Baleen Whale Broad-Scale Distribution

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Summary

Cetacean sightings will be collected during the AFSC/NOAA walleye pollock (*Theragra chalcogramma*) stock assessment surveys (Figure 1; O2.26). Sightings will be analyzed to estimate density and abundance. Cetacean distribution data and density estimates will be modeled in terms of oceanographic and bathymetric variables and prey distribution and density to investigate cetacean habitat characteristics and to create predictive models of cetacean distribution. All analyses will focus on fin and humpback whales, but other cetaceans will be included as sample sizes permit.

This project is one component of the Bering Sea Integrated Ecosystem Research Program (BSIERP). The integrated program hypotheses and projects are listed in Tables 1 and 2.

Background

Synoptic, multi-scale, and multi-disciplinary research is necessary to examine ecosystems and the effects of climate change in marine environments (Weimerskirch *et al.* 2003, Montevecchi *et al.* 2006, Scott *et al.* 2006). Top predators that forage and breed near their physiological and behavioral limits in the northern boundaries of marine ecosystems offer the best opportunity to study changes in marine systems (Montevecchi *et al.* 2006). In the Bering Sea ecosystem, the upper trophic levels include large whales and seabirds. The baleen whales consume large quantities of plankton and fish, and not being tied to a central place to raise their young, are consummate samplers of the prey base. Large baleen whales were severely depleted by commercial whaling until the late 20th Century (Clapham *et al.*, 1999), but since protection was afforded, many populations have been increasing. Examples include humpback and fin whales feeding in the Bering Sea and the Aleutian Islands (e.g. Moore *et al.* 2002, Zerbini *et al.* 2006, Friday *et al.* in prep). Recovery of these species will likely have important ecological implications to these ecosystems because whales remove large quantities of prey biomass during feeding. Therefore they have the potential for modifying community structure through an increase in predation at mid-trophic levels and an enhancement of inter-specific competition among consumers of plankton and forage fish (Bowen, 1997).

Because cetaceans are long-lived species, effects of foraging conditions on demography are not measurable in a 3-year study. However, we can relate cetacean distribution to oceanographic and potential prey variables to improve predictions of how they will be affected by changing ocean conditions (Redfern *et al.* 2006). Placing cetacean observers on the AFSC/NOAA walleye pollock (*Theragra chalcogramma*) stock assessment surveys will allow for concurrent observation of cetaceans, their potential prey, and ocean conditions (oceanographic and bathymetric variables). If bird observers are placed on the same surveys (O4.36), we will also be able to relate cetacean and bird distribution. Detailed models of cetacean distribution and relative abundance versus oceanographic variables and the distribution of potential prey may identify oceanographic proxies for prey distribution. The FEAST model (M.47) will predict prey fields for a number of potential cetacean prey species. The proposed cetacean sightings surveys can be used to investigate if cetacean sightings match predictions of predator-prey field responses.

Species and Geographic Scope

This study will examine the summer distribution, abundance, and habitat characteristics of fin and humpback whales on the eastern Bering Sea shelf.

Hypotheses

This study will address the following BSIERP hypotheses (Tables 2 and 3): 3b-c, 4a, 5c.

Project Description

The main objectives of this project are to (1) assess the distribution, (2) estimate abundance, (3) model oceanographic and bathymetric variables and potential prey distribution and density to build predictive models of cetacean distribution and abundance, and (4) if possible, estimate trends in abundance. Emphasis will be given to large baleen whales (fin and humpback), but information on other species will be collected and analyzed if sample sizes permit.

Visual surveys will be conducted on board of the AFSC/NOAA walleye pollock (*Theragra chalcogramma*) stock assessment surveys (Figure 1; e.g. Moore et al., 2002, Friday et al. in preparation). Cetacean sightings will be collected using standard line-transect methods (Buckland et al. 2001, 2004; Moore et al. 2002, Friday et al. in preparation) from the flying bridge of a NOAA vessel at speeds varying from 18.5-22km/h (10-12 kts). Two observers will use 25X (Big Eye) binoculars at port and starboard stations to search for groups of cetaceans. The port observer will scan from 10° right to 90° left of the trackline, and the starboard observer from 10° left to 90° right. A third observer will guard the trackline scanning the entire 180° area forward of the ship using Fujinon 7x50 reticled binocular. This observer will also act as data recorder. Information pertaining to each sighting (e.g. species identification, horizontal distance, angle, and group size), effort data (date, time, and position of the vessel) and environmental variables (e.g. wind speed, sea state, swell height, cloud cover) will be recorded and entered into event log software (WinCruz).

