



Finding the calls in the CHAOZ: marine mammals and oceanographic conditions off Alaska's northern slope

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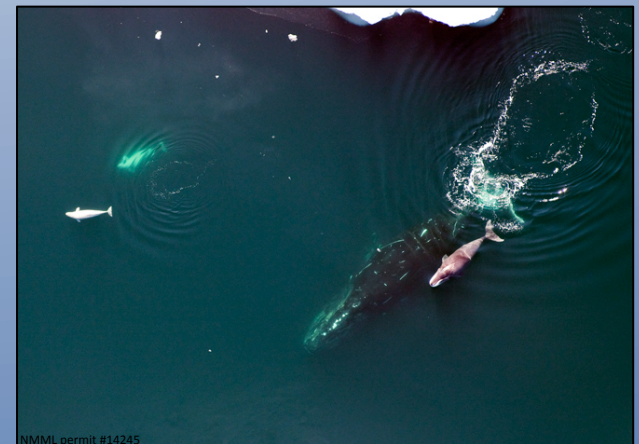
Chukchi Acoustics, Oceanography, & Zooplankton (CHAOZ) Project

“...document the distribution of large whales in areas of potential seismic activity, and to relate these changes to oceanographic conditions, indices of potential prey density, and anthropogenic activities.”

5 main components:

- Passive acoustics of large whales
- Oceanography
- Zooplankton
- Climate and sea ice modeling
- Chukchi Sea noise budget

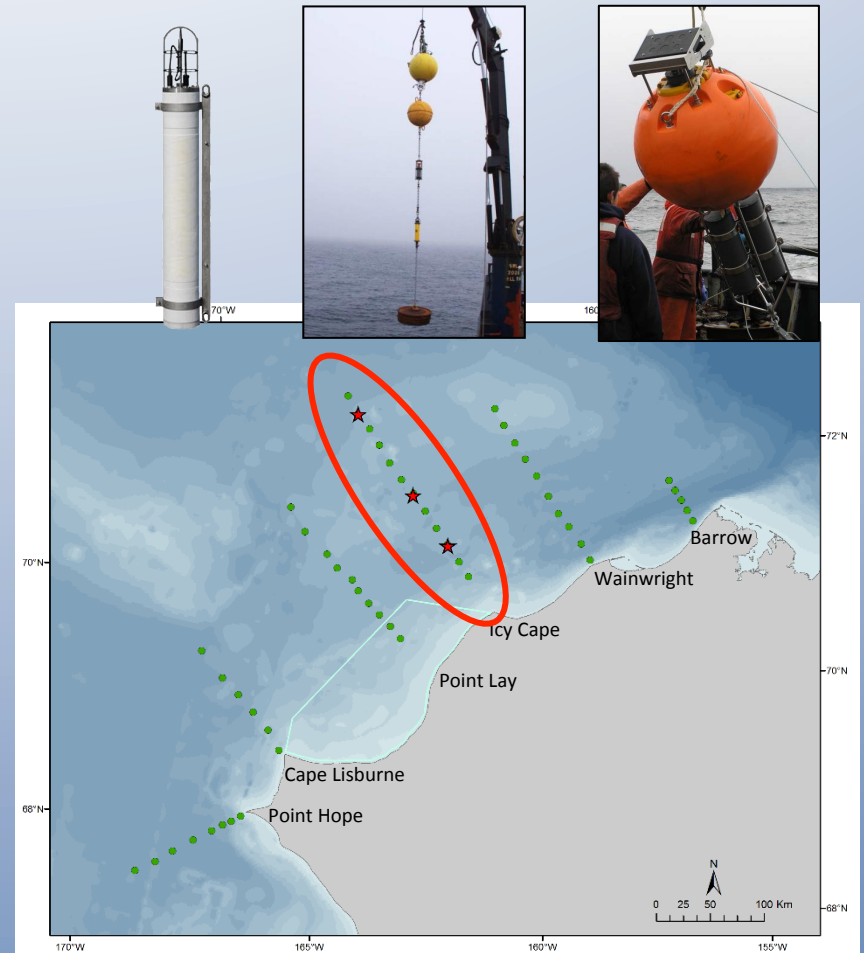
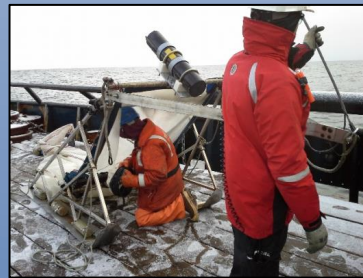
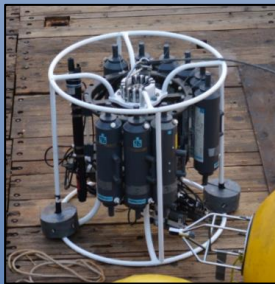
(Cornell University, BRP)



NMML permit #14245

Methods

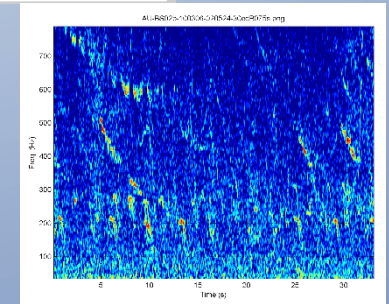
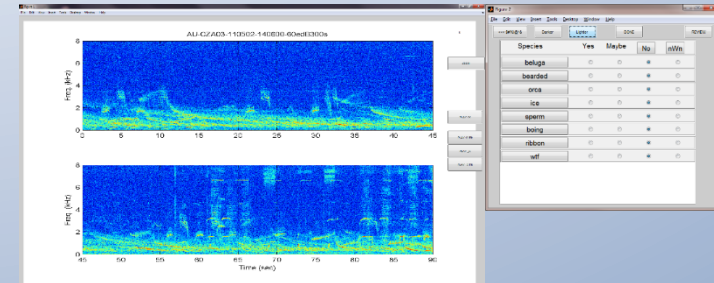
- Biophysical mooring clusters
Passive acoustic, oceanographic, and zooplankton instruments
- Transect line sampling
CTD casts, zooplankton net tows
- Marine mammal surveys
Visual and acoustic (sonobuoys)



Methods – Analyses

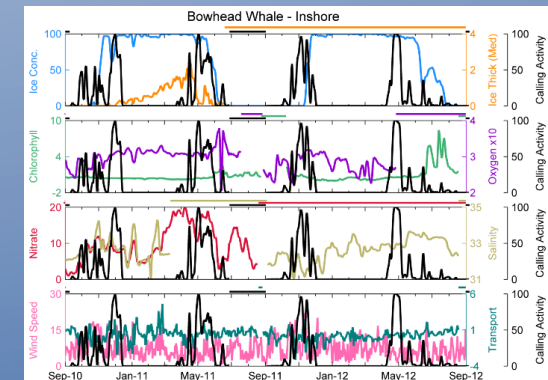
Long-term data

- Passive acoustics
 - Analyzed 100% of recordings
 - 12 species of marine mammals (MM)
 - Anthropogenic and environmental sources
- Generalized Additive Models (GAMs)
 - Correlate MM distribution with oceanographic parameters
 - Executed in R
- MM calling plotted vs. 8 variables



Short-term data

- Transect data plotted vs. visual/acoustic results



Methods - GAMs

- Five resident Arctic “proxy” species
 - Different dietary niches
- 19 variables (oceanographic and environmental)
- Inshore, midshore, and offshore - both years

500,000 models

	A	B	C	D	E	F	G	H	I	J	K	T	U	V	W	X	Y	Z
1	ADCP (600)													Ice thickness	Ice Concentration (%)	Chlorophyll (fluorescence)	PAR (1m)	Temperature (°C)
2	Date	Gunshot call	Bowhead	Gray	Walrus	Beluga	Bearded	Ice	GunshotM	acks	scattering	backscat	Average	Median	St. Dev			
66	2010-11-01	0.0	33.1	0.0	0.0	0.0	0.3	0.0	0.0	-36.955445	-69.34677	0.02	0	0.06	36.29	0.444	4.39E-06	-9.9105
69	2010-11-02	0.0	70.9	0.0	0.0	2.6	0.3	0.0	1.5	-45.586623	-67.22466	0.02	0	0.09	53.86	0.455	1.85E-06	-9.9893
70	2010-11-03	0.0	99.2	0.0	0.0	0.3	1.7	0.0	1.6	-35.516343	-66.7993	0.02	0	0.12	70.43	0.438	1.90E-06	-9.9129
71	2010-11-04	0.0	80.7	0.0	0.0	0.3	2.1	1.8	0.0	-39.034155	-68.5123	0.05	0	0.15	74.93	0.470	3.47E-06	-1.1163
72	2010-11-05	0.0	37.9	0.0	0.0	0.0	0.3	2.1	9.0	-30.703385	-71.8092	0.09	0	0.31	79.86	0.452	4.29E-06	-1.3073
74	2010-11-06	0.0	5.5	0.0	0.0	0.0	0.3	5.7	20.0	-49.34862	-70.6039	0.06	0	0.28	89.07	0.436	3.71E-06	-1.4355
74	2010-11-07	0.0	17.2	0.0	0.0	0.6	2.6	4.2	33.6	-52.472873	-69.1932	0.08	0	0.35	93.43	0.438	1.16E-06	-1.6014
75	2010-11-08	0.0	23.4	0.0	0.0	0.3	1.0	3.4	62.5	-52.648414	-69.5993	0.07	0.02	0.25	98.07	0.440	3.04E-06	-1.6176
76	2010-11-09	0.0	13.8	0.0	0.0	0.0	3.9	11.0	60.1	-54.325811	-71.9331	0.05	0	0.21	99.93	0.437	1.25E-06	-1.5912
77	2010-11-10	0.0	0.7	0.0	0.0	0.3	2.1	19.7	49.0	-53.381681	-72.4165	0.18	0.03	0.48	99.93	0.437	4.38E-06	-1.4168
78	2010-11-11	0.0	0.0	0.0	0.0	0.0	6.3	6.9	31.0	-55.746681	-73.3005	0.15	0.07	0.43	100	0.434	3.13E-06	-1.2976
79	2010-11-12	0.0	0.0	0.0	0.7	0.0	9.7	0.0	9.7	-57.102015	-74.7031	0.15	0.06	0.44	100	0.429	1.18E-06	-1.3425
80	2010-11-13	0.0	0.0	0.0	0.0	0.0	0.3	8.8	0.8	-58.384705	-75.3668	0.36	0.19	0.62	96.64	0.434	3.76E-06	-1.2308
81	2010-11-14	0.0	0.0	0.0	0.0	0.0	5.7	15.5	0.0	-58.894196	-76.0508	0.18	0.09	0.38	96.36	0.438	3.34E-06	-1.1782
81	2010-11-15	0.0	0.0	0.0	0.0	0.0	9.3	11.6	0.0	-59.839595	-76.5652	0.18	0.09	0.41	95.43	0.446	2.82E-06	-1.1381
83	2010-11-16	0.0	0.0	0.0	0.0	0.0	2.4	11.3	0.0	-56.987583	-76.8625	0.12	0.01	0.36	95.93	0.439	2.75E-06	-1.4592
84	2010-11-17	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.7	-54.442574	-74.602	0.23	0.09	0.4	97.07	0.427	2.31E-06	-1.3703
85	2010-11-18	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	-59.952001	-75.7914	0.29	0.15	0.45	95.96	0.432	2.29E-06	-1.4406
86	2010-11-19	0.0	0.0	0.0	0.0	0.0	0.0	15.2	0.0	-58.423128	-75.4004	0.35	0.16	0.59	96	0.430	5.23E-06	-1.5046
87	2010-11-20	0.0	12.4	0.0	0.0	0.0	0.0	12.0	0.0	-58.623081	-75.4074	0.36	0.31	0.28	96.36	0.429	3.43E-06	-1.2263
88	2010-11-21	0.0	2.1	0.0	0.0	0.6	0.0	0.3	0.7	-56.536191	-73.4187	0.42	0.43	0.38	85.29	0.449	4.60E-06	-1.5915
89	2010-11-22	0.0	19.4	0.0	0.0	0.0	0.0	0.0	0.7	-55.985231	-73.8188	0.27	0.08	0.38	87.86	0.442	2.88E-06	-1.6058
90	2010-11-23	0.0	15.6	0.0	0.0	0.0	0.0	0.0	0.0	-41.989214	-70.3753	0.16	0.03	0.24	50.57	0.472	5.55E-07	-1.7622
91	2010-11-24	0.0	52.4	0.0	0.0	7.2	6.0	0.0	0.7	-56.188894	-73.7916	0.02	0	0.06	50	0.508	4.54E-06	-1.7253
92	2010-11-25	5.5	100.0	0.0	0.0	9.0	16.7	0.0	8.3	-56.280105	-74.3911	0.01	0	0.03	60.36	0.484	1.90E-06	-1.7642
93	2010-11-26	0.7	97.2	0.0	0.0	8.1	4.8	0.0	2.8	-55.874069	-72.8055	0.04	0	0.09	53.64	0.480	3.36E-06	-1.7458
94	2010-11-27	0.0	92.5	0.0	0.0	11.3	6.8	0.0	0.0	-54.276144	-71.254	0.04	0	0.09	49.29	0.455	3.48E-06	-1.7475

