

Southeast mooring;

Beaufort

The State of Alaska $2.7 mil was a capital investment to get it started, and was not intended to be sustainable funding for this effort. Requests to the state for O&M, for a much smaller amount is not happening now. Between NOAA and AOOS funding, GAKOA (Gak1) and M2 (Bering Strait) are the only moored OA stations that can be sustained for the next 3-4 years, and this will just cover enough expenses to maintain these moorings.

WHAT TECHNOLOGIES on these buoys? (partially answered in later sections)

Another activity underway in Alaska is aimed at installing monitoring systems in shellfish hatcheries. The first installation was put in the Alutiiq Pride Shellfish Hatchery in Seward, AK.

**New OA Activities in Alaska 2016 - \***

* In 2016, the plan is to install a dosing system at Alutiiq Pride Shellfish Hatchery, to help remediate periods where OA conditions in the ambient waters would be detrimental to the hatchery activities.
* There is a second planned hatchery OA sensor installation in Ketchikan, AK for 2016.
* Dr. Amanda Kelley will join OARC at UAF in June 2016 and is a biologist looking at effects of OA on the species level. She plans to build out and develop the biological impact program for the state.
* OA sensors will be installed on two MARES (LOCATION..ARCTIC?) subsurface moorings in the \_\_\_\_\_\_\_\_\_(owned by Dr. Robert Pickart, WHOI).
* The NOAA ARCTIC research program will fund a glider program in the Arctic in 2016. There is only one wave glider for now and supplemental mooring, but only on a seasonal basis. One wave glider in Arctic for sure, 2nd wave glider is proposed and less certain.
* 2017 two wave gliders will be on the West Coast.
* The same two were used in GOA and PWS in 2014.

**Technologies and Platforms**

NOAA is currently testing its new autonomous platform called the Saildrone. This makes surface measurements only. They have successfully deployed this platform at sea for 97 days, and made over 200K measurements covering a distance of 7600 km. It was deployed off of Dutch Harbor. It currently only accommodates a CTD payload, and will operate in the Arctic through the NW Passage for 5 months during 2017-2018 (from Dutch Harbor to Halifax, Canada).

A question was raised about how much the OA mooring installations cost compared to the glider and other autonomous platforms.

Moorings: $100K with OA instruments per year; Need two sets/kinds of OA sensing equipment for each location.

Wave glider: $60K (no sensors, ~3 months)), and $150K with OA and auxiliary instruments (CTD).

The Saildrone $60K (no sensors); Regular deployment on the order of days ($2500/day (basic sensor suite T,S,DO, Chla, CDOM, Backscatter and Met package); ($1200/day sensor integration/testing prior to mission (e.g., MApCO2, pH). (Jessica Cross)

Moorings, surface gliders and Sail drones all have MApCO2 sensors installed; however, moorings cannot utilize MApCO2 at depths below the surface.

Comment Wiley: Deeper moored measurements rely on other sensing technologies, as subsurface PCO2 are not as reliable and can only be used on moorings in open water (not subsurface). MApCO2 is only for surface platforms. The reason is that it functions based on equilibration of a carrier gas (marine air usually) with the seawater pCO2. The carrier gas xCO2 is then measured using NDIR. These systems are highly robust and accurate because they self-calibrate every 6-hr or so (user programmable) using gases of known CO2 concentration (usually a zero and span gas).

Mooring M2 has MApCO2 installed for summer months, and SAMI PCO2 plus SAMI pH during winter months, and this is possible as there are two turnaround cruises each year tending this mooring location. To accomplish something similar in the Arctic will be harder to do, and current plans are to only install subsurface moorings (SAMI sensors). Unfortunately, the underwater technologies are not yet able to get “climate level” quality measurements (part per million level accuracy). To operate MApCO2 moorings requires two identical moorings for turn around, and no ice.

MApCO2 and similar systems are being tested on tour boats and passenger ferries, but are primarily installed on container ships. The same system PMEL uses on container vessels (General Oceanics) was installed and operated by *Glacier Tours* out of Seward in 2015 (2014 or 2015?). The operator was Major Marine Tours and the vessel was the M/V Fairweather Express II out of Whittier.

Comment Wiley: On this project, a public outreach poster was developed to go along with the boat operating the OA underway system, and an onboard naturalist (National Parks Service) highlighted the ongoing OA work. This tour boat had the advantage over larger ships in that it was able to get up closer to glaciers and make some critical measurements there. 90 days of data x 140 max passengers per day = 12,000 people potentially reached through this project.

The MApCO2 underway system is sold by General Oceanics (GO), and Dick Feely has 12 of these systems installed on research and container ships, including some Horizon Container vessels that travel to Alaska. The instrument sends information back via automated email, and has internal calibration capabilities.

MApCO2 Specs

* Cost: $80-85K, dependent on the add-ons and choice of LI-COR
* Data Quality: Climate level measurements (< XXXX as defined by GOAN).
* Functionality: Filters are installed in the system that get changed, which helps with fouling.
* Instrument Characteristics: Response time is not an issue as it logs GPS measurements where samples are made. It takes ~ 2.5-5 minutes to process sample… (Jeremy said 15 minutes). The systems always knows where the sample was made.
* Response time is the time it takes the system to respond to a change in CO2 associated with crossing a front, typically reported as 64% of final value, and that is likely order seconds. Equilibration time is how long the system takes to return to an equilibrated head space state following the introduction of a modified head space gas CO2. This is an important number for describing the functionality of the equilibrator, and is likely order minutes.
* Wiley Comment: It may be more informative to report the accuracy of the data. For the GO system, this is dependent on the propagated uncertainties associated with the LI-COR accuracy (model dependent), accuracy of the T and S data, the P sensor accuracy, and your confidence in any needed lag correction. Typical accuracies for GO systems are ~2 uatm.
* Data acquisition: It logs the location and keeps the sample data aligned with the GPS location. The system also measures CTD parameters (temperature and salinity) as well as dissolved oxygen. All data including the CTD-DO data are logged using customized LabVIEW programming.
* The only measurements that are needed are T and S (for solubility, TA:S, CO2SYS calculations. Everything else is extra.

Wiley added here that one can use TA (total alkalinity) and Salinity relationship plots derived empirically for a given region to back out information as a cross check.

**Seward Line**

The Seward Line has been sampled for OA parameters since 2008 (8 years).

High quality water sample measurements for OA are being made on this line, and allowing good empirical measurements. Empirically derive carbonate parameters from this work is helping derivation of algorithms. Once 10 years are reached, it is possible to relocated resources, but we will need to go back every couple years as relationships will change with increasing CO2 and changing FW (freshwater) discharges into the bay.

AOOS currently contributes $80K a year. Real cost of doing this work is probably double that.

* Bob Foy Question: How far away from the transect stations can you use the algorithms?
* Wiley Answer: They are not very good in the nearshore with brackish water, but okay for Northern GOA.
* Richard Feely: Algorithms are based on the highest quality measurements, so are good for using as a basis for tracking other sensor calibration, e.g. pH sensors from drift. Like the deep water (or stable region) TS plot that is often used for calibration of CTD that does not have water samples to compare (i.e., Argo CTDs).

Gliders complete sections inshore for example, and there is no easy way to calibrate (better word is to validate) glider data. So, users take it to the deep “calibration” (or validation) location, look at the algorithm derived there for sensor validations, and use this to “validate” (or reference check) the sensors. This will work for GOA.

This is not the best approach for the Arctic (Jessica Cross). Inter-annual variability is too high, and there are constantly changing contributions. Also with long-term changing conditions with climate change pose issues.

* Molly asked if it was because we do not have enough measurements?
* Answer: There is no way to get enough measurements and the algorithms would be very complicated anyway (computing power not possible (Jessica Cross)). Top quality measurements are needed there.

**2015 NOA GOA OA Cruise**

Good cruise coverage of the coastline including 14 transects. This ran from SE to past Kodiak along the shelf. Seward Line and into lower Cook Inlet. They were able to apply an algorithm developed from data on the Seward line, to see how good it was for rest of the GOA. They developed a region where the algorithm worked well doing this. **This effort will also help identify where other transect work would be good (priority) to complete annually. Right now, the Seward line is leveraged with multiple sources of funding. It can be hard to find a boat that has the capability to go far enough offshore whilst getting the right measurements. It just is expensive to get a lone OA line going. The realized costs are most possible to meet with leveraging.**

Doing an OA monitoring line elsewhere (other than Seward Line) will cost a lot more because of the cost sharing that occurs for Seward Line. Perhaps a glider repeat transect can do some of the work, but it will have to have the MAP CO2 system installed to be of comparable quality data, and actually, the algorithms used to correct the data will require water samples anyway.

Comment Wiley: MApCO2 will not work on underwater gliders, but have been demonstrated on surface dwelling wave gliders. The Seward line data could be used to develop / update the algorithms (we’ve already made) that then are applied to nearby glider data. However, gliders take full time piloting and that is a big, often not fully appreciated, undertaking.

The current goal is to occupy the Seward Line for 10 years. Observable (which relates back to the accuracy of the measurements) OA trends require a long time series. Though the level of change may seem small, the impacts of these long-term trends are huge. And the GOA cruise goal is a 4-year cycle, rotating between US. Areas with funding from NOAA OA program.

Comment Wiley: If the seawater pCO2 is tracking the atmospheric CO2 increase of 2.5 uatm (ppm) per year, then over 10 years the pCO2 increase would be 25 uatm. If we assume T, S, TA and initial pCO2 to be 10, 30, 2200 and 350, then pH and omega have changed by 0.03 and 0.05 units, respectively. It would take 40 years to match the 0.1 and 0.3 global pH and omega changes that have occurred since the pre-industrial. So the records need to be long. This calculation is over-simplified and surface water oriented, and we know history matters as deep water would have gained its atmospheric CO2 signature at some point in the past.