Distribution data will be mapped and examined using GIS software (ArcMap, ESRI) and abundance estimates will be obtained using multiple covariate distance sampling methods (e.g. Buckland et al 2004, Zerbini et al. 2006, Friday et al. in preparation). Sample size will be increased by pooling perpendicular distance data from previous surveys conducted in the Bering Sea (Moore et al., 2002, Friday et al. in preparation). Detection probability will be estimated using half-normal and hazard rate models with and without covariates. Best explanatory models will be selected by the Akaike Information Criterion (AIC) and model selection uncertainty will be incorporated by model averaging. Data analysis will be conducted using the Mark-Recapture Distance Sampling (MRDS) package for software R (Laake, unpublished data).

Cetacean distribution data and density estimates will be integrated with potential prey distribution and abundance as well as environmental variables (e.g. oceanographic and bathymetric data) to investigate habitat characteristics and to create predictive models of cetacean distribution (e.g. Redfern et al. 2006). Abundance will also be used to compute trends. Estimates are expected to have coefficient of variations (CV) of 0.3-0.7 (Friday et al. in preparation, Appendix 1). Some of these precision levels may result in low power to detect trends in population size using traditional statistical methods (e.g., regression analysis), but may provide sufficient information to detect changes in abundance caused by shifts in distribution of the whales (see examples in Appendix 1). Because of the potential low power using traditional statistical methods, alternate methods (e.g., Bayesian regression) will also be explored to estimate trends in population size.

Project Reporting

Research Products: Cetacean sightings data (e.g., location and number of each cetacean species sighted) will be collected by dedicated cetacean observers aboard the AFSC/NOAA walleye pollock (*Theragra* *chalcogramma*) stock assessment surveys in 2008 and 2010 (exact years to be determined). Analyses will focus on fin and humpback whales, but other species will be included if sample sizes permit. Sightings data will be used to estimate cetacean density and abundance. Cetacean abundance and densities will be modeled in terms of potential prey distribution and abundance and environmental variables (e.g. oceanographic and bathymetric data) to investigate habitat characteristics and to create predictive models of cetacean distribution. If possible, estimates of cetacean abundance will be analyzes to estimate trends in abundance. These research products also will serve as input to the integrated modeling.

<u>Research Links</u>: This project depends on the ability of dedicated cetacean observers to use the AFSC/NOAA walleye pollock (*Theragra chalcogramma*) stock assessment surveys (O2.26) as a platform for cetacean sighting surveys. It also depends on the measurement of environmental variables and of potential prey abundance and density (O2.26) for the habitat models. This project will provide data on cetacean distribution to the Seabird and Cetacean Foraging Response to Prey Persistence project (O4.40). This project will also provide data on cetacean distribution and abundance to be used to corroborate the potential prey concentrations predicted by the FEAST model (M.47).

<u>Research Reporting</u>: Data collection will be completed during June and July of 2008 and 2010 (exact years to be determined). Sightings data will be proofed and delivered to the modeling group by January 15 following each survey. Sightings data will be analyzed to estimate density and abundance during the following fall and winter with estimates presented to the modelers in the winter following each survey. Density and abundance estimates will be incorporated into habitat models with oceanographic and bathymetric variables and potential prey distribution and density; a preliminary model will be completed by the end of 2009 with a final model completed by the end of 2011. A manuscript on abundance will be submitted to a peer-reviewed journal by fall of 2011. A habitat model manuscript will be submitted to a peer-reviewed journal by fall of 2012. Semi-annual reports will be completed by January 15 and July 15 each year, and a final project report will be completed in the fall of 2012.

<u>Dissemination</u>:
Cetacean distribution and abundance on the Eastern Bering Sea shelf.
Environmental variables influencing distribution of large baleen whales on the Eastern Bering Sea shelf.

<u>Graduate Students and Post-docs</u>:
None.

Figures and Tables

Table 1. Project list.