Predominantly benthic,
Can be generalist



Predominantly pelagic



Generalist



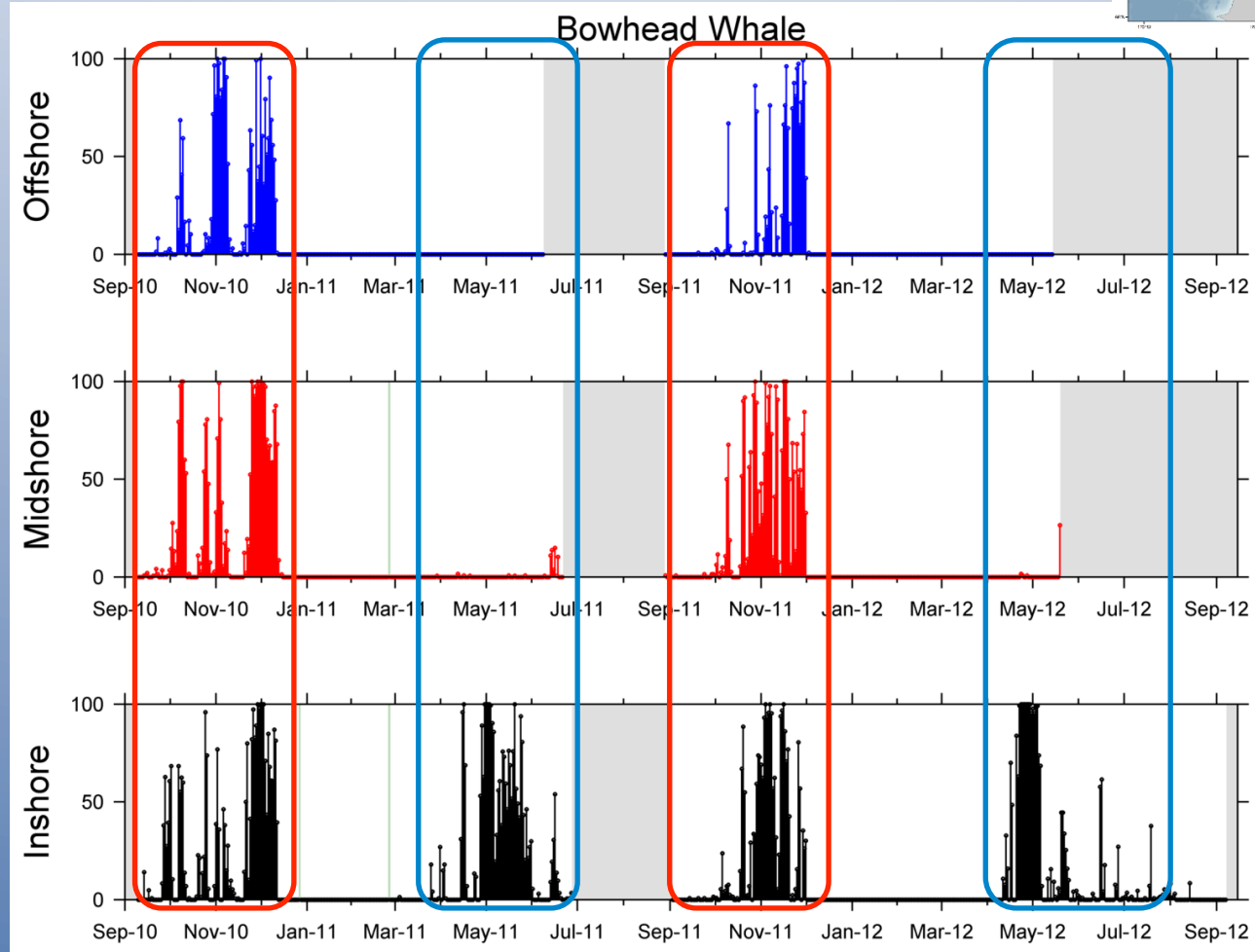
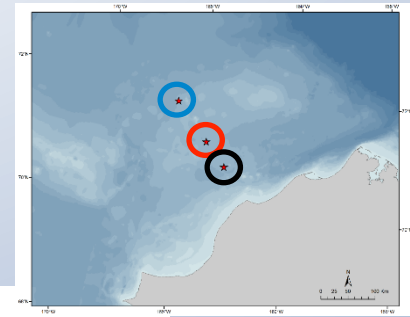
Benthic specialist



Predominantly benthic,
Can be generalist



Results – Bowhead whales



Predominantly benthic,
can be generalist



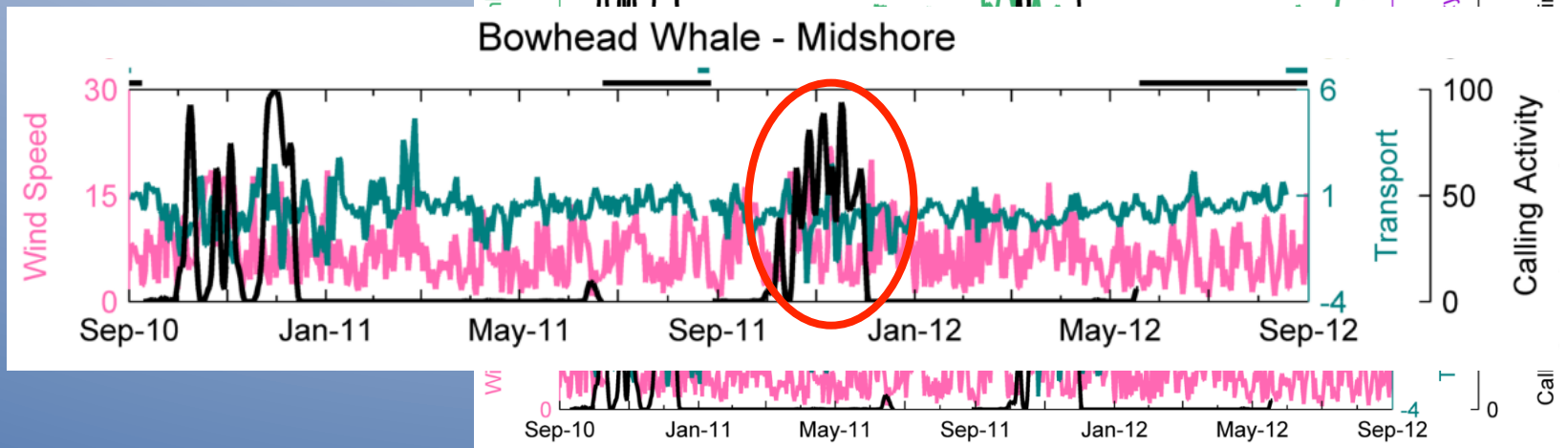
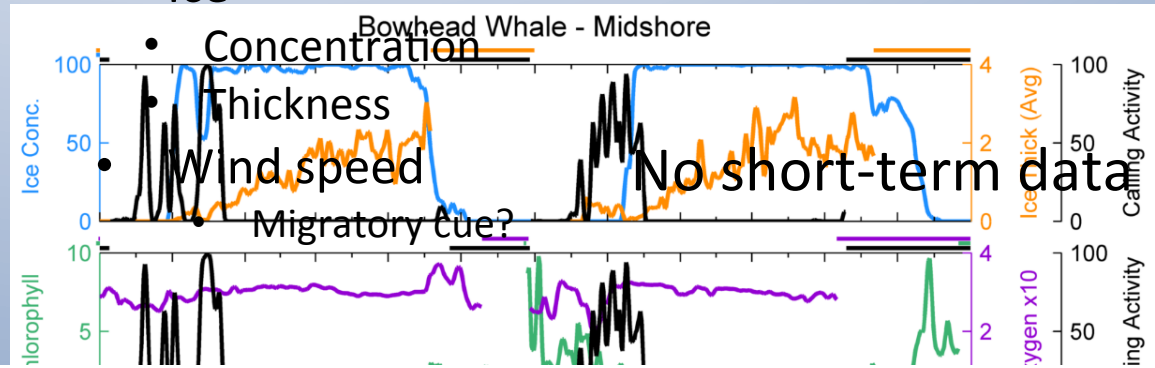
Results – Bowhead whales