Question: **Can you develop algorithms with the MApCO2 data without water samples?**

Wiley: Yes, if you have pCO2, TCO2 (or pH – but less ideal), NO2, DO concurrently being measured. This requires more than a MApCO2 system.

Carol Janzen: What quality do the auxiliary but required parameters need to be? T, S, DO? Jeremey answered they need to be at the “Sea-Bird” level (translated, this means part per million, or 3 decimal place level. T ~ 0.001-0.003 deg C, S ~ 0.002-0.005, DO ~ 1 micromolar).

Might try to get data on Rob Campbell’s profiling mooring to try to validate an algorithm for Prince William Sound. (How can AOOS support this effort?)

Modeling efforts are underway, Siedlecki et al. in prep.

Darren Pilcher (NOAA PMEL) is working on an OA model for Bering Sea.

Year that the Annual Average Aragonite Saturation Thresholds are expected to reach the following basins (Based on Mathis publication 2015):

* Beaufort already reached the < 1 in 2010
* Pacific Arctic Region 2030
* Chukchi 2030
* Bering 2070

Wiley showed that threshold is not necessarily 1. It can be 1.5 to 2.0 for some areas. It is species and life state dependent, and 1.5 is a literature average. Bob Foy is also looking at where the changes are critical.

OA synthesis products. RANK PLOT. Get Rank Plot from Jeremy

**Dick Feely 10:30**

History of OA Monitoring Programs:

* GO-SHIP Program: Global Ocean Ship-based Hydrographic Investigations Program Decadal Repeat Hydrography OA Determinations in the Gulf of AK
  + This program is collection high quality climate level measurements.
  + Repeat of subset of WOCE and other High Quality past lines. N-S Pacific line from Antarctica to Kodiak and E-W line across the North Pacific
  + Estimating anthropogenic CO2 signal and trying to determine how much it affects the patterns.
* GEOSECS 1970s
* 1990s WOCE
* JGOFS

GO-SHIP had a few OA Reference Sections (Jessica Cross and others got data out).

P02 and PL16 lines.

Anthropogenic carbon determinations

Thermocline anthropogenic carbon concentrations from the Eastern North Pacific Gyre P16 line were used to estimate Canth (anthropogenic Carbon) concentration in the upwelling water for the years with data. The data are gridded on lines of constant potential density (rather than depth). (NOTE: This is a common way to remove the pressure affect from derived variables in the water column so discrete measurements can be compared in time, even if the depth where the measurements are made vary somewhat over time).

Canth:Sigma-Theta plots (micromoles kg-1 y-axis to sigma-theta (kg m-3)

These plots are capable of detecting decadal anthropogenic CO2 uptake in the Pacific along lines P16 and P02. To separate the pre-industrial and anthropogenic signal, can look at separation of signal from the time series of 5-6 years or more. We already see clean separation in open ocean waters and in coastal waters in the winter. There is some overlap in coastal waters in the upwelling period.

This method can identify the “spiciness” of Canth that comes into nearshore Alaskan waters.

It was shown that the decadal aragonite saturation decreased along P12 and P16.

Scientists were also able to separate the respiration, and subtract out other oceanographic processes, so they could isolate the anthropogenic sources (Canth) with some confidence.

Dissolution and calcification as indicators of present and future impacts

1. Table of pteropod responses (shell state under a light microscope and scanning electron microscope and calcification), alongside aragonite saturation state related to their biological status. Indicator species can be also collected on cruises as an additional integrated impact measure. Studies that use the time that organisms are in the undersaturated conditions will help develop information on how to use shell condition to assess how long these conditions have existed a studied region.
2. Time series of area density (shell thickness of planktonic forams G bulloides sig correlated with ambient CO3-2), Osborne et al, in prep. Osborne also compared area density to PMEL Upwelling indices (inverted y-axis). Emily Osborne et. al., in prep using data from 1980 to present.
3. Mooring observations are giving us the rate of acidification: Sutton et al, 2014 GBC. This work clarifies why we need long-term measurements.
4. Starting to look at the open ocean (HOTS – Hawaii Ocean Time Series), at CHAVA (PNW - Jan Newton). They are observing large variability in open ocean. But coastal regions are even more variable. Dick thinks we can get the trend out of the coastal measurements despite the large signal to noise ratio.
5. Pacific Ocean OA mooring time series data synthesis products are capable of isolating the anthropogenic contribution based on preindustrial period conditions.

We need to think about where do we want the long-time series to be made to complete the necessary data synthesis products. (Sutton et. al., in prep).

* WHAT PRODUCTS DO WE WANT?
* HOW DO WE WANT TO USE THEM?
* HOW DO WE GET AFTER THEM?

Nina B. has archiving data on pteropods.

Russ Hopcroft also has samples going back to the 80s.

Bill Peterson in Newport, Oregon, has archival of 20 years pteropod samples…working with Nina Bednarsek…unpublished. Those data are showing decrease pteropod abundance only during upwelling months.

Nina and Mark Ullman, LTER system, show many species of pteropods try to avoid acidic water.

**Bob Foy 11:20**

Bob will start by addressing the 2014 Workshop Recommendations

1. Have priorities changed?
2. What else do we know now?
3. Are we doing the appropriate monitoring efforts?

List of publications: (Carol: get from Bob)

NOAA Alaska Fisheries Science Center Research Approach

Focal species:

* Commercially important fish and shellfish species
* Prey (Calcareous plankton)
* Shelter organisms (corals)

Objectives:

* Ocean pH Monitoring
* Understand species specific physical responses
* Forecast population impacts and economic consequences

**Crabs:**

* Red King, Blue Kin, Golden King (snow) biggest shellfish industry in nation
* Life stages: mature, juvenile, larval, egg
* Shelf locations (intertidal, subtidal, middle, outer), slope (Upper and lower), Canyon (Upper and Lower)
* Depths: Golden crabs are deep species going down to 1000 m, where waters are corrosive

Life histories: Crabs go through all the conditions we are observing now.

Question 1: Can we narrow down the periods when the organisms are in corrosive waters and how is it impacting them at those times?

Question 2: What are we trying to measure? For example, are we looking at the affect of just pH? pH affects ability to get oxygen across gills.

Effects by CACO3 dissolution to to aragonite sat.

Response variable: Survival, fecundity, morphometrics (image analysis), growth (width and wet mass), calcification.

**Treatment system (2006-2007)**

* Flow thru CO2 delivery system
* pH control
* Daily pH, temp, salinity measurement
* Weekly water samples taken for DIC (dissolved inorganic carbon) and Alkalinity

**Experiments 2010-2015**

Response variables:

Survival, fecundity, morphometrics, growth, etc.

Red King Crab, individual and population effects during larval, juvenile, adult

1. Issue with survival and lack of development at embryo and larval stages. (smaller eggs, smaller embryos larger yolks);
2. They grew, but did not have enough food to maintain growth;
3. Increased calcification in larvae;
4. Juvenile growth length and mass was reduced;
5. Juvenile calcium content did not change;
6. Survival decreased with decreasing pH;
7. Larval morphometrics varied.

**Micromechanical processes**: Can we measure something in the shell that tells us something (crystallization, hardness). Turns out that the answer is yes, we can.

**Impact on feeding and respiration:**

Using stock assessment model for Bering sea, incorporated observed mortality, modeled stocks into the future, and assessed impacts on stocks into the future.

* pH at 7.7, red King has 20 years before stock starts having impacts.
* Economic impacts are $100 millions (reported in climate change economics publications).

Expecting an increase in recruitment, but all factors are going to change. An increase in fishing efforts, eventually stocks start to drop.

**Shell Mechanics:**  Micro hardness, thickness and exo and endocuticle (too hard, break easier, can’t get food…so this becomes an issue); other (in publication)

**Red King Respiration:** Respiration is increasing, but it is feeding less as pH decreases.

**Temperature and other stressors work:** Thermal warming, pH, models.

This year is 4 deg warmer. This with pH together, it could lead to large mortalities.

(reference: Jonathan Stillman, Scott Fay, et al. - Interactive Effects of Ocean Acid and Warming).

**Tanner Crab**: Papers are coming out describing the same type of studies as Red King Crabs.

Tanner Crabs cell functions are different in higher acidic environments.

Held Tanners for 2 years…keeping them in acid environments. What happened?

1. Hatching success was lower in Year 2 and there was a Year 1-carryover effect.
2. LONGTERM EXPOSURE IS THE ISSUE for Tanners (Short-term studies do not work for this species).
3. Tried to regulate diurnal variability, but kept the sample lower pH to keep the various life stages in these conditions. I.e. Keep mother at condition during all her stages … to see what carryover stresses are from mother to offspring.
   1. Crack Crabs. (Than you Jan!)

**Walleye Pollock:** Largest fishery, what are the OA effects?

Take home message last year: There hasn’t been an affect of OA in general, though there might be evidence of some signal in the growth of larvae.

More recent work suggests effects.

**Northern rock sole**: Appear more sensitive to OA.

Lower growth rates and condition factors observed at high CO2 levels.

Trend toward higher mortality rates at elevated CO2.

**Need to expand studies to consider OA in a multiple-stressor context:**

For example, studies that include combined effects from pollution, hypoxia, nutritional stress, etc. Most studies currently look at OA alone, or OA and Temperature.

**What is going on now?**

**Snow Crab**

Larval effects. These crab live deeper, so might be already experiencing higher corrosive conditions already.

**What is the Evidence?**

**Red tree coral**: Ecologically important at 125-400 m (under ice glaciers in AK), Washington to the Eastern Bering Sea, and provides essential fish habitat for commercial fish. All deep water corals reside below 400-600 m.