Project	Project Components	Label	Principal Investigators	NPRB ($)	In-kind ($)
Lower trophic level	Biophysical moorings (4)	O1.1	Stabeno, Whitledge, Napp	$ 732,259	$ 1,707,106
Ichthyoplankton	Ichthyoplankton surveys	O2.7	Hillgruber, Duffy-Anderson, Napp, Matarese, Eisner	$ 1,068,052	$ 1,245,612
	Seasonal bioenergetics	O2.24	Heintz	$ 250,000	$ 373,400
Fish	Acoustic survey	O2.26	Wilson	$ 154,499	$ 2,349,000
	Surface trawl survey	O2.23	Farley	$ -	$ 1,516,200
	Surface trawl survey acoustics	O2.28	Horne, Parker-Stetter, Farley	$ 425,731	$ -
	Bottom trawl survey (epi-benthic)	O2.25	Lauth	$ -	$ 3,240,000
	Pollock & cod distribution	O2.19	Ciannelli, Bailey	$ 332,313	$ -
	Functional foraging response	O2.16	Aydin, Farley	$ 258,260	$ 23,040
	Forage distribution & ocean conditions	O2.17	Hollowed, Wilson, Kotwicki, DeRobertis, Ressler, Cokelet	$ 567,123	$ 553,311
Trophic interactions	Fish, birds & mammals	O3.30	Mueter, Kruse	$ 286,913	$ -
	Hot spot persistence	O4.40	Sigler, Kuletz, Wilson	$ -	$ 55,200
Seabirds	Seabird telemetry	O4.35	Irons, Byrd, Roby	$ 600,000	$ 303,000
	Seabird broad-scale distribution	O4.36	Kuletz	$ 550,438	$ 555,000
	Seabird colony-based	O4.37	Byrd	$ 350,000	$ 1,179,000
Patch	Patch Dynamics	O4.62	Trites, Jay, Grebmeier, Benoit-Byrd, Heppell, Sampson, Irons, Byrd, Roby, Kytasky, Kuletz	$ 2,300,000	
Marine mammals	Whale broad-scale distribution	O4.38	Friday, Moore, Zerbini, Clapham	$ 300,000	$ -
	Fur Seal colony-based		Ream	$ -	$ -
Local and Traditional Knowledge	Local & traditional knowledge	O5.41	Sepez, Hunn, Huntington, Langdon, Zavadil, Fall	$ 1,000,000	$ 49,190
Modeling			to be determined	$ 2,500,000	
	potential		***potential***		
	Forage euphausiid (FEAST)	M.47	Aydin		
	Behavioral foraging	M.54	Mangel		
	Biomass dynamics	M.61	Mueter, Kruse		
	Integrate economic-ecological	M.48	Dalton, Aydin, Haynie		
	Spatial fishery choices	M.49	Haynie		
	Management strategy resilience	M.50	Criddle, Valcic, Greenberg		
	Blended forecasts, Management strategy evaluation	M.55	Punt		
Education and Outreach			Deans (NPRB)	$ 100,000	
Data Management	Data Management		Coyle	$ 800,000	
Program Management			NPRB	$ 600,000	
Total				**$ 13,175,588**	**$ 13,149,059**

Table 2. BSIERP hypotheses: Climate models predict warming over the next 30 years (IPCC 2007). Predictions from climate models show no indication of a strengthening of summer winds. In fact, there has been a decrease in wind strength and lengthening of summer conditions over the last decade (Overland and Stabeno 2004; Stabeno and Overland 2001). Projected warming on the southeastern shelf of the Bering Sea will profoundly alter ecosystem structure by changing pathways of energy flow and the spatial distribution and species composition of fish, seabird and marine mammal communities, thereby affecting commercial and subsistence fisheries.