GAMs

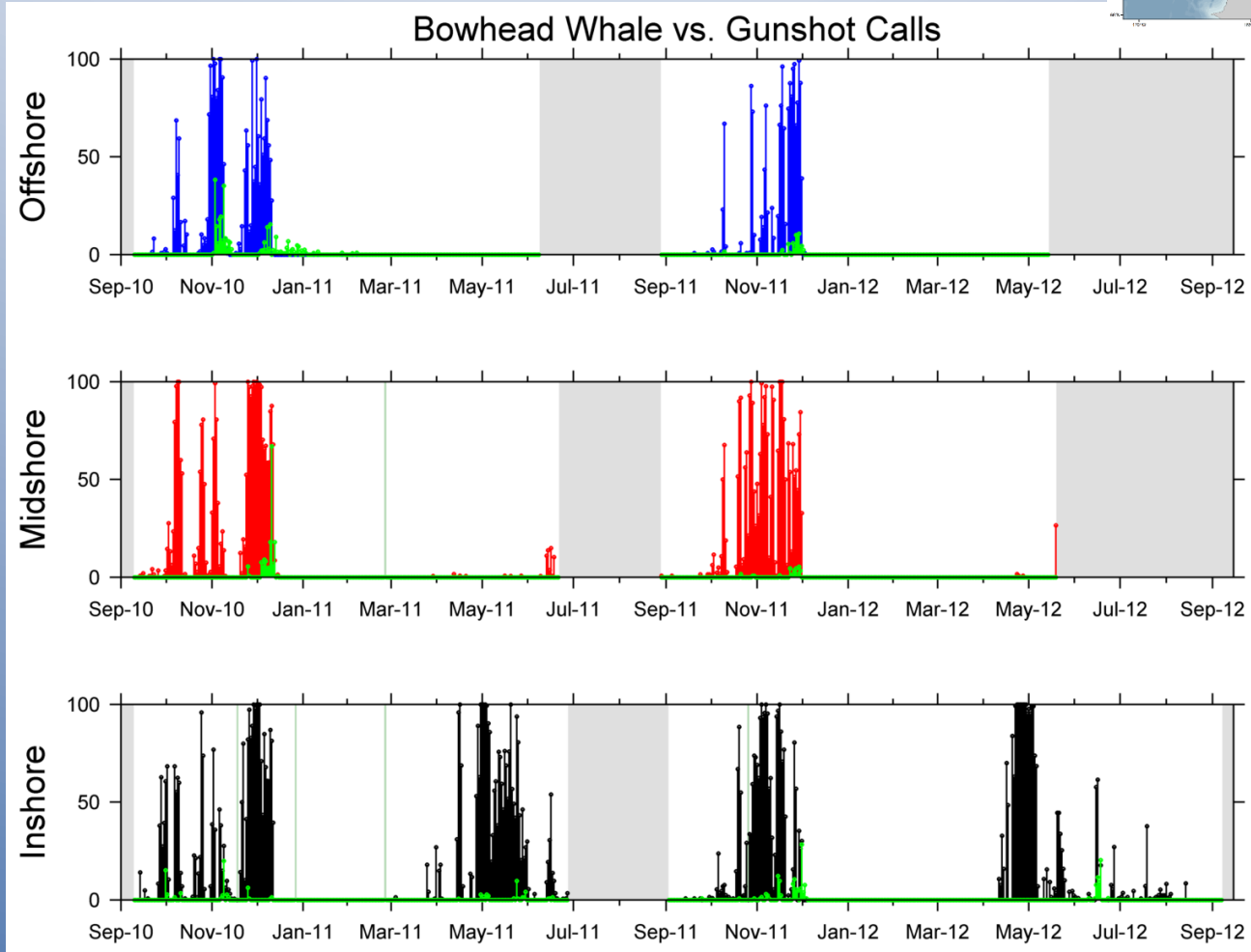
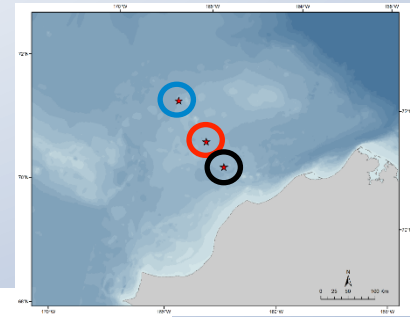
- Month
- Ice concentration
 - Innate migration patterns
- Wind speed

Long-term plots

- Ice



Results – Gunshot calls



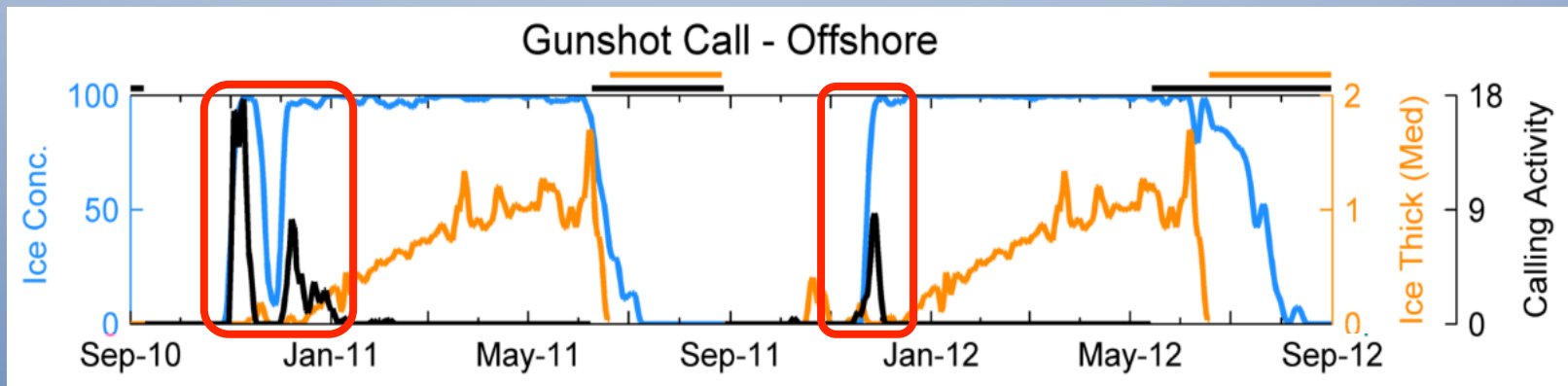
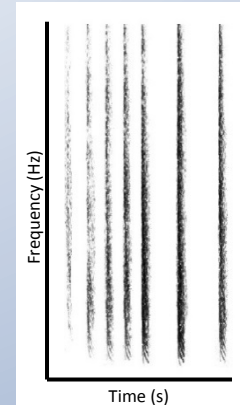
Results – Gunshot calls

GAMs

- Month
- Ice concentration

Long-term plots

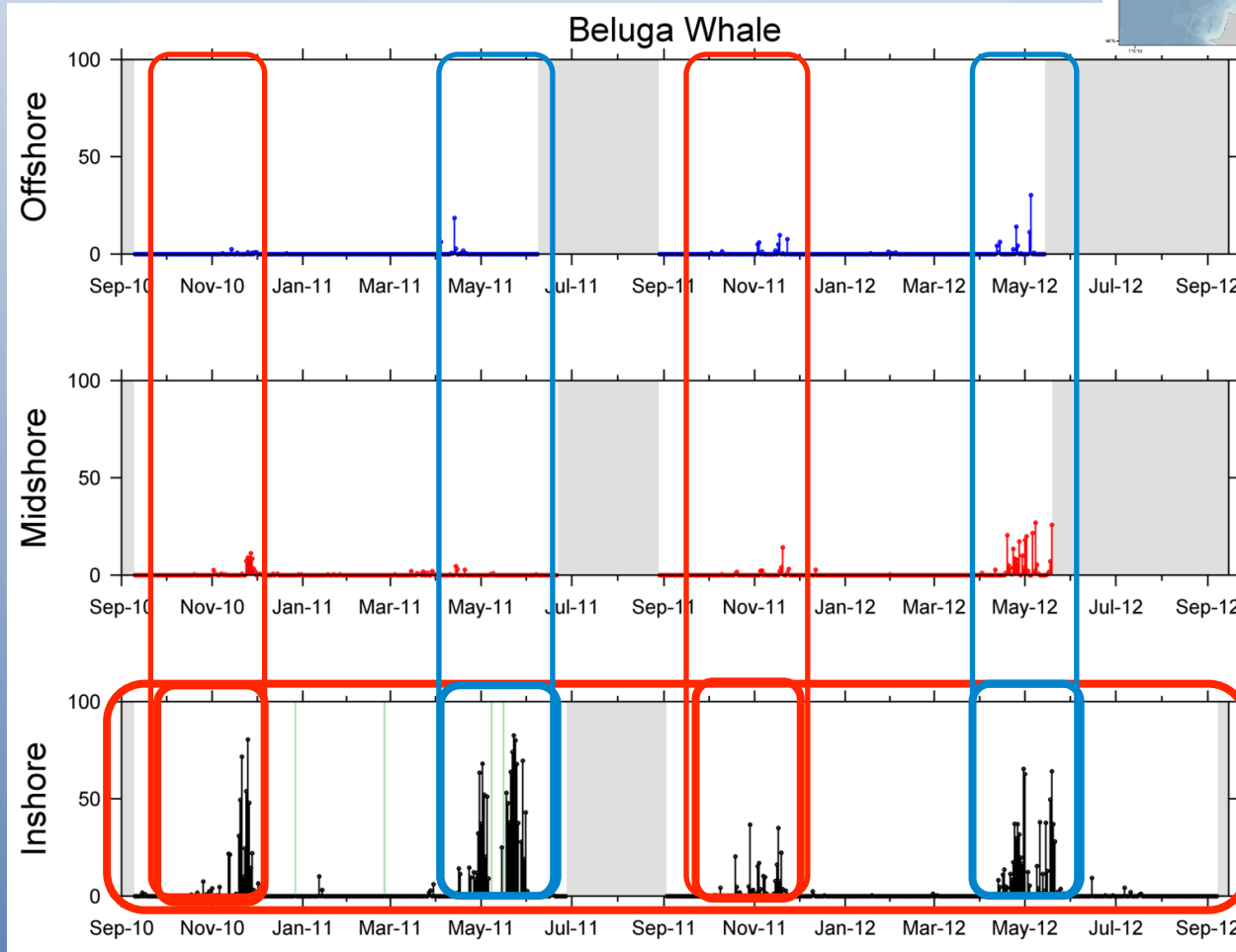
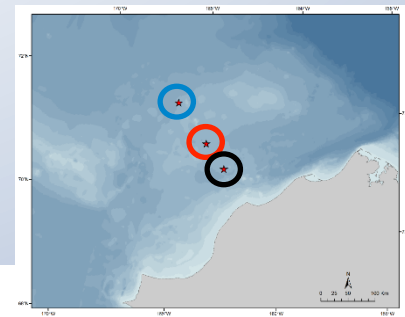
- Ice
- Navigation
 - FM calls^{1,2}



1. George et al. 1989. *Arctic* 42: 24-30.

2. Clark and Ellison. 2004. Pp. 564-582 in *Echolocation in bats and dolphins*.

Results – Beluga whales



Garland et al. 2015. *Polar Biology* 38(5): 747-754.