**Walleye Pollock**: Prey scent detection, multiple stressors

**Red King Crab:** interannual variability still being worked on.

**How do you understand the impact of OA with all the other stressors going on?** OA from anthropogenic contributions of CO2 to the atmosphere has received most of the attention, but that in conjunction with respiration driven acidification and changes in temperature, dissolved oxygen, and other variables is not well understood.

**Effects of OA on Development of AK crab larvae:**

Range pH 8.1-7.5

We need to know the ambient variability first, then go from there to observe the impacts of trends.

**Monitoring Efforts:**

AUKE BAY LAB – NOAA (Mark Carls)

There is not enough funding in the AK science center. Auke Bay has seawater system.

Bottle collections over time in Icy strait, related to salinity and develop other relationships.

Been working on this 1.5 years-2 years.

Kodiak:

Surface and near-bottom water samples for 2 years once a month at Kodiak.

Is that enough? Suggests we need more.

Is any of this helpful?

Is monitoring worthwhile?

Low cost??? (Not really saving money…unless you are already there, or going there already for something else).

Molly Question: We care about biological impact.

Is there a field component in monitoring we should be doing?

Bob Foy Response: We should work towards getting control samples, or baseline data first. WE need to try to decide what we should monitor first…as there is so much variability.

* What species could we use for this?
* Example: Crabs make up a commercial fishery…but other fish do too.
* Euphausids are the kingpin for all fisheries…so is sampling Euphausids worthwhile?

Question: Is Pacific Krill work being done? Or is this just being done in Antarctica?

Question: Will temperature overwhelm OA effects on crabs?

Answer: No. Crabs move. They will move to favorable places if possible and available.

* Physical oceanography will determine where recruitment occurs and larvae hang out.
* Crabs will migrate to colder water.
* But moving to deeper depths puts them at more risk in corrosive water
* For example: Red King Crabs will go north and are already observed in Norton Sound.
* Biggest impact will be on drift of larvae, so physical changes in circulation are also important.

AMBON is doing some of this kind of work, and the Distributed Biological Observatory program, particularly at stations DBO3 and DBO4.

Trawls…looking at some stuff. BUT HOW OFTEN CAN THEY DO THIS?

Economic model is driven by the assessment model. We see an increase in mortality in 50 years. Put this information into a stock assessment mode and model the biomass of adult stock over time; incur management practices (removals) and $ gets put on that. This makes it easier to model the $ input from stock reduction.

Doing work on Blue King Crabs and Goldens too. It is harder to raise the Goldens. They are already in corrosive waters. Their larvae are impacted by pH reduction. Larvae have stayed at depth.

**1:00 Dave Murphy: OA Technologies and pH sensors**

pH measurements made historically with traditional bulb type sensors

Newer pH technologies include optical, Spectrophotometric (SAMI), ISFET (SeaFET )

**Traditional pH Bulbs:**

* Accuracy +/- 0.1
* They are not known for their stability: offset shifts in time, on the shelf, in the field, and they require frequent calibration
* Most are calibrated with freshwater buffers, and therefore are not accurate for applications in seawater
* **Not useful for climate change measurements.**
* Field endurance typically less than 90 days.

**Emerging newer technologies:**

XPRIZE competition held in 2014-2015 for development of ocean ready technology

Winning required (a) accuracy to 2000 meters ocean depth and (b) affordability

Competing technologies were:

-In situ spectrophotometry (this was the winner)

This method was calibrated against shipboard standard so had an expected good agreement

- ISFET Ion spec field effect transistor 2nd place

Others technologies did not perform well in time-series or profiling tests

- Optical luminescence was tested by two teams (shows promise, but has a way to go)

- Hybrid: bulb electrode calibrated at interval by spectrophotometric method

- Voltammetry

The Xprize validation measurement uncertainty with discrete bottle samples indicates uncertainty in the validation pH measurement was close to 0.010 pH units in the upper 500 dbar, increasing fairly linearly to 0.023 pH units at 3000 dbar, indicating the difficulty at getting accuracies < 0.01.

**Optical Luminescence:**

(Manufacturer: Aanderaa) Analog to optical oxygen sensing

Been investigated for use for coastal areas since the early 2000s

Shows promise in lab and near-shore, but performed poorly in Xprize ocean work.

* Can measure accuracy +/- 0.05 pH
* Res 0.01 pH
* Drift of about 0.05 per day at pH = 7 with 1-minute sampling
* There is no ocean sensor currently available
* Has issues with salinity correction, photo bleaching, pressure hysteresis.
* Not for sale at moment.
* Uses a different luminophor than oxygen sensor and it measures H+ concentration.
* Pressure effect showed up on Xprize.

**In Situ Spectrophotometry**:

(Manufacturer: SunBurst Sensors) Submersible Autonomous Moored Instrument (SAMI) and Autonomous Flow thru Instrument (AFT).

* Measures either CO2 or pH
* Lower power for longer deployment
* Logs and transmits data (RS-232)
* Supports up to 3 external instruments (1 can be RS232), rated to 600 m
* Can also be hooked up to a CTD
* Accuracy is +/- 0.003 pH units for SAMI (3 microatm)
* Precision < 0.001 pH units
* pH range 7-9 (150-700 microatm)
* Response time ~5 minutes
* Long-term drift spec < 1 microatm units over 6 months
* Works best in practical salinity range 25-40 (not quite coastal levels)
* Dye is T, S, P dependent, so you need good TSP (depth) data to get this measurement to work with DYE.
* Lab data shows it works well within 0.005.
* Deployment duration ~10,000 measurements

Question: Is this technology fast enough for glider or ferry? (Wiley and Jeremy?)

Answer: (Dave Murphy) The SAMI response time on the Xprize was ~ 3 minutes…they profiled on Xprize at 30 m/minute (half the normal rate of 1 m/s), and it appeared to worked fine there.

**ISFET**:

Sensors made with a Honeywell Durafet, which uses an AgCl reference electrode. This was added for use in seawater.

* Accuracy +/- 0.02
* Resolution +/- 0.004
* Stability 0.003 pH/month
* Internal reference electrode was not in contact with saltwater, so they modified it at MBARI (Monterey Bay Aquarium Research Institute) to put an external electrode outside.
* +/- 0.03 accuracy is more realistic expectation from this technology based on current experience.

Dick suggests that the drift in SAMI is overstated in accuracy. Jeremy agrees.

He observed SeaFET and Sami side by side, and there was no relationship.??

Natalie mentioned that their experience with SAMI was it did not last long enough on any of their moored deployments (6 weeks on yearlong mooring) to see drift. Pumps go bad first.

**Operation of ISFET:**

* ISFET is a type of MOSFET (gate is pH sensitive material that is exposed to the environment).
* Sensor consists of ISFET, a bias electrode (Counter electrode) and a reference electrode
* Constant current flows from drain to source controlled by pH and counter electrode voltage. Reference is a Cl- sensitive electrode.
* Voltage on reference depends on counter electrode voltage and concentration of Cl-.
* Must calculate chlorinity from salinity and then calculate pH
* Can be a bit drifty initially in the field, as the AgCl reference becomes equilibrated to the in-situ bromide concentration.
* Reference voltage changes depending on makeup of electrode. Bromine changes that, so causes drift. Sea-Bird Electronics is working to see if they can overcome this problem.
* Calibration is performed in 0.01M HCl over ocean temperatures and pressure ranges.
* Slope is linear in Temperature, and offset shifts with pressure.
* To resolve, pick a pressure close to expected operating depth, and use that thermal correction (with pressure).
* When you decompose the pressure effect on the ISFET itself, calibration may be correcting for the flex in the silicon or the plastic mounting material.
* The correction is hyperbolic (nonlinear).
* Offset (K0) done by flowing seawater over probe and measuring seawater pH with a spectrophotometer
* Can take a week or more to stabilize in seawater.
* When completed, this offset is used rather than the one based on the HCl calibration solution however the sensor may drift in offset for a few days after deployment as the reference equilibrates to the seawater where the work is being done.

Field Example: Lydia Kapsenberg reported uncertainties in her data +/- 0.03 pH using SeaFets. She had three instruments sampling in a coastal study off Santa Cruz Islands. Some behaved better than others. (Reference: Ocean pH time-series and drivers of variability along the northern Channel Islands, California, USA, Lydia Kapsenberg, Gretchen E. Hofmann, Limnol. Oceanogr. 00, 2016, 00–00)

The Honeywell Durafet offering doesn’t have pressure tolerance (< 70 dbar), their reference electrode is internal, and simply is not robust for oceanic deployment. The references are stable except for bromination problem.

Field Example: SOCCOM program – pH on Argo floats in the Antarctic, Sea-Bird provided 2 pH sensors like these and integrated them onto Argo CTDs, and will be supplying all the pH probes for 30 floats a year. 200 floats in total.

* They are trying to ground truth this sensor with 2nd decimal standard
* Trying to make a ppm sensor using ppt standard
* This is Not possible
* Differences are sampling error and dissociation coefficient inaccuracies.

Jeremy is concerned about the durability and operability…many of these instruments have had flooding problems.

Question: What levels in pH and Aragonite Saturation are needed to establish what the biological response is? i.e. aragonite saturation of 0.2. So for accuracy, what would be a guideline for biology? For climate, you need it better for sure! But what about Biology?

Wiley: Bob or Amanda should fill this in if possible. The accuracy of the data will determine how fine-tuned your analysis can be. For instance, if you are brute forcing an incubation experiment and changing the CO2 chemistry over a huge range, then accuracy is less of a concern than if you are doing some detailed incremental experiment to know at what point across the continuum of CO2 conditions some gene is going to express itself.

**Jan Newton**

**Data management in context of GOAN and IPACOA**

OA is a global condition with local effects. We know basins have similar response, but it is being played out differently on various beaches.

* Need local through global scale observations in order to get either correct.
* This issue demands our coordination, networked skill, and open analysis.
* Recognized the need to “climate” and “weather” type OA data.