1. Climate-induced changes in physical forcing will modify the availability and partitioning of food for all trophic levels through bottom-up processes. Specifically:
   a. Earlier sea ice retreat expected as a result of warming will result in a later (May-June), warm-water spring phytoplankton bloom, increased coupling with zooplankton and greater pelagic secondary productivity. Benthic secondary productivity will decrease.
   b. Reduced frequency and intensity of summer storms will reduce surface mixing and increase sea surface temperature, thereby increasing stratification. A substantial decrease in summer winds will result in a mixed layer that is shallower than the euphotic zone, extensive subsurface primary production and depletion of nutrients in the entire water column. There will be no fall phytoplankton bloom. A moderate decrease or no change in the intensity of summer storms will reduce replenishment of nutrients to the euphotic zone, lowering summer primary and secondary production. Both scenarios will reduce juvenile fish production by reducing their condition (energy density) and over-wintering capability.
   c. Earlier spring transition will lengthen the period of time of organized onshore flow along the Alaska Peninsula, thus transporting larvae away from outer domain piscivores.
2. Climate and ocean conditions influencing water temperature, circulation patterns and domain boundaries impact fish reproduction, survival and distribution, the intensity of predator-prey relationships and the location of zoogeographic provinces through bottom-up processes. Specifically:
   a. As heat content increases, the area suitable for spawning and foraging by subarctic species will expand northward and subarctic species will occupy areas formerly occupied by Arctic species.
   b. Reduced cold pool extent will increase overlap of inner domain forage fish and outer domain piscivores.
   c. Strength of frontal boundaries will weaken due to absence of the summer cold pool, allowing expansion of the inner domain and juvenile and forage fish habitat there. Weaker winds will enhance this effect.
   d. Sporadic reversals to cold conditions (e.g., 1999) will have strong effects on the subarctic community and result in increased interannual variability in abundance and pelagic productivity of piscivorous fish, seabirds and marine mammals.
   e. Expected decreases in benthic productivity will negatively affect feeding and survival of small flatfish and crab thereby lowering population levels.
3. Later spring phytoplankton blooms as a result of early ice retreat will increase zooplankton production, thereby resulting in increased abundances of piscivorous fish (pollock, cod and arrowtooth flounder) and a community controlled by top-down processes [Oscillating Control Hypothesis] with the possible trophic consequences:
   a. Competition with abundant, piscivorous fish species for forage species will lead to a decline in murres, kittiwakes and fur seals.
   b. Growing populations of humpback and fin whales increasingly will both consume and compete with forage fish (juvenile pollock) for zooplankton (euphausiids and copepods). By reducing the prey base of forage fish, whales not only reduce the amount of forage fish available to other predators, but also their quality (lipid content).
   c. In a top-down control community, fishing will reduce the degree of top-down control of forage species (including juvenile pollock) by adult pollock, cod and arrowtooth flounder. Owing to light exploitation rates, top-down control by arrowtooth flounder will increase, as will their level

of competition with piscivorous fish, seabirds and marine mammals. As a result of these two processes, arrowtooth flounder will determine ultimate community composition, such that the climax community will be arrowtooth flounder-dominated (similar to the Gulf of Alaska).

4. Climate and ocean conditions influencing circulation patterns and domain boundaries will affect the distribution, frequency and persistence of fronts and other prey-concentrating features and thus the foraging success of marine birds and mammals largely through bottom-up processes. Specifically:
   a. Climate-ocean changes will displace predictably located, abundant prey (hot spots) necessary for successful foraging by central place (seabirds and fur seals while nurturing young) and hot spot (baleen whales, walrus) foragers.
   b. Central place foragers will shift their diet, foraging locations or rookery locations to increase foraging opportunities (based on differential foraging success).
5. Climate-ocean conditions will change and thus affect the abundance and distribution of commercial and subsistence fisheries. Specifically:
   a. For commercial fishermen, these changes will lead to: 1) a change in home ports and distribution of fishing vessel rents, 2) vessels traveling further, incurring greater fuel costs and peril at sea and 3) greater burden on smaller vessels.
   b. For subsistence users, these changes will lead to: 1) greater reliance on owners of larger vessels that can travel farther to harvest and distribute subsistence goods, 2) decreased consumption of species with decreased local abundance and 3) adoption of new species into the diet as these species colonize local areas.
   c. Current management strategies for fish, seabirds and marine mammals in the Bering Sea are robust to climate scenarios (range of frequencies of cold and warm years) and associated range of trophic relationships and spatial redistributions.

Table 3. Project links to BSIERP hypotheses. The BSIERP hypotheses are numbered 1-5 and are described in the BSIERP study plan.

Projects	**Label**	1a	1b	1c	2a	2b	2c	2d	2e	3a	3b	3c	4a	4b	5a	5b	5c
Biophysical moorings (4)	O1.1																
Summer plankton survey	O1.2																
Ichthyoplankton	O2.7, O2.24																
Fish	O2.26, O2.23, O2.28, O2.25, O2.19, O2.16, O2.17																
Trophic interactions	O3.30																
Seabirds	O4.35, O4.36, O4.37																
Patch dynamics	O4.62																
Marine mammals	O4.38																
Local and Traditional Knowledge	O5.41, O5.42																
Lower trophic level modeling	M.3, M.4, M.5																
Forage euphausiid (FEAST)	M.47																
Behavioral foraging	M.54																
Biomass dynamics	M.61																
Economic-ecological spatial	M.48, M.49																
Management strategy resilience	M.50																
Blended forecasts, Management strategy evaluation	M.55																

Table 4. Research products and timelines provided by BSIERP.