Results – Beluga whales

Predominantly pelagic



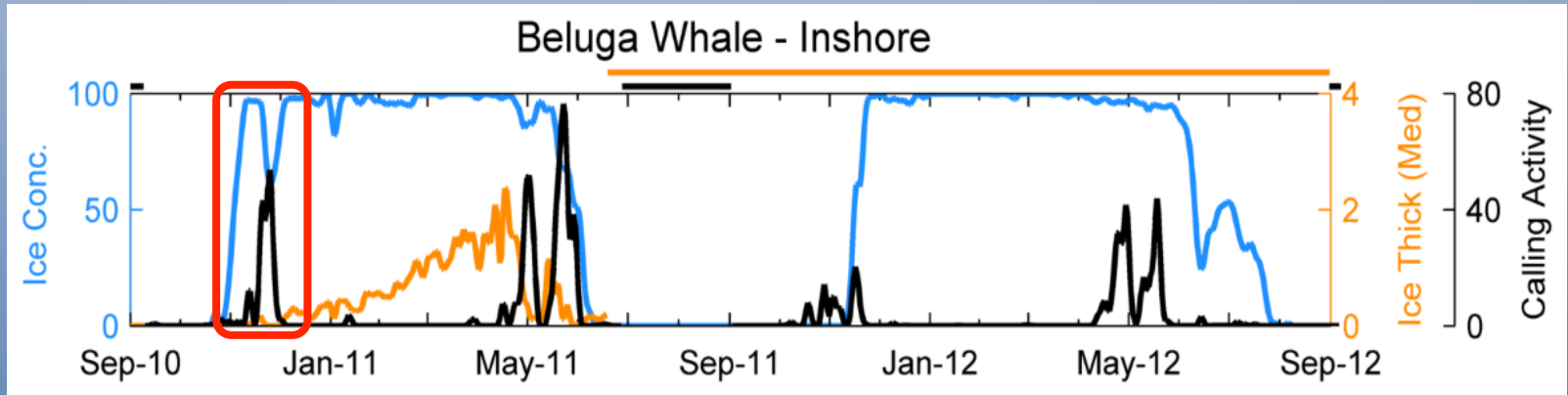
GAMs

- Month
- Temperature
- Ice concentration
 - Innate migration patterns

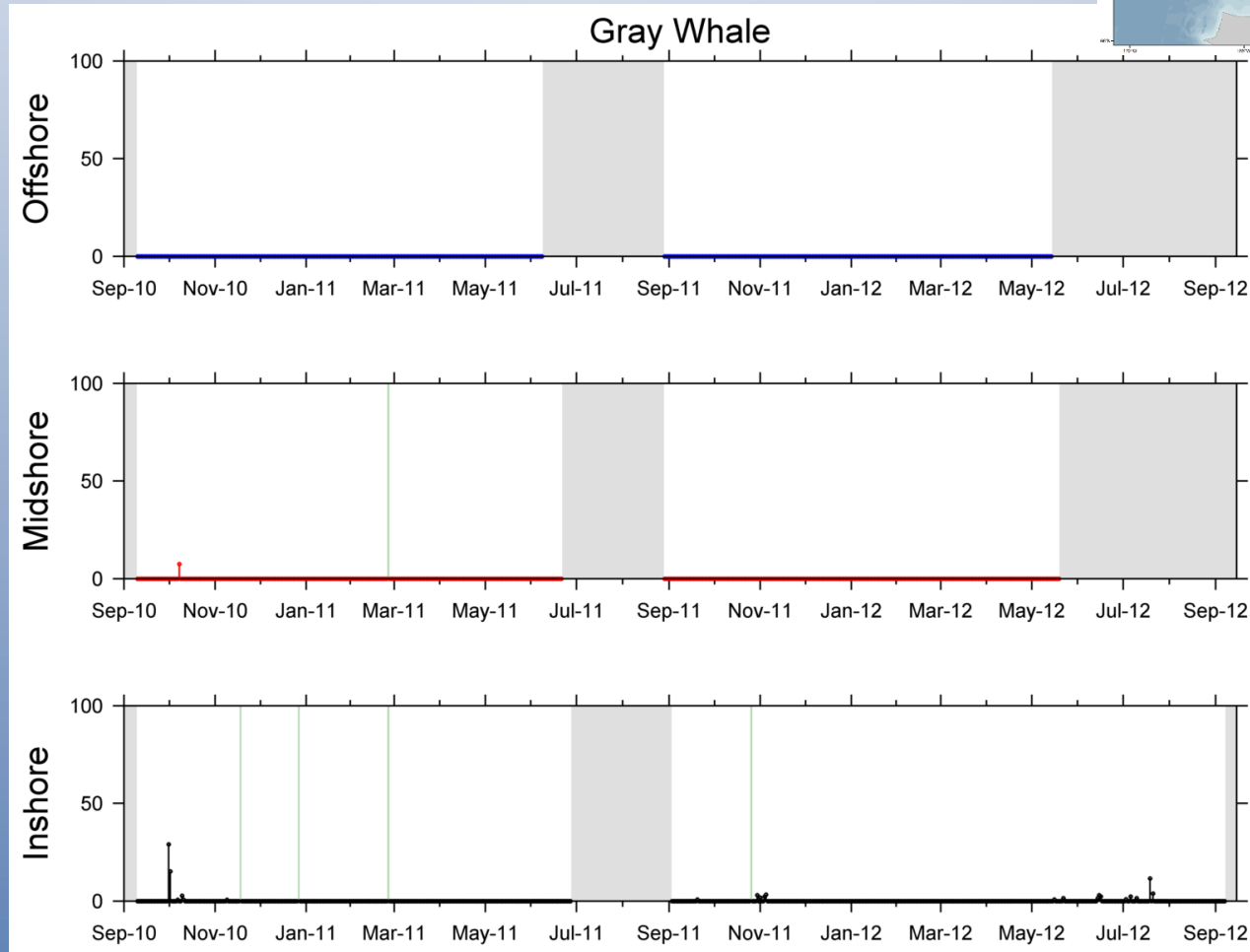
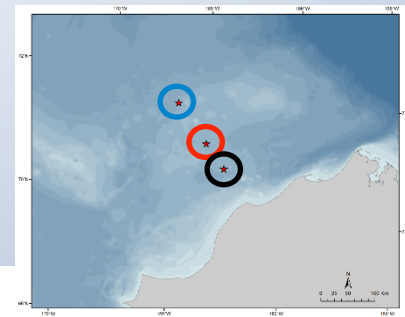
Long-term plots

- Ice
- Polynyas

No short-term data



Results – Gray whales



Clarke et al. 2011. Final Report, OCS Study BOEMRE 2011-06.