***What is GOA-ON?***

It is an International partnership established to document status and progress of OA in open ocean, coastal, estuarine, and coral reef environments. It is to promote understanding of the impacts of OA on diverse marine ecosystems and societies, and support forecast capability so we know where things are headed.

[www.GOA-ON.org](http://www.GOA-ON.org)

100 countries participated. Workshops on determining the requirements and standards.

1. Climate data: of sufficient quality to assess long term trends and define level of confidence that can detect changes in OA stat over multi-decadal timescales.
2. Weather data: of sufficient and defined quality to identify relative spatial patterns and short-term changes (mechanistic interpretation of the ecosystem response to local, immediate OA dynamics).

Define this: Key attributes of an effective OAH (ocean acidification and hypoxia) monitoring network - AK not there yet.

If we are going to have monitoring, it has to accomplish the following:

* support the decision makers;
* measure an array of physical, chemical and bio variables;
* build on ongoing efforts;
* develop and sustains intellectual capacity (training on use of instruments and methods…best practices).

OAH Strategy:

* Answer a series of questions
* From those, identify data needs.
* Do not develop a singular monitoring strategy for all areas (one size does not fit all)
* A key question is What product do you want to end up with?
* Develop a partial inventory of OA and Hypoxias monitoring assets
* Using this inventory…identify which data are weather quality and which are climate quality, cross reference questions you want to know with what specific sampling program or series of measurements. (exactly what I want AK participants to do).

Steps to implement:

* define management needs from OAH;
* assess how well existing monitoring efforts meet those needs;
* evaluated prioritize needs for new investment;
* enhance consistency amongst programs thru training and QA…develop a centralized portal for access OAH;
* develop and sustain intellectual capability;

Lines of defense for adaptation:

* Real-time observing at hatchery or fishery growing sites;
* Real-time observing at the adjacent estuary, sea, or ocean;
* Regional forecasts on days to weeks--scale (weather); forecasts on months to years (seasonal-interannual);
* Communication.

***What do we need?***

1. Need to improve observing capability, assets and sensors in the water; etc.
2. IOOS OTT (Ocean Technology Transfer) “Headlights on High”
   1. Shellfish Hatcheries, Taylor United (shellfish grower in South Puget Sound), Whiskey Creek and Carlsbad.
3. New sensor development testing and expansion of OA monitoring to new sites;
   1. Hales Burkolator.
   2. ACDC (new Burke Hales instrument working with SunBurst sensors)….moored application (Maybe trialed 2016-17).

Technical Know-How:

* The global GOA-ON Plan provides leadership on consistent best practices for OA observations.
* Experts are working with shellfish growers and helping with QA and training.
* Central QA/QC is being provided from NOAA PMEL lab.
* Samples are being sent to one place for analysis, providing consistency.
* Now we can compare Burkolator, ACDC, other sensors to water samples.

IOOS Pacific Region Ocean Acidification Portal:

* The goal was to compare Burkolator data sets.
* Pooled NOAA OAP funded assets, and let regional associations (RAs, like AOOS, NaNOOS) post other data streams.
* It is a Data Portal and Information link.
* Funded by a joint project that funds shellfish work at hatcheries.
  + Can get real-time aragonite saturation data from the Hatcheries.

What do you want to know, and how does this fit in the OA portfolio?

* AOOS has a portal. The portal then feeds into IPACOA which serves the west coast. IPACOA then feeds US sites, which feed GOA-ON.
  + Primarily now has NOAA and BoL
* Are these similar data quality?
* Are QA/QC consistent event if same sensor?

Need to refine portal to provide more metadata e.g. pH scales, data quality objectives, QA procedures, level of representativeness, units, etc…we need units to be consistent…and this needs to be done with community definitions, consensus/buy-in. Ernan Garcia (Oceanography paper on data quality). Jan thinks our data needs to be discoverable.

***How to discern the quality of data required for OA monitoring efforts?***

* Get after what you are trying to do…if you use certain sensors, this is what you can or cannot do.
* How to differential various levels of quality?
* How data quality is being handled by IPACOA and West coast .

*Question: Angela*- if this is going to be set up for managers and planners, there needs to be more synthesis products… (back to Wiley’s point, you need to identify products you want to develop). Plots like Adrian Sutton is making .

*Question: Dick* is asking how we will implement gaps in posting near-real-time data that is NOT QA/QC’d…to QA/QC’d data. The QA/QC times series is available but data demarked as to what is not QA/QC’d. Is there a process out there to the providers that will allow them to do to make the data ready? But how easy is it to get people to do it all the same way??? ARGO is having trouble doing this. Angela suggested we do what NERRS does; everybody coordinates across NERRs organization, they get consistently trained, all do same QAQC. Kris argues that this takes money to do that and analysis. It is a struggle to get it all done.

*Question: Molly*:-thinks the climate vs. weather level is reversed. The climate and weather quality data will have criteria…but this won’t be a public definition. Education of the user.

*Comment: Wiley* thinks they can get climate level with Burkolator. IPACOA nodes are not all doing the certified reference samples as well as possible, however...if they did, they might be able to get the quality data they need. DIC

References: GOA-ON Website: <http://www.goa-on.org/>

GOA-ON Report: <http://www.goa-on.org/docs/GOA-ON_2nd_edition_final.pdf>

**OA MOORING INSTALLATIONS IN ALASKA**

**GAK1 and GAKOA – Ongoing installation in the Gulf of Alaska, Seward, AK**

Two moorings very close to each other.

* GAK1 is a long-term station turned mooring (1998) that measures CTD only at 6 depths subsurface, not real-time.
* GAKOA has a Surface MApCO2 and SBE SEACAT CTD (SBE 16+) reporting near real-time
  + Depths are Subsurface and near-bottom PCo2/pH both SAMI and SBE Seacat
  + Only Carbon package is transmitting Real-Time…this package is on a few moorings to keep things operational and not interfering.

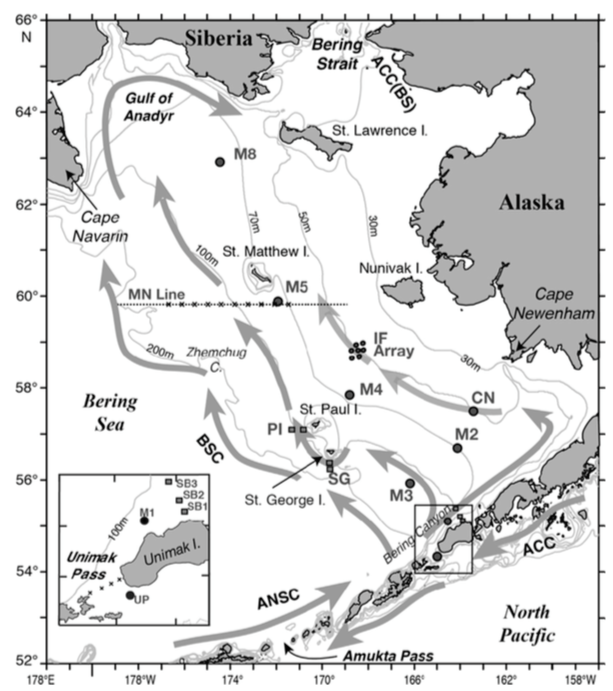
*Comment:* Molly asked if we could get MET (wind speed/direction, etc.) - yes, however, with separate telemetry.

*Comment:* The GAK buoys are not where Seward stakeholders want waves measurements. This was moved out of way of waves…too rough.

**Kodiak (PMEL) Mooring (Not sure who PI is) [2013-2015]**

* This OA mooring is discontinued and OA equipment is being pulled as of winter 2016…not sure if it is just OA or entire mooring

**M2 PMEL (Stabeno, PI) – 56.87, -164.05 - ongoing installation in the Bering Sea [2011 -\*]**

* Surface MApCO2 and SBE CTD deployed in an open water system;
* Also had SAMI PCO2, and pH
* Subsurface and near-bottom SAMI PCO2, SeaFet pH, an SBE 16+ SEACAT CTD with dissolved oxygen (SBE 43) – operational year-round.
  + best sight for PCO
  + Talked with Seth about possibly making an M2 a fully kitted out Ecosystem mooring (Seth is suggesting M8 for this).
* This site has surface MAP CO2 system from May to October. From October to May, winter, we have the same package as M8 at the bottom, 67m.
* 

**Southeast AK NOAA buoy near Chatham Strait – coming out in early 2016 [2013-2016?]**

It is coming out soon in 2016, 5 years. It has MApCO2 and subsurface SeaFET and Seacat in bridle.

**M8 PMEL (Stabeno PI) – OA sensors coming out in 2016 (Lat/Lon: 62.20/ -174.65)**

Subsurface - Carbon package on this mooring…but it was a trial run after switching from SAMI to SeaFET pH sensing technology. One or both were flooding there. 2015-2016 mooring was pulled Sept 2016. Another package was deployed for the 2016-2017 mooring season.

**UW APL Historic stations (Woodgate PI) (A1, A2, A3, A3’))**, One of these (or more?) was equipped for OA measurements, but people attending this workshop do not believe these sensors ever worked (SAMIs). Station with OA was just south of ST. Lawrence (A1?). Mooring is still there, but not doing OA anymore.