Project	Project Components	Label	Products	Water column	Surface only	Point sample	Transect	Sample spacing (km)	Year 2008	Year 2009	Year 2010	Month 1	2	3	4	5	6	7	8	9	10	11	12
Lower trophic level	Biophysical moorings (4)	O1.1	Temperature, salinity, flourescence	■		■		~260	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Summer plankton survey	O1.2	Phytoplankton & zooplankton abundance and rates																				
Ichthyoplankton	Ichthyoplankton surveys	O2.7	Pollock, cod and arrowtooth flounder ichthyoplankton seasonal abundance	■		■			■	■	■					■		■					
	Seasonal bioenergetics	O2.24	Pollock, cod and arrowtooth flounder seasonal energy content						■	■	■					■	■	■	■	■			
Fish	Acoustic survey	O2.26	Pollock abundance and spatial distribution	■			■	37	■	■	■						■	■					
	Surface trawl survey	O2.23	Juvenile pollock spatial distribution		■	■		~56	■	■	■								■	■			
			Temperature, salinity, flourescence, light		■		■		■	■	■								■	■			
			Temperature, salinity, flourescence, nutrients, oxygen, light, turbidity, phytoplankton, zooplankton	■		■			■	■	■								■	■			
	Surface trawl survey acoustics	O2.28	Pollock abundance and spatial distribution	■			■		■	■	■								■	■			
	Bottom trawl survey (epi-benthic)	O2.25	Pollock, cod and arrowtooth flounder abundance and spatial distribution			■		37	■	■	■						■	■					
	Pollock & cod distribution	O2.19	Spatial distributions of spawning pollock and cod and their eggs and larvae (retrospective)																				
	Functional foraging response	O2.16	Pollock, cod and arrowtooth flounder diet composition						■	■	■						■	■					
	Forage distribution & ocean conditions	O2.17	Temperature and salinity	■		■			■	■	■		■	■			■	■		■	■		
			Temperature, salinity, flourescence, nitrate, and oxygen		■		■		■	■	■						■	■					
			Euphausiid, myctophid and capelin abundance and spatial distribution	■			■		■	■	■						■	■					
Trophic interactions	Fish, birds & mammals	O3.30	Environmental influences and trophic interactions for seabirds, marine mammals, and groundfish and shellfish (retrospective)																				
	Hot spot persistence	O4.40	Seabird and cetacean foraging response to prey persistence						■	■	■						■	■					
Seabirds	Seabird telemetry	O4.35	Colony-based seabird distribution, diet						■	■	■							■	■				
	Seabird broad-scale distribution	O4.36	Seabird spatial distribution, diet		■		■		■	■	■						■	■					
	Seabird colony-based	O4.37	Seabird reproductive success, diet						■	■	■							■	■				
Patch dynamics	Patch dynamics	O4.62	Fur seal, murre, kittiwake, walrus and their prey, fine-scale spatial distribution	■	■		■		■	■								■	■				
Marine mammals	Whale broad-scale distribution	O4.38	Humpback and fin whale spatial distribution		■		■		■		■						■	■					
Local and Traditional Knowledge	Local & traditional knowledge	O5.41	Ethnographic interviews, subsistence surveys, community view of ecosystem																				
Modeling	Climate downscaling	M.3	Integrated spatial predictions of forage fields, fishery value, patchiness, hotspot dynamics , and local impacts on top predators, (birds, mammals, humans)																				
	Spatial ocean (ROMS)	M.4																					
	Lower trophic level (NPZ)	M.5																					
	Forage euphausiid (FEAST)	M.47																					
	Behavioral foraging	M.54																					
	Biomass dynamics	M.61																					
	Integrate economic-ecological	M.48																					
	Spatial fishery choices	M.49																					
	Management strategy resilience	M.50																					
	Blended forecasts, Management strategy evaluation	M.55																					
Data Management	Data Management		Study database																				
Program Management	Program Management		Periodic status reports																				

Table 5. The proposed timeline for research reporting by quarter is summarized below. Highlighted cells denote quarters when activities occur, x's denote specific deliverables to be completed by the end of the indicated quarter as described below. The schedules for some research activities are generalized; for example, seasonal bioenergetics (O2.24) samples are collected during several surveys (e.g., Spring ichthyoplankton survey) and analyzed in the laboratory (Laboratory analysis activity). Semi-annual reports are due January 15 and July 15 each year.