Results – Gray whales

Generalist

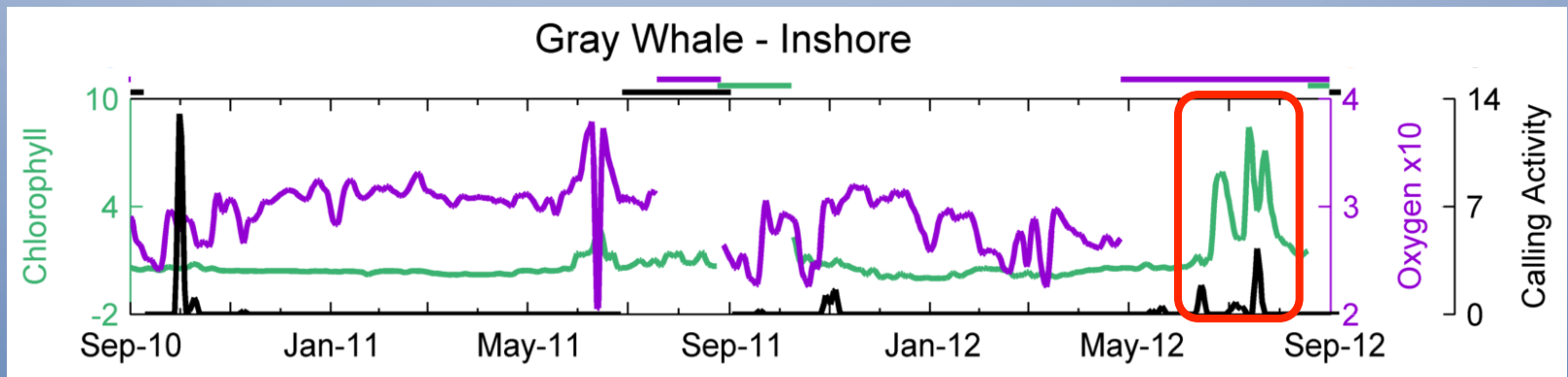


GAMs

- Inconclusive

Long-term plots

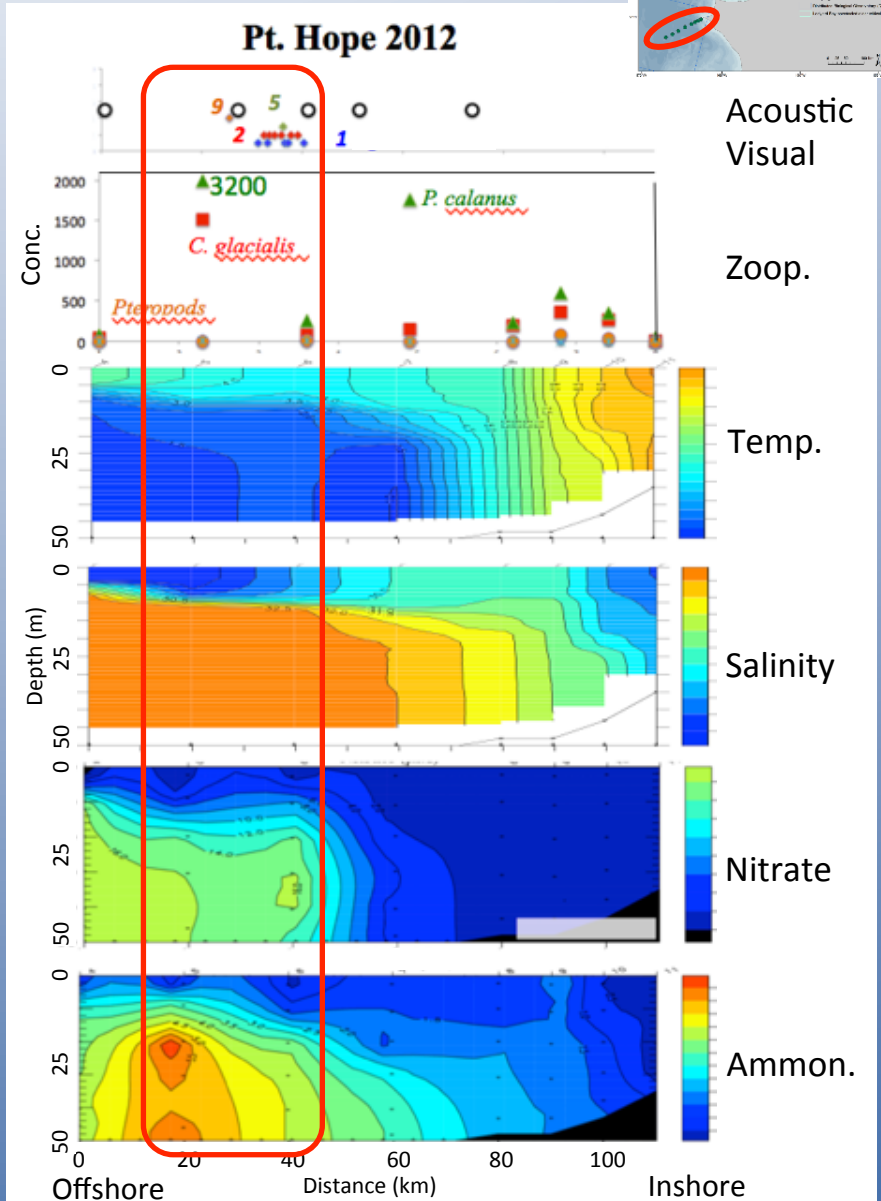
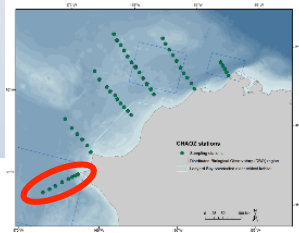
- Ice – negative
- Chlorophyll
 - Proxy for prey



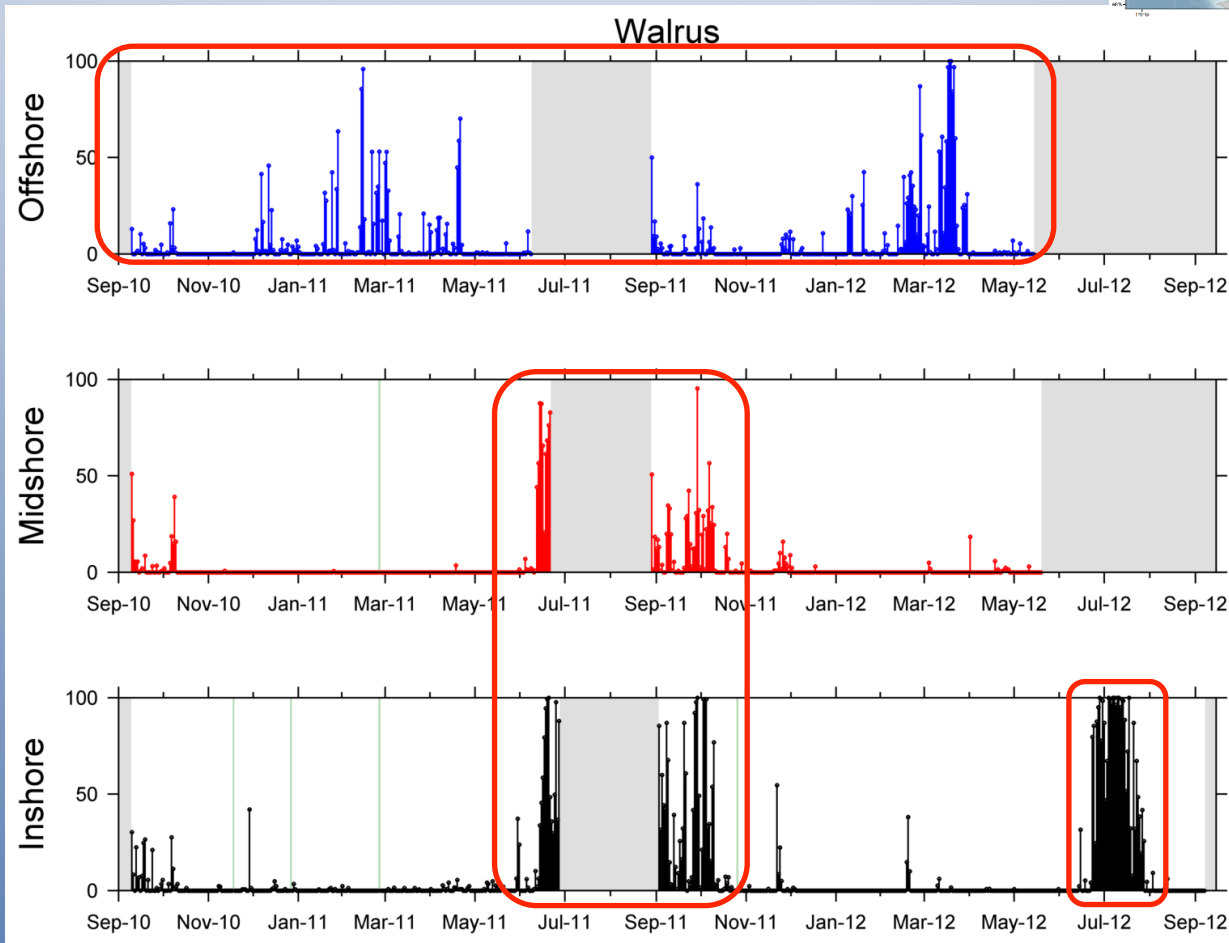
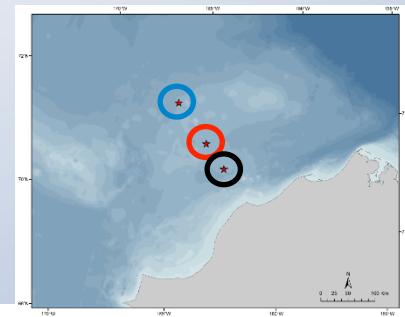
Results – Gray whales