Figure of UW APL (Woodgate) Moorings, described at: http://psc.apl.washington.edu/HLD/Bstrait/bstrait.html

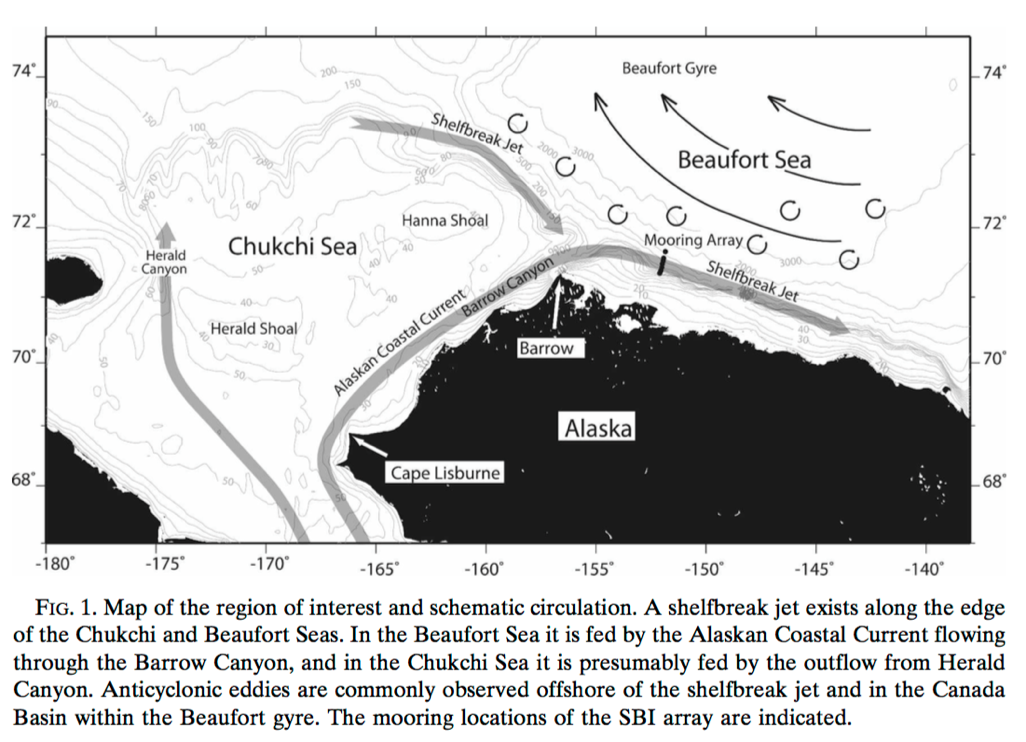
Woodgate mooring linked references:

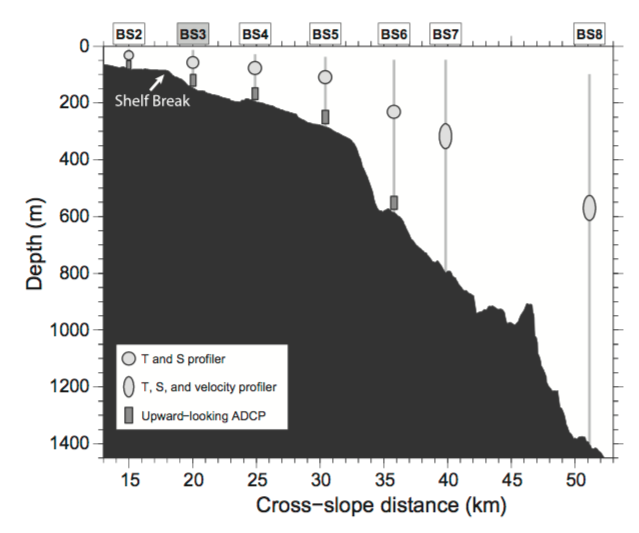
[25 years (1990-2015) of year-round measurements in the Bering Strait,Woodgate, 2015, PDF of Presentation for the Arctic Observing Network Meeting, Seattle, Nov 2015](http://psc.apl.washington.edu/HLD/Bstrait/Woodgate_AONSeattleNov2015_17thNov2015.pdf)  
  
[A Synthesis of Year-round Interdisciplinary Mooring Measurements in the Bering Strait (1990-2014) and the RUSALCA years (2004-2011) Woodgate, Stafford and Prahl, Oceanography, 2015](http://psc.apl.washington.edu/HLD/Bstrait/BStraitMooringSynthesis2015.html)

**Barrow-152 West-historical (Positioned east of Barrow)**

5 years. AON-BS3 time series sites - BS3 is the Shelf Break site.

Sub - Sami PCO2, at 2 depths (subsurface, near-bottom) 2010-2013





**NEW Mares Mooring Plan - Eastern Beaufort Sea**

* Bob Pickart's profiling CTD
* 2 moorings planned in the Eastern Beaufort for 2016

**SITKA Marine Science Center Mooring Plan – DISCUSSION**

Sitka just got instrumentation (Sitka Science Center)

1 SBE SeapHox at 10 m, and one SeaFET at \_\_\_\_m - Sitka Science Center (SeaGrant)

* This is a Sea Grant study - Xylem Brand - Harbor Buoy, USCG academy owned instrumentation. All sensors are YSI sensors, and they are not sure where they are going to be deployed. Whole buoy system. pH, Temp, DO, T, S on one instrument.
* Open to putting more sensors on the USCG mooring. It is a project with Sitka Science Center, a project to do coastal resiliency work. They can pull it at any given moment… but they do not want to commit to other equipment as they are not sure how long it (the buoy) will be in the water.
* It is a nearshore mooring, in shallow water, with real-time telemetry capability. This will provide easy access for bad weather day.
  + Announced that the SUNBURST Sami data cannot be telemetered without MApCO2.
  + Jeremey suggests asking USCG if they would be willing to put a better (more robust and more accurate) system out there.
* AK Seagrant Funded Coastal Resiliency. Lauren is doing water samples for this???

**Sitka Tribe Mooring Plan - DISCUSSION**: Esther Kennedy.

* Nearshore surface buoy, plan to locate it inshore as well. They have buoy and a mooring weight.
* They were planning a SAMI PCo2, but wondering if they should use a MApCO2.
  + The buoy needs to be custom made for the MApCO2 system (according to Jeremy).
* They are thinking about SeapHOx and PCO2.
  + ProOceanus was suggested as an alternative.
  + And water samples.
  + Kristy?? is making Alkalinity measurements on these water samples…and hopefully doing PCO2 and oxygen Winklers (not sure they will need that…using optical oxy from SBE 63).
* Two buoys…one is USCG/Sitka Science Center; one belongs with the Tribe.
* This is current at least, not a cooperative effort, and probably won’t be due to timing (and USCG will not want to change their plan…educational effort).
* Other issues:
  + These buoys are going into nearshore waters that are complicated to characterize.
  + Sitka Science Program wants to reach and increase the fisherman’s awareness of OA. To show it is not stable thing. To report out a daily pH…
    - Jeremy suggested that broadcasting an uncalibrated and variable pH data value is not useful. What is the message? If you want to educate…put a sensor out, show them what you are doing…make plots, show them what we are learning. No good will come from just saying what the pH is every hour. The data need to be presented in context.
    - Dick has done this at Seattle Aquarium, San Francisco, Longbeach. They display the science behind the measurement…and explain that rather than just live feed output.
    - Educate. Natural variability vs. long-term trend. This was recommended over what was suggested they wanted to do.
* What is Sitka Tribe goal?
* Kris Holderied suggested reducing complexity by moving mooring position offshore.
* Jeremy suggested collecting monthly water samples or bimonthly samples would be more useful to the OA effort, because the sensor technology effort is complicated and difficult, and expensive.
  + Not necessarily useful to make sensor measurements if you are not calibrating or doing validation. And you need to know how to analyze the data.
  + Though offshore moorings are needed, but might not be possible with small chunks of change. These are expensive to maintain properly at this time.
  + It might lend more to the OA Network effort if groups like these two Sitka entities pooled their resources (though this will be difficult as USCG has a specific goal of using moorings for education, not science necessarily), and if organizations working or wanting to work on OA in Alaska figured out how they could best contribute to meeting regional OA data needs, rather than carving out their isolated OA programs.
  + Scale the tool to the question that needs to be answered.
* *Seth comment*: Based on how much money you have, what should you do? It would be best to match expectations with available resources.

Equipment costs: SAMI is ~$17k

ProOceanus is ~$\_\_\_

SeaFET is ~$25K

*Question:* Would it be more useful to put a Burkalator at the site in Sitka?

1. Much more money to do that.
2. What about the ACDC? This is still an unknown quantity.

**NERRS Mooring Plan Discussion:**

* NERRS AK wants to put the SeaFET in subsurface and near bottom positions.
  + Question: Is that good use of resources?
    - Jeremy says it could be appropriate to help scale the variability. But calibration issues might report values that are not accurate because it is showing a calibration or a temperature offset. Monthly calibration is required at a minimum (with water samples?).
    - Dave Murphy showed some results from Lydia Kapsenberg’s sensors, and showed how each one was slightly different.
    - Dick F. - The data sets need to be high quality enough and require discrete samples to make sure they are okay.
    - Bottom line: You need to have high quality data to be of any use. It is expensive either way. So some thought is required. It is more than just putting instruments in the water at the moment anyway.
* Perhaps NERRS should consider starting with well made water samples collection efforts. Then relax and go measure stuff you can measure well, like dissolved oxygen can be made very well (though still requires water samples for validation of sensors, but the technology is getting better and more stable, and most competent labs can run a decent Winkler Titration).
* If you can’t measure pH very well, get oxygen very well instead.
  + Hypoxia correlates with high PCo2. Having good DO information will help focus on prioritizing areas where we need to do more sensitivity work.
  + If you decide to take high quality discrete water samples that can be used for OA analysis while getting good Oxygen and CTD data (temperature and salinity)…you will be helping the community to develop algorithms that will enable them to get the measurements that will be useful later.

*Comment:* This becomes an environmental intelligence question. Being able to prioritize locations for sampling would be very beneficial in AK with limited resources.

*Comment:* Cost of installing a Burkolator for a mooring option: $57K to just buy hardware

This does not include flow thru SBE 45 system necessary for this to work (and other parameters T, and S), etc. and does not include labor. Jeff Hettrick said it costs about $80k of hatchery money a year to run the Burkolator…and the hatchery $30-40K from IOOS to pay for Wiley’s time to help out and do analysis and QA/QC.

*Bob Foy Comment:* We should not just put sensors in the water because we have a lab on the water, and do not shop the data to the public to show them we are doing something just for the sake of showing the public we are doing something. Rather, put instruments in the system for a reason, understand and define what your question is you are trying to answer, what is the goal, name the (s) for the mooring (or water sampling, etc.), understand the limitation of the measurement you will make, understand the cost, understand the commitment to do it right, then proceed.

**Chukchi Sea Ecosystem Mooring Observatory Summary**:

* At the moment, this mooring (deployed since 2014) does not have OA sensors installed.
* The plan is to put in subsurface OA sensors on the mooring.
* Considering Contros PCO2 Sensor or SBE Oxygen and SeaFET pH (The SeaPHOx).
* Water samplers will also be on the mooring.
  + GreenEyes…has chambers to collect water samples.
  + Can get DIC.
  + Has a pump that fixes the water sample, so they can calibrate the sensor.
  + Hydro C sensor built by CONTROS is likely the one they will use on this mooring.

**OA MOORING DISCUSSION WRAP-UP**

12 OA moorings listed here

* 1 never produced OA data (Bering Woodgate Mooring A1)
* 4 no longer are hosting active OA sensors (including A1 that never worked, M8, Kodiak, and SE AK)
* 6 are new to OA mooring network as of 2016 (2 MARES, CSESMO, Sitka region (2), NERRS)
* 2 are ongoing and still actively serving OA sensors (M2, Barrow)

*Jeremy Comment:* If one has instruments, well by all means, just use them. Maybe they will work, but just be aware that sometimes they won’t. However, if I have $20K and have not purchased instruments already, and you are in a position to collect water samples, then it might make more sense to take water samples with CTD measurements and wait for the in situ technologies to improve. Doing this is more likely to provide meaningful data to the OA community at this point in time.

*Question:* How is community based sampling under Wiley’s direction getting TS (temperature and salinity) data?

*Answer:* They are collecting water samples…taking a NISST Temp measure at time of sample…and the salinity is being determined using YSI calibrated against CRMs (bottled conductivity standards).

*Carol Comment:* This is a low quality/rough salinity measurement that might be good to maybe 0.1 psu. It might me useful to define the quality requirements for T and S in making good algorithms. This will help advise on the quality needed in auxiliary measurements.

*Rob Campbell comment*-PWS profiling Mooring. Currently there is no OA on this mooring, but can do, and they can also collect water samples.

**OA Shipboard Sampling and Transects**

The Seward line is a long-term historical, ongoing transect: Using SOP (Standard Operating Protocols)

Jeremy Mathis survey ran during 2015 was a one-time effort and collected water samples, using an SOP. The idea is that these transects would get revisited every so often (\_\_\_ Years?) and would go on a rotation with other regional OA sampling efforts in other regions.

Prince William Sound shipboard sampling involves 15 stations (13 at surface, two at depth) and include water samples. Evans is providing training on how to collect samples and preserve samples.

Kachemak Bay Research samples 5 Transects, with water samples collected in the middle stations. Jacqueline from Alutiiq Pride lab provided instruction, but they could benefit from hands on training.

*Comment:* Collecting replicate samples can help constrain some of the sampling variability and help advise where sampling protocol could be improved.

*Natalie Monacci* *Comment:* SOPs are required for collecting samples, or use of a best practices guide. The Sitka Science Center samples are being run by Natalie, but not necessarily being used for science. If they want to have their samples be more useful, they may need to up their game and get some sampling training as well as make some replicate field sampling QC measures, including blanks. This costs more as you are adding samples, but they pay the same price for each sample whether it is good or poor, so might as well get it right and qualify the quality.

**OA Underway Vessel Systems (Ferry Box Systems)**

R/V Dyson makes high quality shipboard OA measurements while underway, including PCo2 and pH.

Use GEOCO2 (made by General Oceanics).

Ship techs are collecting water samples for validation of the instrumentation.

The equipment alone costs about $100k for installation, and $50k for annual O&M including water sample collection and analysis.

NOAA is outfitting as many ships as possible with these systems, but resources are not allowing it to be done at the scale possible.

*Question:* How many ships are currently carrying this technology in Alaskan routes?

Wiley: Wiley: Sikuliaq (LDEO), Oscar Dyson (NOAA), Healy (LDEO), select container ships (NOAA; with repeated tracks across GOA and through Unimak Pass).

Wiley: Deployment of the GO PCO2 system on the PWS tour boat out of Whittier…had a 3 min response time. Shallow surface samples for comparison were made from he

17:00 End of Day 1

**09:00 Start of DAY 2**

Summarized mooring discussion and address questions.

*Question:* Does it make sense to put a mooring in the same place it was before? i.e. M8 is being pulled this year…would we make that a priority then if money came available for a deployment?

Not necessarily. It should get reviewed first.

Kris added to this question: what about other historical moorings…does it make sense to deploy OA moorings at historical sites of just regular moorings?

**9:20 Shallin Busch – CANs US Coordination on OA, Regional Acidification Networks**

CANS are

* nexus for stakeholder input
* help coordinate and lobby for OA work/monitoring and research.

*Question: HOW ARE CANS STAFFED?*

Webinar, synthesis, translation….these are what CANS offer

* State of Science workshops (much of what we are having here)…though Shallin thinks we are only talking about monitoring in this workshop and not the biology.
* Summary articles on OA workshops are written for both experts and no experts
* Stakeholder engagement workshops (for non-experts but given by experts)
* Get buy in to help develop Implementation plans for the region

The goals are to build connections and guidance, and then revisit the state of affairs in the next 5-10 years.

Reference: Gled Hill et al. in TOS

***Stakeholder workshops:*** inform and learn from fishermen, aquaculturists, shellfish growers and coastal water quality groups concerns and issues regarding Ocean and Coastal Acidification.

Nearshore complication: It is difficult to explain nearshore issues based on OA research.

Not part of the OA CAN, but the Northeast Region (New England) is using nearshore networking to include OA and nutrients, and the Southeast Region (south Atlantic) is combining ocean and coastal acidification network.

***Guidance:*** review, assess, NECAN Steering Committee, members from agencies, IOOS RA, industry, policy Outreach and education. Work on technical memorandum expanded and updated state of science.

***Implementation strategy:*** communicate to funding (both federal and state) a viable strategy for furthering ocean and coastal acidification in the NECAN region that is responsive to stakeholder interest groups.

***Practical monitoring guide:*** how to requirements for establishing interdisciplinary OA monitoring in the NECAN.

***Starting a CAN***

* Challenges: forming engaged group, seeing the collective whole
* Benefits: engaged stakeholder group, comprehensively developed needs assessment document
* Success: raising profile of issue, community engagement across disciplines and awareness
* What is needed: Leader in an organization willing to do legwork; an engaged committee; collaborative team members (willing to work without pay; some outside funding and some internal funding (core) helps.

Last year, not much interest in AK CAN, but timing might be better now.

Jeremy is concerned about area covered…too big. Challenging as we compete with other CANs for resources.

SECAN: articulated needs of products; focused on products, and all efforts were used to produce them.

See recent articles in The Oceanography magazine (TOS?) (get refs from Dick Feely).

What do we do next and evolve in a way that works with changing climate, with successes and all the new OA efforts?

How do we provide a service to the community with all these new roles?

* Dick suggests taking it in segments, like 3 year plans….a bit at a time.
  + Do the big things first, then tackle the local issues.
  + Reasons for dividing into three regions: funding support across the CANS equally distributed….so strategy for getting support for the area we need to actually cover.
* Jan thinks you can have the same network, with focus on subregions.
  + She advises against dividing into three regions.

Carol and Molly advocated that AK CAN use tools developed by other CANS when relevant.

Kris Holderied: We do not want to create new entities which take resources away from current activities. By having AOOS do this activity, we use an existing entity that is set up to do this sort of work and help make it happen.

Angela raised the need for making sure the work that is going forward is good, but be aware there are communities that are setting up their own programs, and having them feed into the network would help localize the process.

Molly is asking if We as AK… how are we unique? We cannot ignore oceanic processes. Do we have stronger and more critical drivers here in AK than other regions?

Jeremy concerned that we do not have the coastal resources and data in AK to connect offshore to inshore, so we have to deal with more issues to understand.

Jan mentioned that SEACAN did not spend time on sampling plan. They did webinars, outreach, questionnaires.

Dick says this is a NOAA responsibility. Federal responsibility is large scale. However, the local government, federal agencies, state agencies, where does it feed in? Let’s strategically place our moorings where we get large scale features, where we can calibrate those moorings. Then we can bring that into what is going on nearshore. Our main drivers are same in AK and that is the larger scale circulations.

In NECAN, mostly concerned about nutrients, so coupled processes. More local roles are needed there.

Need to strategize layout of what the various agencies roles are in the Network.