Transect lines

- High zooplankton concentrations
- Ammonium/nitrate
- High benthic biomass



Results – Walrus



Results – Walrus

Benthic specialist

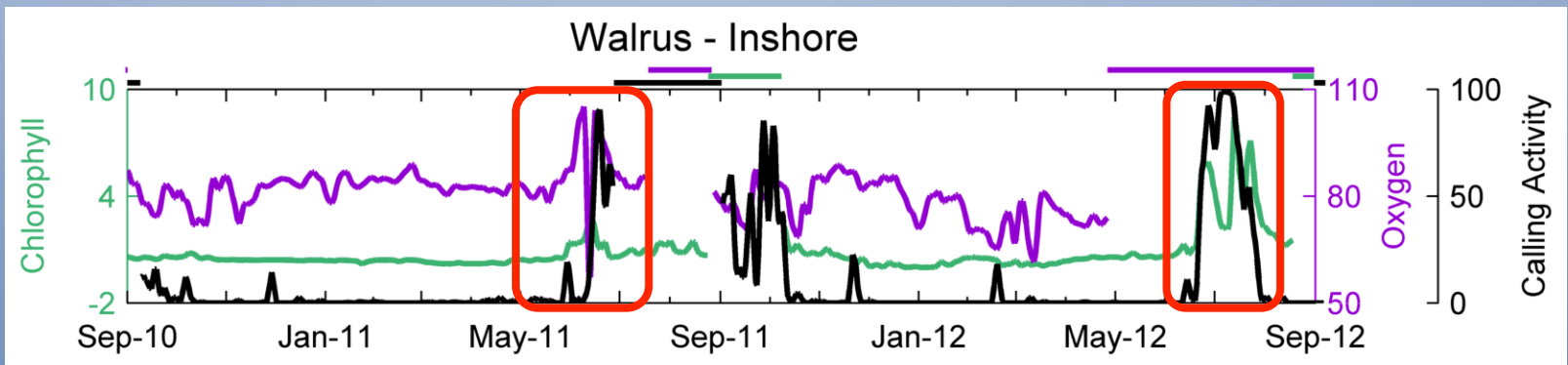


GAMs

- Month
- Wind speed
- Proxies for prey

Long-term plots

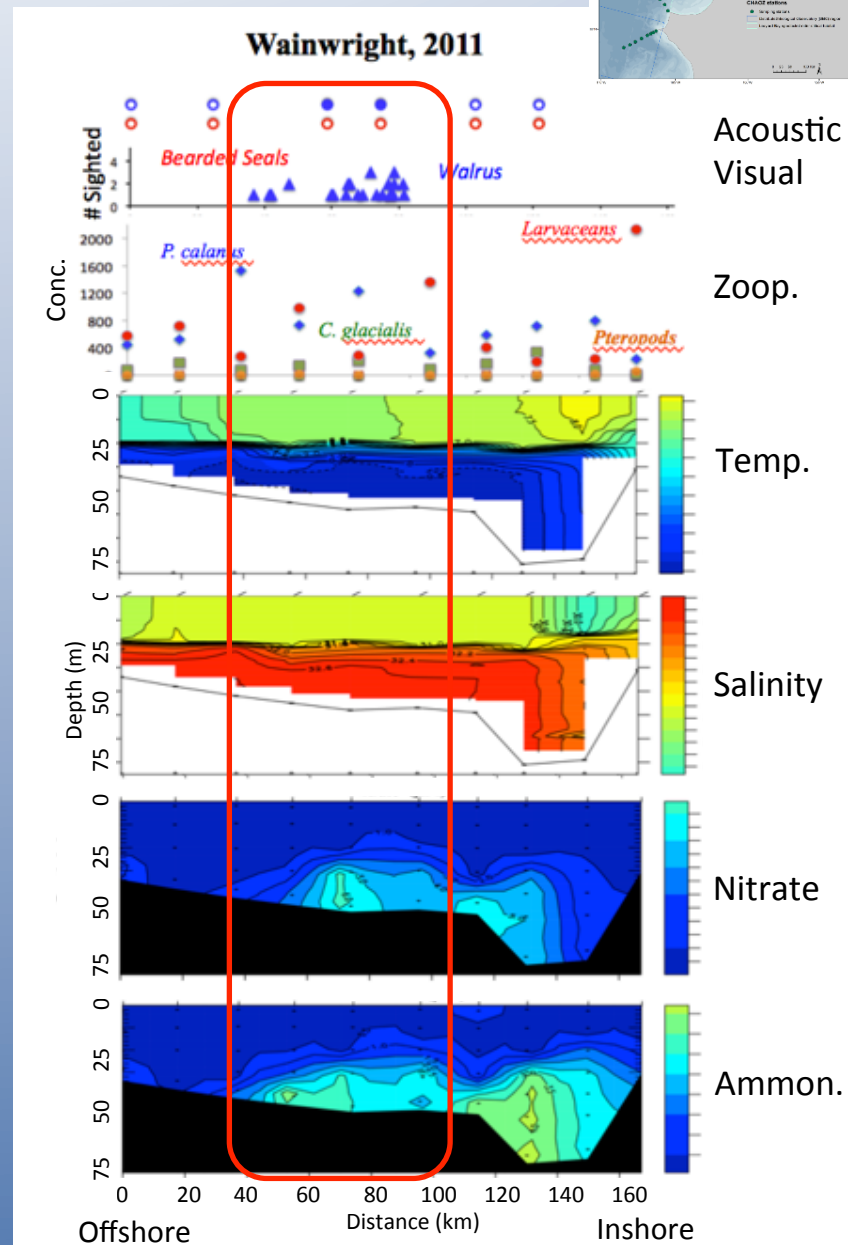
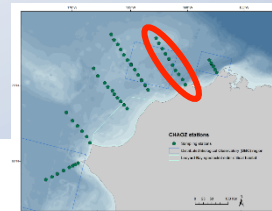
- Ice - negative
- Proxies for prey
- No pattern at offshore



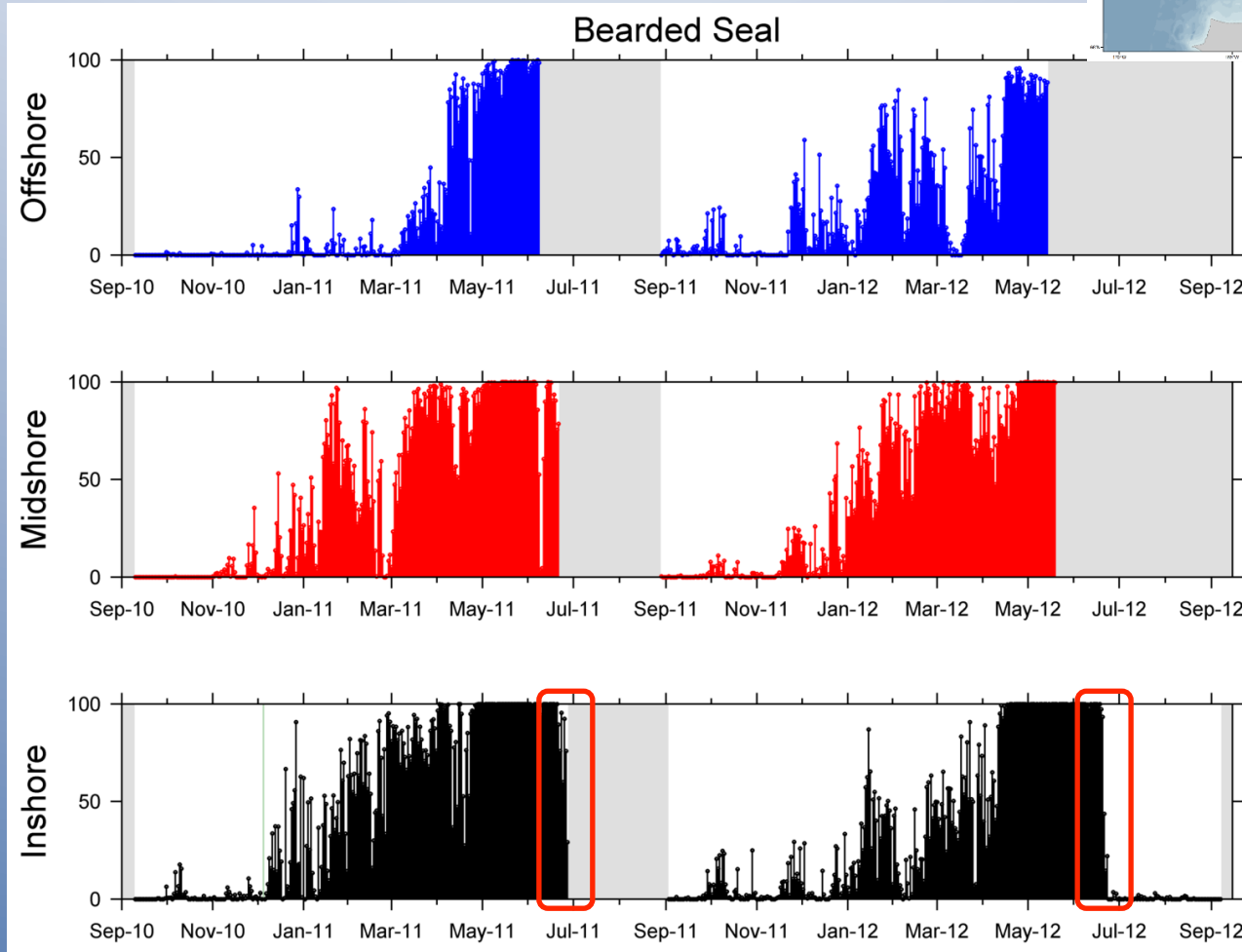
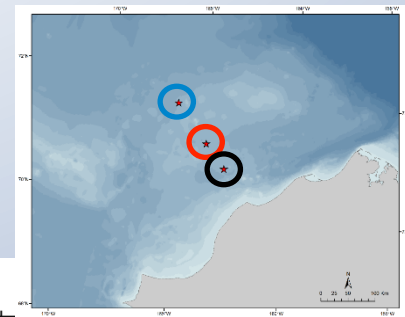
Results – Walrus

Transect lines

- Near Hanna Shoal
- Near high zoop. concentrations
- Ammonium/nitrate
- Areas of high benthic biomass
 - Benthic specialists



Results – Bearded seal



Results – Bearded seal

Predominantly benthic,
Can be generalist

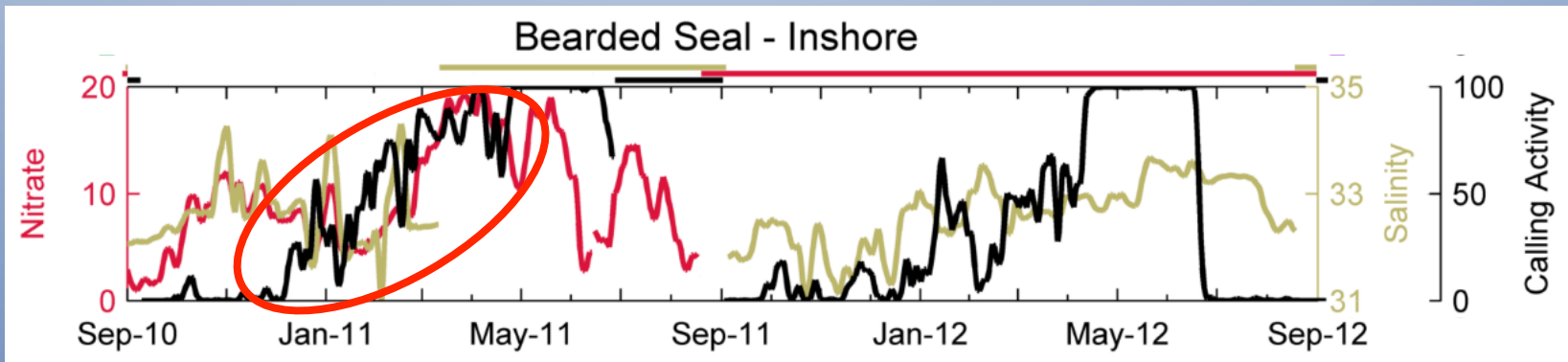


GAMs

- Month
- Wind speed
- Proxies for prey

Long-term plots

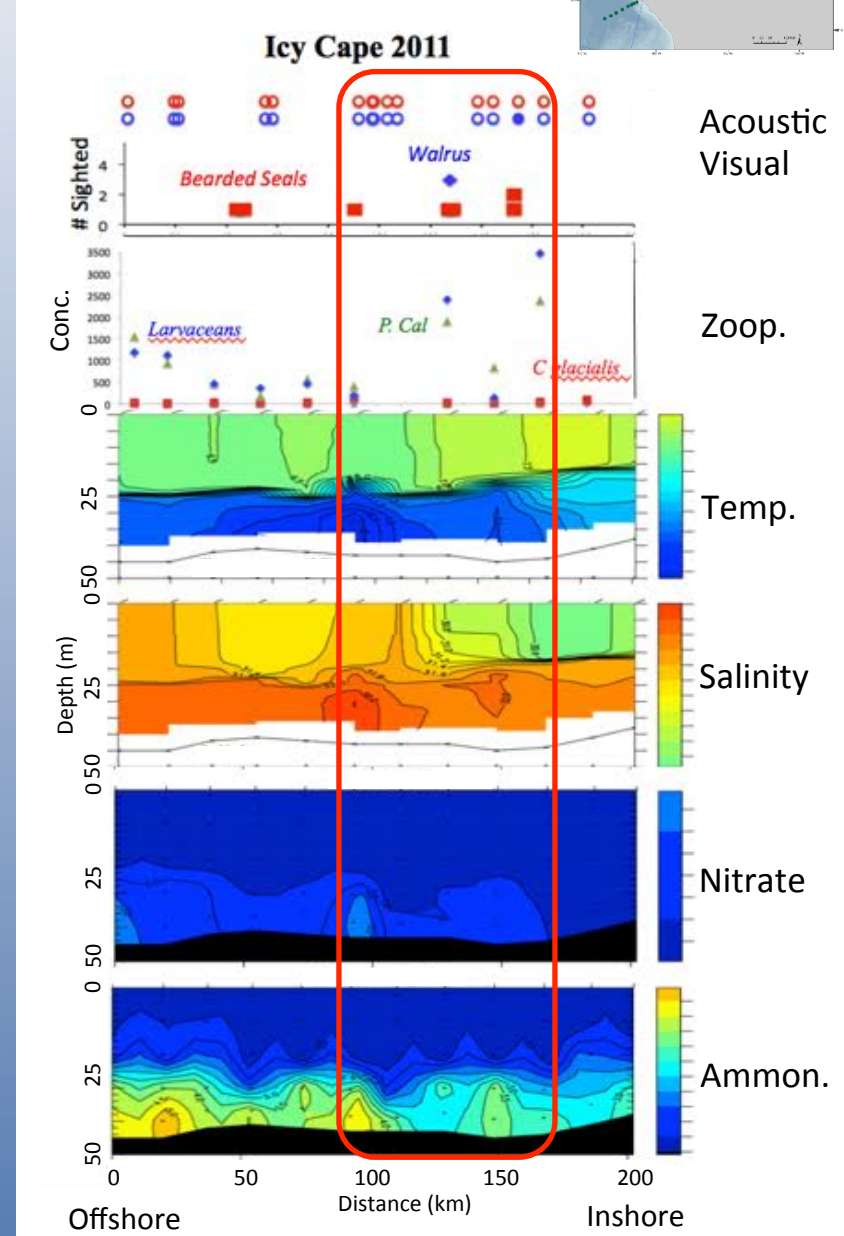
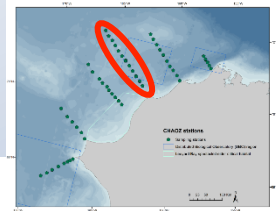
- Ice
- Proxies for prey