**Jeff Hettrick: Alutiiq Shellfish Hatchery**

**How Alutiiq got started in Water Quality work**

* Money to setup the Alutiiq Pride Shellfish Hatchery came from Exxon.
* The Quteckak Native Tribe of Seward was the original contractor who ran it initially.
* The operational contract was transferred to the Chugach Regional Resource Commission in 1996
* Ownership of the facility was transferred to the City of Seward.
* It was slow to develop.
* Hatchery cannot support itself on seed sales (geoducks and oysters).
* The funding source is not the aquatic shellfish funding (CIRC and AP).
* They had to destroy # GD last year, so the year was a bust.
* Articles on OA on crabs is what brought experienced interest in AK. (poor hatchery production in the NW of lucrative crab industry in danger, sea change – Seattle times). SEACHANGE series
* PMEL came up and installed OA devices…Jacqueline Ramsey ran this for 1 year
* Original SUNBURST super CO2 (CO2 analyzer getting Partial Pressure) showed there was an issue.
* Upgraded with Burke Hales Burkolator.
  + He is under contract to install devices and now they are dosing.
  + Wiley can remotely monitor how the Burkolator is working.
  + Jeff says this is a tremendous tool. It provides continuous monitoring.
  + Jeff will be using it to monitor when to dose. ADAPATATION.
  + Taylor United in Washington uses it…and they find when they raise Aragonite saturation up above saturation values, their output production is higher.
* It takes about $80K a year to run and operate….mostly labor.
  + Wiley (running 3 right now)…and Jeremy: In-kind time
  + Module costs $8000 year in O&M (Operation and Maintenance)
  + Consumables is about $5000 year
  + $75K for initial purchase of Burkolator and ancillary equipment

Jeremy suggested that all shell fish farms just add soda ash to their water…

No need for Burkolator other than as a pulse point and monitoring.

$35million (not confirmed) year savings at Taylor United in WA from doing the soda ash OA modification.

Burke Hales ACDC instrument will measure Partial Pressure paired with a low-cost pH….maybe in 5 years this will be tested, proved, manufactureable and marketable. Planned cost $5K each.

*Question:* Is soda ash dangerous?

Wiley said it is not always the savior. They use industrial grade version. It could have trace metals.

Alutiiq gets money from other organizations to do work on sea cucumber, crabs, etc.

CRRC (Chugach Regional Resource Commission) is funded by BIA (Bureau of Indian Affairs) and villages are funded by IGAP EPA programs (both specifically for native programs). The whole project has been taken “out of hide” at Alutiiq, because it is important.

**What does it look like for Southeast communities in Alaska?**

**Community Based sampling program:**

Community observers throughout the region are going to sample near all the local villages to establish a near shore Southeast sampling program.

* Community involvement key.
* Program integrates between sites and offshore (samples 1/week or 2/week…no hypothesis, just looking at what is there). This is expected to fill potential important data gaps.
* Plan to use a novel large volume dosing system.
* Monitoring will be completed with pre-made sample kits. Efforts included holding a gathering in Anchorage, showing the end-user the Seward Alutiiq lab facility, training on best practices, and having scientific partners help with training.
* Probably will run this community based sampling for 1-2 years, to see what is there, look for hot spots;
  + Proof of concept that Alutiiq can use the Burkolator at a higher capacity than it has been used before.
  + Alutiiq will be using their Burkolator to analyze all the water samples collected under this program.
* They are fixing samples with Mercuric Chloride, which has some responsibility concerns.
* Use of kits: protocols. Bottles (beer bottles), caps and cappers, pain pens, thermometers, sample logs, and fixative.
  + The Mercuric Chloride cannot get back into the environment…they need to strip the waste water and get permits.

ISSUES WITH THE OPERATION and COMMUNITY EFFORT:

* Small staff at Hatchery.
  + Jeff underestimated the time it would take to get this going.
  + He needs support for technician to run samples.
    - we talked about this, intern for 1 year after school?
* What they are doing now: For laboratory work they are running the Burkolator continuously.
  + Community observing samples involves taking this continuous sampling offline to run discrete water samples
* Dosing Lab: Setting up, and testing it with logger? species. Not sure what biometric is yet to measure.
  + Evaluate different doses of aragonite saturation in triplicate with control in triplicate.

Goals and questions from this effort will drive the SOP:

* How to sample?
* How to replicate?
* Depends on the question.
  + Analytical program samples within one bottle.
  + Field sampling variability is multiple bottles.
  + Dick says they did a lot on replicate sampling for different missions…see if we can get a copy of that work.

*Question: Angela* Are both surface and subsurface sample useful?

*Answer:* Yes, but only if you get Temperature and Salinity.

Dick also suggests replication in any sampling Protocol.

*Question: Shallin* What was going to happen to the data?

Jeff said thinking about getting a Post Doc to analyze the data, and perhaps enlist the new OARC professor, who is a biologist, to work on OA impacts on organisms.

Regardless, the data will be shared with that.

Animals currently being raised: Pacific oyster, Gooey duck clams, basket cockle, pacific Razor, Littleneck clam, purple hinge rock scallop, blue kind crab, red king crab, California sea cucumber, pinto abalone, butter clams.

Hard shellfish not recruiting since 2009. (Long Island Sound crash of shell fishery).

The Alutiiq facility can be a great training facility, or center of excellence for hatchery monitoring, and provide a good learning facility for research of students.

*Comment:* Shallin mentioned anthropology studies. Not scope here.

It costs $25 a sample on this program, and that is with a Burkolator that is heavily subsidized. All of the costs are heavily subsidized.

Number at Hatchery, $60-70 per sample.

***Identify where this community program will be taking place (locations)***

* Map of community work going on.
* Seward
* Ketchikan, OARC equipment, Oceans AK , running continuously…coop effort with many players
* If you could put one Burkolator more in, where would it go?

***Costs:***

* DIC (Dissolved Inorganic Caron) and T-ALK (total alkalinity) estimated cost for the pair is $125 per sample. (Dick and Dixon). Cost estimate based on what it cost to run lab, but this estimate did not include costs of replacement for equipment. The actual cost is higher. Everybody is trying to run on the cheap, but it costs to do this work.
* Natalie has run a maximum of 6K samples a year. Need to maintain the data stream for IPACOA, which limits ability to do more.
* Burkolator is not easy to run. Need a Burke or Wiley to run it. So it is not just something to do. We set up a program, but need a place to send samples to validate.
* Jan Newton added that of the 5 sites using Burkolator, the Wiley Evans supported sites are managed properly.
  + There is an ACDC coming to Alaska…not sited yet.

10;45- 11:00 Break:

**11 am OA Monitoring at Shellfish hatcheries and in local communities: Wrap Up**

1. Sam Siedlecki: Models are working well offshore, but not so great inshore…so good to hear they are collecting more data.
2. Bob Foy: Again asked the focus questions: What do we do where and what is going to help us most?
3. Sam: Other measurements can be used for identifying Hotspots, for example, collecting quality dissolved oxygen samples. It takes quite a lot of money ($100K-$150) a year to run the models operationally.
   1. Jan said Parker McCready was saying models are about $250K a year.
4. Seth comment on modeling: Two newer models up here are doing better on coastal salinity…that might help with OA models.

**Wiley Evans, Ferry and Glider moving platform spatial sampling efforts**

1. General Oceanics MApCO2 systems used on container ships

*Question:* How fast are these ships going? *Answer:* 14 knots

* There were initial technical issues onboard, but they were able to overcome them with USCG.
* Discharge issues with Coast Guard.
* No pvc was below water line.
* Direct discharge usually comes straight out of hull on boats with plumbing below water line.

1. Ferry Installation, Whittier to Glacier.

* 90 days of 140 passengers +> 12K people educated on OA
* This boat travels at 25 knots.
* Intake 1 m depth on the starboard hull.
* The method “Grabs” a sample, records a synced GPS at time of sample grab, and collocates it.
* Takes about 3.5 minute for instrument to response (response time)
  + Jeremy said the response of MApCO2 is ~ 15 min.
* LICOR Li7000, control, samples goes into a wet box for equilibration of sample. TSG. Pulling water from cooling lines. Worked great at mapping the OA signal.

1. Allison Bidlack is helping spearhead a AK Marine Highway Ferry mapping project:

* Motivation for this: 2nd or 3rd highest rate of glacier loss in the world; Tongass has the largest carbon reservoir; There is as much water as that from the MISSISSIPPI water shed coming into the Gulf of Alaska. With lower snow pack but more rain predicted for the future, there will be more water coming off land scape (with dissolved constituents like DIC), and more glacial melt (which tends to have a lower pH, hence higher acidity).
* Highly interdependent system. Allison has been working with AK Marine HWY Ferry management to instrument their boat M/V Columbia that is currently in dry dock in Bellingham through May. We need to decide on funding this soon.

*Comment:* Dick suggested we get some vertical data on cruises going up this way from time to time.

Allison: We got a NSF grant to look at rainforest linkages.

*Question:* Dave Murphy: Do these installations have cleaning and maintenance systems in place? Are they validating salinity, DO?

Answer: There is no salinity validation at the moment. Dave recommended that while taking water samples to validate the PCO2, they should also make the occasional Salinity sample (which requires less skill so ship crews can do this easily with simple training). This is because drawing surface water into the plumbing brings in oils and floating debris that can contaminate and foul sensors causing them to drift. Perhaps simple training on a wash-rinse while in port would be helpful too.

Decide if they need to consider the response time for continuous flow through systems…especially when moving at 40 knots! Think about a CTD profile speed…those are moving nor more than about 2 m/s which equates to about 4 knots max. After this, data quality can suffer due to spatial and temporal resolution limitations, at least for CTD profiling. For horizontal mapping, this maybe less of a concern.

If instrument samples at 4 Hz (4 times a second), and has a response time of 0.5 seconds (temperature on the SBE 45 and SBE 38), and if you are moving at 25 knots (~13 m/s), your 1 tau (63% of the final value in a step change) spatial resolution will be 6.5 m multiplied by 2 (Nyquist requirement, you need 2 points to resolve a signal)….The spatial resolution is going to be limited by sensor response time in this example, and the resolution will be at best 13 m (for 63% final signal). If you want to be 99% to the final value when traversing a step change, then your best spatial resolution in this example will be closer to 65 m, or Order 0.1 km. This maybe adequate for OA, where changes in OA are small. But keep this in mind for response time of T and S, especially when mapping up fjords. If the PCO2 response time is 3 minutes…this will make your 63% resolved signal resolved at about 5 km spatially, and 99% resolved signal at about 23.5 km spatially.