Results – Transect lines

Bearded seal

- High zooplankton concentrations
- Ammonium
- Areas of high benthic biomass
 - Predominantly benthic feeders

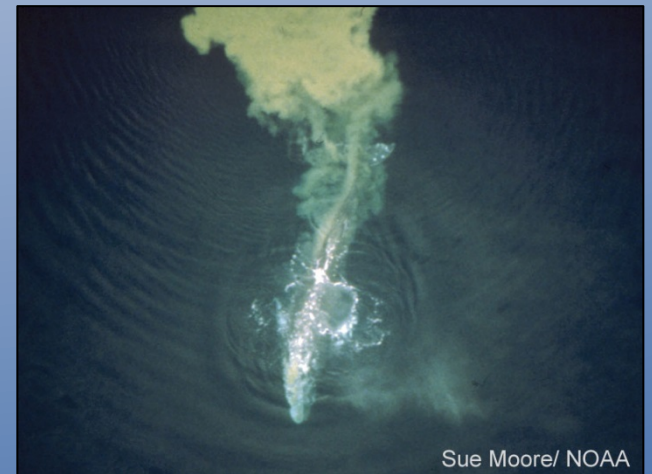


Summary

Able to correlate MM calling with oceanographic variables & prey

- GAMs
 - Now have more complete dataset with CHAOZ-X and ARCWEST
- Long-term plots
 - Positive/negative associations
 - Quantitative analyses
- Transect line sampling with MM survey data
- Apply same techniques to larger dataset

What will they do as sea ice continues to change?



Acknowledgments

- Bureau of Ocean Energy Management (BOEM): Heather Crowley, Chuck Monnett – Funding and project support
- Sonobuoys: Jeff Leonhard, Ed Rainey, Todd Mequet, and Edgar Brown (Naval Surface Warfare Center, Crane Division), Theresa Yost (Naval Operational Logistics Support Center), Capt. Robin Fitch (I&E Director Marine Science, Office of the Assistant Secretary of the Navy), Anu Kumar
- Captain and crew of F/V *Mystery Bay*, F/V *Alaskan Enterprise*, F/V *Aquila*
- Field crew and analysts
- Stephanie Grassia
- Sue Moore for her advice and expertise

Questions?

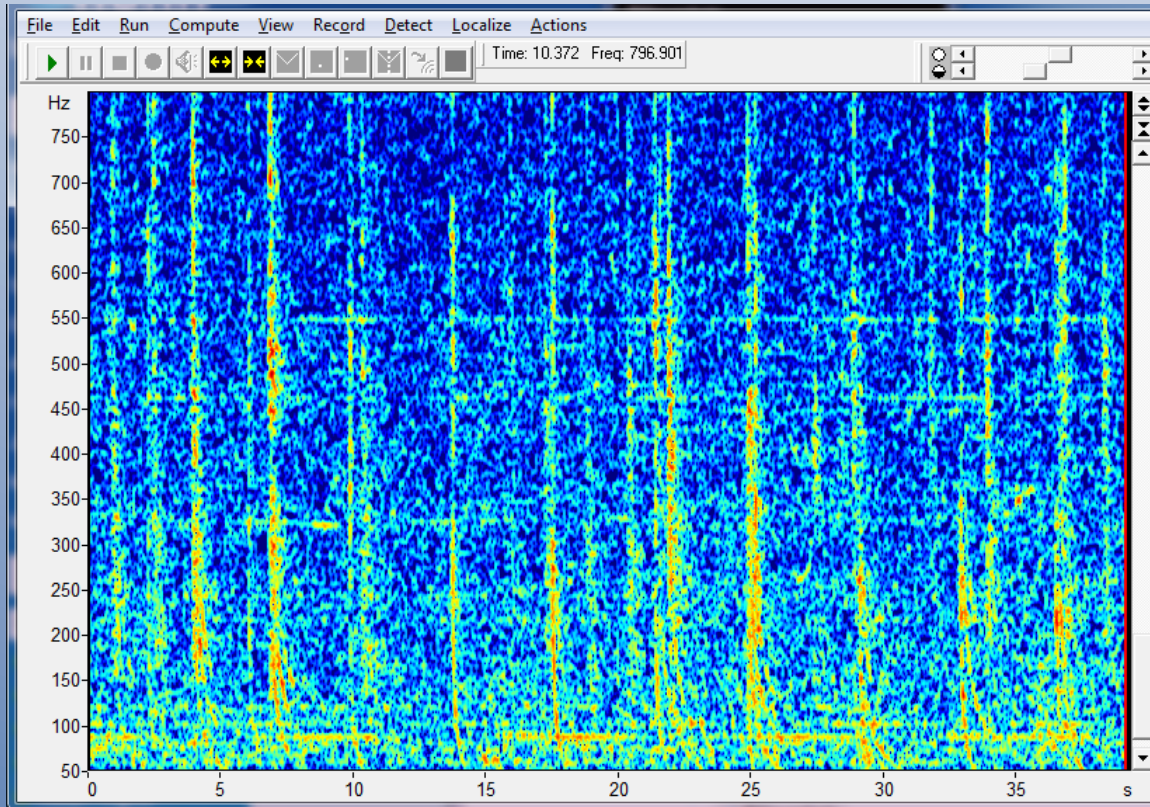


References

1. George et al. 1989. Observations on the ice-breaking and ice navigation behavior of migrating bowhead whales (*Balaena mysticetus*) near Point Barrow, Alaska, spring 1985. *Arctic* 42: 24-30.
2. Clark, C.W. and W.T. Ellison. 2004. Potential use of low-frequency sounds by baleen whales for probing the environment: evidence from models and empirical measurements. Pp. 564-582 In *Echolocation in bats and dolphins*. University of Chicago Press, Chicago, IL.
3. Garland et al. 2015. Temporal peaks in beluga whale (*Delphinapterus leucas*) acoustic detections in the northern Bering, northeastern Chukchi, and western Beaufort Seas: 2010-2011. *Polar Biology* 38(5): 747-754.
4. Clarke et al. 2011. Chukchi Offshore Monitoring in Drilling Area (COMIDA) Distribution and Relative Abundance of Marine Mammals: Aerial Surveys. Final Report, OCS Study BOEMRE 2011-06. National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way NE, F/AKC3, Seattle, WA 98115-6349



Gunshot call



Methods – Long-term moorings

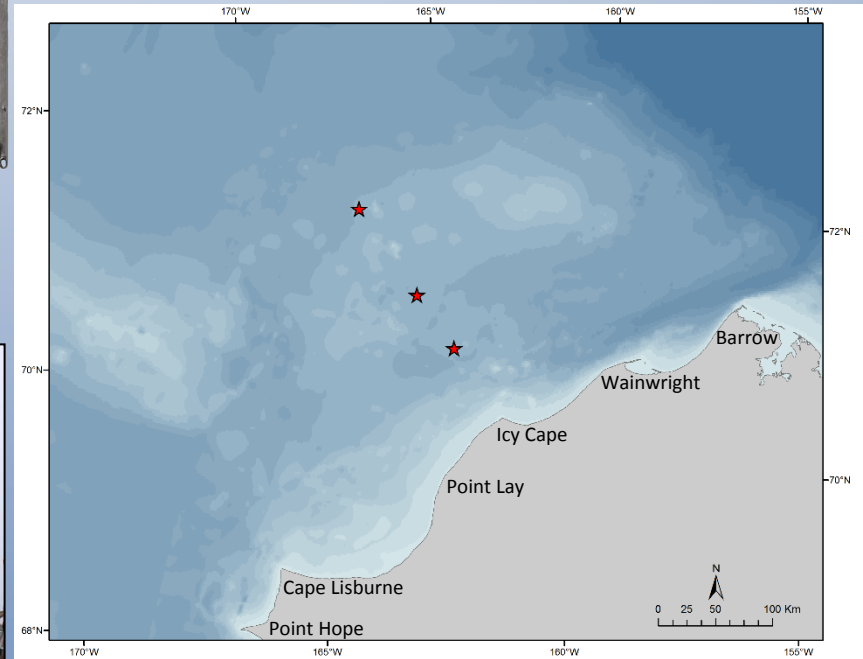
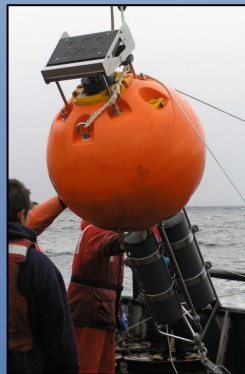
- Passive acoustic recorder
Sound, T, P



- ADCP
Currents, T, P, Par, S, fluor, nitrate

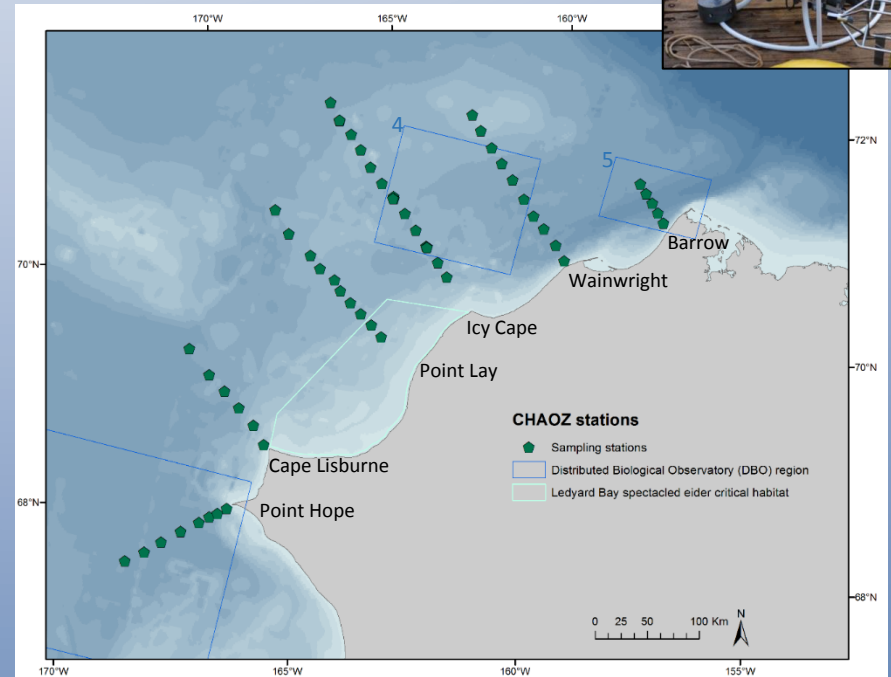
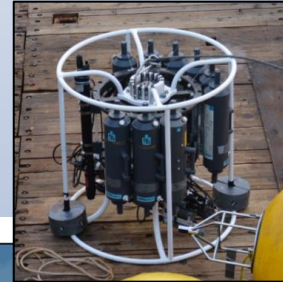
- Ice profiler
Ice depth, T, P, O₂, S, bottom currents, turbidity

- TAPS
Zooplankton



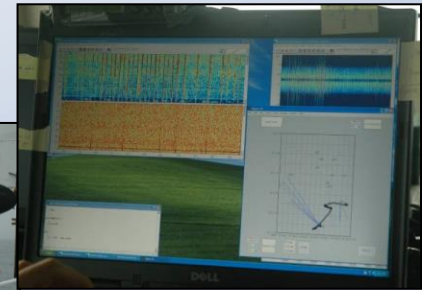
Methods – Sampling Stations

- August – September
- CTDs
T, O₂, PAR, S, Fluorescence,
Nutrients
- Tucker sled tows
Zooplankton, larval fish

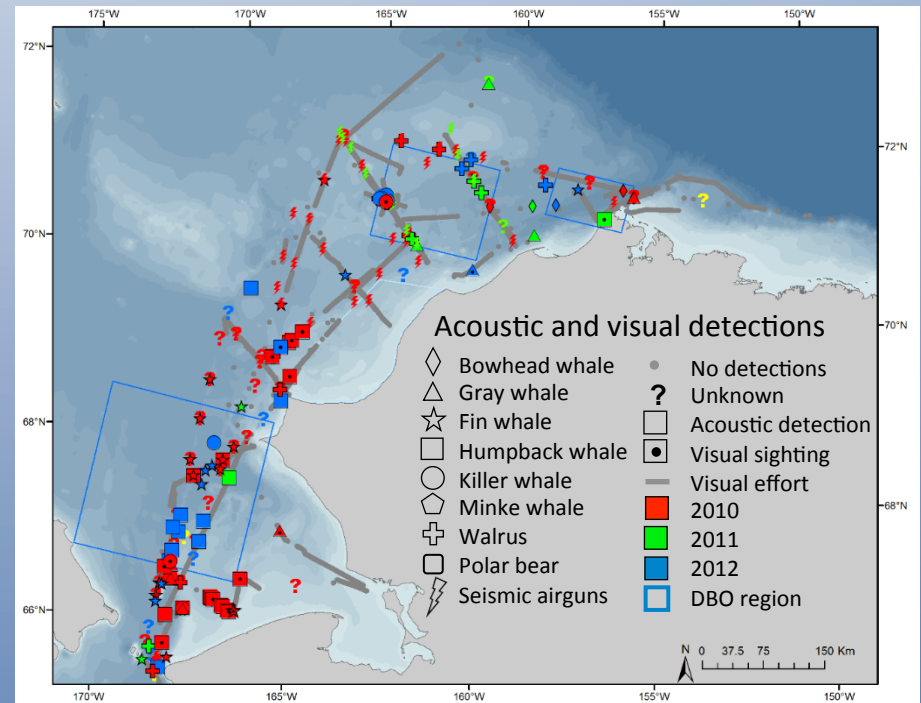


Methods – Surveys

- Passive acoustics monitoring
Sonobuoys deployed every 3 hours, real-time 24/7 monitoring
- Visual surveys
25x “big eye” binoculars, scan 90° port to 90° starboard



NMML permit #14245



Results – Subarctic species

- Minke whales
 - Only visually sighted
- Killer whales
- Humpback whales
- Fin whales
 - Acoustic detection off Barrow Canyon¹



Need both acoustic and
visual methods!

1. Crance, J.L., C.L. Berchok, J. Bonnel, A.M. Thode. 2015. Northeasternmost record of a North Pacific fin whale (*Balaenoptera physalus*) in the Alaskan Chukchi Sea. *Polar Biology* 38(10): 1767-1773.

Moving forward

CHAOZ → CHAOZ-X and ARCWEST

CHAOZ-X

Hanna Shoal

- Chukchi Acoustics, Oceanography, and Zooplankton - Extension Study

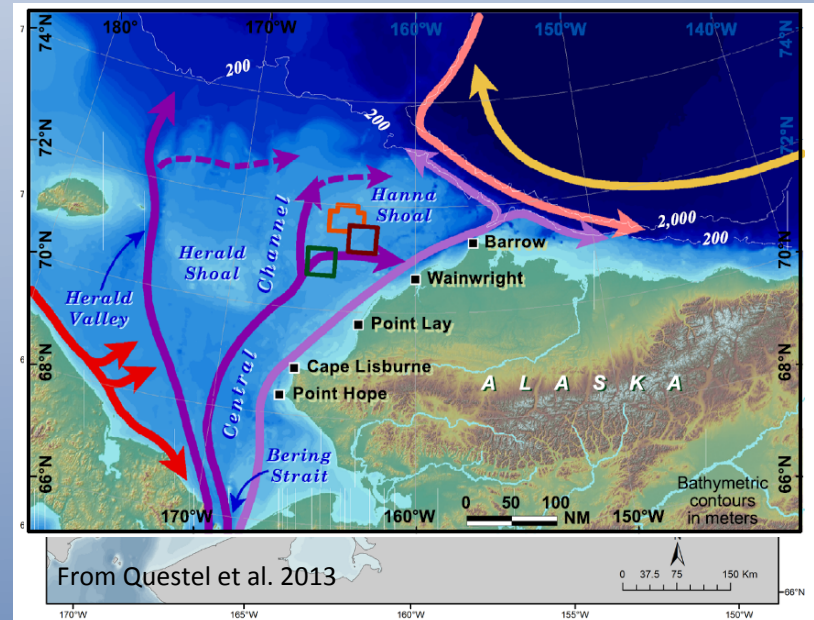
ARCWEST

Barrow Arch

- Arctic Whale Ecology Study

BOTH

- 2012-2017
- Field seasons 2013, 2014, 2015





Bowhead whale

	Inshore	Midshore	Offshore
Top AIC model		ADCP_colSa	ADCP_colSa
		Chlorophyll	
	Currents_botU		
		Currents_botV	
	Ice_conc	Ice_conc	Ice_conc
			IceThick_avg
	Month	Month	Month
	Nitrate	Nitrate	
	O2_mmol		
			O2_%sat
		PAR	PAR
	Salinity	Salinity	
	Transport		
		Turbidity	Turbidity
	Wind_spd	Wind_spd	
Wind_v		Wind_v	
Common sign. parameters		Chlorophyll	
		Currents_botV	
	Ice_conc	Ice_conc	Ice_conc
	Month	Month	Month
	Transport		
	Turbidity		
	Wind_spd	Wind_spd	

Gunshot call

	Inshore	Midshore	Offshore
Top AIC model		ADCP_colSa	
			Currents_botU
			Currents_botV
			Ice_conc
		Month	Month
	Nitrate	Nitrate	Nitrate
	O2_mMol		
	PAR		
		Salinity	
		Turbidity	
	Wind_spd	Wind_spd	
Common sign. parameters			Ice_conc
			Currents_botU
			Currents_botV
		Month	Month
	Salinity		
	Wind_spd		



Beluga whale

	Inshore	Midshore	Offshore
Top AIC model		ADCP_colSa	ADCP_colSa
	Chlorophyll	Chlorophyll	
	Ice_conc	Ice_conc	Ice_conc
	Month	Month	
		Nitrate	
		PAR	PAR
		Salinity	Salinity
	Temperature	Temperature	
	Turbidity	Turbidity	Turbidity
	Wind_spd	Wind_spd	
Common sign. parameters	Ice_conc Month	Chlorophyll Month Nitrate PAR	ADCP_ColA
	Temperature	Temperature	

Gray whale

	Inshore	Midshore	Offshore
Top AIC model	Chlorophyll		
	Ice_conc	Ice_conc	
	Salinity		
	Temperature	Temperature	
	Turbidity		
	Wind_spd		
	Wind_v		
Common sign. parameters	Temperature	Ice_conc	



Walrus

	Inshore	Midshore	Offshore
Top AIC model		ADCP_botSv	
		ADCP_colSa	
		Chlorophyll	
	IceThick_std		
		Month	Month
	Nitrate	Nitrate	
		O2_%sat	
	PAR	PAR	PAR
		Salinity	
	Temperature		Turbidity
	Wind_spd	Wind_spd	
		Wind_u	
Common sign. parameters		ADCP_botV	
		Month	Month
		O2_%sat	
		Salinity	
	Wind_spd	Wind_spd	

Bearded seal

	Inshore	Midshore	Offshore
Top AIC model	ADCP_botSv	ADCP_botSv	ADCP_botSv
		ADCP_colSa	ADCP_colSa
	Currents_botU		
	Currents_botV	Currents_botV	
		Ice_conc	Ice_conc
	Month	Month	Month
		O2_mmol	
	Nitrate	Nitrate	
	PAR		PAR
	Salinity	Salinity	
		Transport	
		Turbidity	Turbidity
	Wind_spd	Wind_spd	
	Wind_v		Wind_v
Common sign. parameters	Currents_botV	ADCP_botV	ADCP_CoIA
	Month	Ice_conc	Month
		Month	
	Wind_spd	Transport	Month