* The M/V Columbia Ferry travels from Bellingham to Skagway every week round-trip.
  + Potential outreach is huge.
  + Posters, and Ferry goes by Key assets (Ocean Site in Ketchikan, and Sitka Marine Science Center).
  + Stable and reliable ferry schedule (weekly Roundtrip).
* Most extensive ferry installation in North America.
  + Rik Wanninkhof has done this on a lot of Cruise Ships.
* R/V Oscar Dyson to travel twice a year WHERE? and they have GO Carbon group system installed – in a proposal with Wiley and Allison
* Prince William Sound Major Marine transport (Kathy Cosca can provide maps to see if this is viable option for such a system)
* Ferry box from Whittier to Glacier. This study by Wiley is a good one to demonstrate utility.

*Comment:* Kris would recommend M/V Kennicott Bellingham – Skagway – PWS – Kodiak

Tustumena…ferries. Would be good…one is doing Aleutian, and the other one is the Southeast.

Wiley and Allison said they wanted to outfit the Kennicott in future…this time M/V Columbia chosen due to time and funding source interest in location.

***Costs:***

76K$, LiCor cost for this specialized hardware alone

Total cost for Ferry box was $30K

***Other works going on in area:***

*Comment:* Angela Doroff mentioned other boats going on with TSG, might be good assets for future.

We are at capacity at the moment. Working on building capacity in the chemistry manpower.

**GLIDERS:**

Annual Arctic Glider deployments

2 wave glider deployments planned.

Nothing for GOA.

These wave gliders carry the MApCO2, which is Slower response, but the glider is also slow moving, so okay.

*Comment:* Jeremy: Talk about putting a less accurate sensor on the “sail drone” and calibrate it against a nearby moored measurement.

*Related Question:* How fast is the drone moving? *Answer* 2-3 knots

*Question:* Molly - Why is the autonomous sampling important?

*Answer:* It is because we can get coverage we can’t get with a ship. Collaborative with cruise, glider, moorings, etc.

*Comment:* Wave Gliders can be used for repeat transects.

Used to explore extent of effect of Glacial melt, and working on times when we cannot sample.

**Scaling the Scope of OA Programs**

1. **Costs, and how to best leverage limited resources**
2. **Identify targeted questions that need to be address**

***What can you do with X amount of $$$?***

Scale OA programs by cost

* If you start from scratch for $10K, what can you do with that?
* LTER program from NSF, this is one that allows you to function in a small area…if you are going to pull resources together and start up a program.
* 4-5 million $ for 5 years.
* When you partner with these larger programs you can do a lot more.
* $500k on Bering Sea OA portion with a multimillion dollar Bering Sea project. This is getting a lot for the value.
* Wiley Prince William Sound project is good example of how to get some specific questions, like the effect of Glacial melt. This took about $300K
* Annual monitoring from a mooring: costs about $100K to turn a typical mooring around, $105K for GAK1.
* Forecast models are not necessarily cheaper, though you get more coverage: $150-250K

How do we get underneath all of this?

* We leverage with other programs.
* Example: Some people are out there. Boats are there, so we can collect samples for example.
  + Is that useful?
* Lots of infrastructure, tight knit community. Can we capitalize on infrastructure?
* But don’t forget, the costs include analysis… and making useful products with the data.

***Targeted Questions that need to be addressed:***

*Comment:* Dick: GO-OAN is having trouble linking how to deal with OA linkages with biology.

* Each region is different in biological issues…so that is hard.
* Can we link biological observations in the field with the chemical/physical measurements we are good at getting in the field? If so, then we will know more.
* How do we do that?
* What work was done with pteropods…field component, need to know what we do to improve how to design biology co-sampling combined with chemical/physical properties.

*Comment:* Bob Foy: We need to define the question, and what is the scale?

Bob has to work on a commercially important species for example…crabs.

1. To answer the question: What is the regional change in OA?
   1. We need baseline data to understand for biological work
   2. Need to know the natural variability…what is the local change versus the natural variability? We do not have a good handle on this.

Example: If the natural variability is so great, is the chosen study organism even going to feel the long-term changes? If not, is that the right organism to study? No However, if you have one who is in less dynamic environment, who is more at risk, or one that is only part-time in that variable environment, then it might make sense to stick to that organism.

1. Do we measure natural variability with a plan or do we measure where we have people who care, or who can do the sampling?
2. Do we put energy and financial resources at hatcheries and fisheries?
   1. It might not help with big picture, but it is important and is needed from resource manager’s perspective.
3. We need to tie OA with fisheries in AK.
4. What kinds of products would help?
   1. Develop an OA index for the State…i.e. Aragonite saturation scale with salinity. Bring this index in for salinity based on historical data or effort, then have a proxy measure…to get it done.
   2. Index is good for about 5-10 years
5. Another question is external forcing:
   1. What is effect of X…are there meta scale processes (sea ice) that we need to consider?
   2. What is carbonate chemistry of sea ice…and how do we get back to crabs?
6. Primary production – with so much carbon getting fixed, what does this mean to OA effect.

*Comment:* Kris: does it make more sense to pool resources to help with the biological work?

Dick: NOAA Long surveys get done every 2-3 years.

What about the Seward Line - Can we co-locate chemistry and biology?

* What biology would be co-located with these measurements?
* Seward Line: Great time series, but the biology is a desert there…relationships to lower trophic levels are available on the transect, but the ties to the variability where shell fish and fish species live…near life histories related to hatchery waters. Hard to get funding to do this, and then how to do it.
* Fisheries and bottom trawl focus cruises, there are currently no chemistry or physical data. But WHO did this from GAK1 to Kodiak. The data was collected for this very purpose, but nobody has had time to analyze it.

Comment Natalie: I believe this was part of the GOA-IERP project with NOAA. Russ Hopcroft would be the best person to ask where this data stands.

* There are examples of data sets to evaluate what the linkages are, and then target something useful to determine what the canary in the coalmine is. If possible.
* Also promote some basic research in this area.

*Comment:* Shallin: In Puget sound, they paired vertical tows and carbon chemistry. They picked two species. Parameterized experiments. Got down to the process level. So do you design targeted process study? Yes.

To analyze effects of variability of the carbon chemistry: use modeling studies.

Nina is a funded OAP scientist: she could be one that does this. She was brought onboard to get this work done.

Three opportunities to link chemistry and biology:

* GOA IRP synthesis: adding component (NPRB)…the data exist.
* Cruise work by NOAA with coastal transects…has all the biology but no money to analyze the data.
* Develop the Arctic IRP (NPRB)…do it here.

*Comment:* Molly wants to see a table:

Key species, OA impact status, how they are, risk

*Comment:* Dick is saying, we have the chemistry, come bring your biology. Need the other way around.

* What the Carbon and Aragonite Saturation states are together.
* Pteropods are ubiquitous, so a good organism to use as it is easy to find.
* Euphausids, patchier, but most important to fish, so again, important.
* Multiple stressors: are there species out there at multiple risk?
  + (Risk index (Jeremy), and Bob (what work he has done?), Hurst paper (Shallin)
* Identify which measurements matter to a given species?
  + Crabs in Bering…life stages…where is the bottle neck with a given species?
* Identify where are changes likely to happen most?
  + What biology is there?
  + How is it we can study what organisms are at risk?

Reference: Mathis et al., 2015 risk assessment paper has a lot of this information:

*Mathis, J.T., Cooley, S.R., Lucey, N., Colt, S., Ekstrom, J., Hurst, T., Hauri, C., Evans, W., Cross, J.N., Feely, R.A., (2015). Ocean Acidification Risk Assessment for Alaska’s Fishery Sector. Progress in Oceanography. doi: 1016/j.pocean.2014.07.001*

* Focus on species commercially and economically important.
* Also on conservation concerns – species persistence, community persistence, marine mammal persistence.

Example: clams that are important to walrus, which then are important to human subsistence hunters; grey whales, clams, trophic linkages.

Perhaps convene a Workshop between biologists, chemists.

* Some regions are going under faster changes than others.
* Combine OA and conditions that facilitate the changes (physical changes) or that are enhancing these changes: map this out and identify priority areas. i.e. change in upwelling frequency.
* Long-term monitoring required…to get after all the life stages in biology…not a trivial task.

**TAKE HOME Points from crowd on scoping OA work in Alaska:**

1. Operate with a Tier system measurement:
   1. Oxygen Tier 1
   2. Nutrients Tier 2\* Depends on platform
2. “Force” collaborations between chemistry and biology on existing efforts.
3. Find qualified persons to do some analyses.
4. Pick what variables will be useful for different areas…and promote this, keeping in mind costs and capability.
   1. Coastal estuarine regions, some parameters will be more useful than others.
   2. If doing Alkalinity near glaciers, would be nice to constrain the nutrient condition.
   3. Chris Hunt at UNH is a good contact for this. Ask him for a table on what do to for coastal waters.
   4. DIC and PCO2…the two best measurements to make anywhere.
   5. Lisa Robbins USGS
   6. Emily Bachmann
5. Best Practices guide: Jeremy and Natalie: it says in there what needs to be done to do it right.
   1. Andrew noted: with respect to the coastal area, we have learned this area sometimes requires more work or slightly different approaches…we have learned since previously mentioned SOP was written (SOP was largely based on blue ocean experience).
   2. Perhaps we should write an addendum to the SOP to include nearshore modifications to the SOP?
6. Concept to ponder: Create a consortium of effort as a community … collect water, send them out, analyze, and then have someone write it up? Make a Product? Define a product to define the effort.

***Followup after this workshop:***

1. Draft Minutes from AOOS will be posted on an OA Page on the AOOS website (Carol Janzen)
2. Report summarizing the key findings in this workshop and recommendations (4-6 pages; Carol Janzen)
3. OA Network – Establish the Alaska OA Network (Darcy Dugan will follow-up)
4. Provide links for the SOPs and risk assessment papers, to form a bibliography (might be an OA Network activity).