		2007				2008				2009				2010				2011				2012			
Research activity or project		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Initial planning meeting																									
Annual meeting																									
Laboratory analyses																									
Data analyses																									
Modeling & retrospective analyses																									
Field data to models																									
Model outputs to fieldwork planning																									
Preparation of manuscripts																			x				x		
Synthesis																									
Semi-annual reports						x		x		x		x		x		x		x		x		x			
Final report																								x	

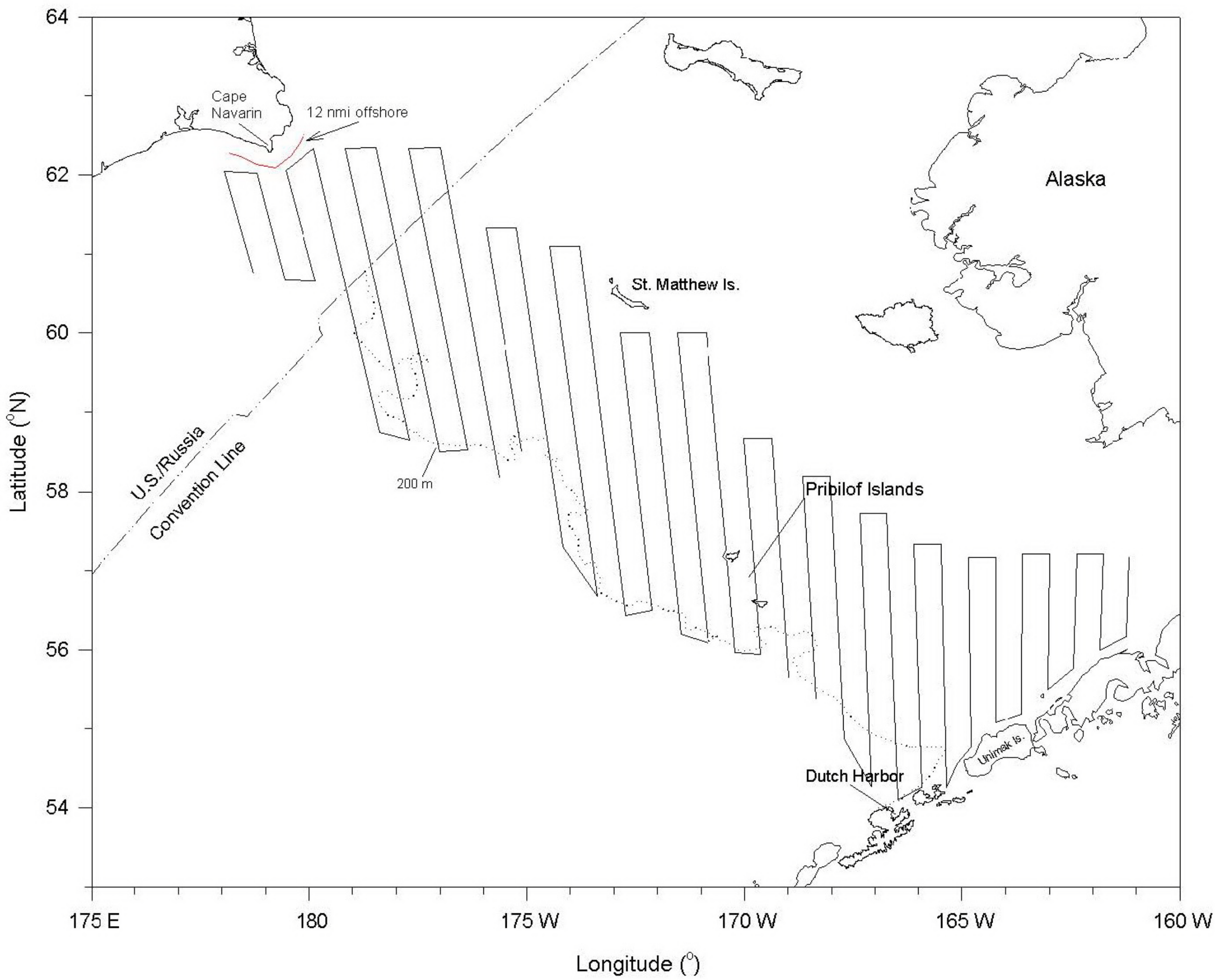

Figure 1. – Proposed tracklines for the AFSC/NOAA walleye pollock (*Theragra chalcogramma*) stock assessment surveys (O2.26) on which we will place cetacean observers.

References

Bowen, WD. 1997. Role of marine mammals in aquatic ecosystems. Marine Ecology Progress Series 158: 267-274

Buckland, ST, Anderson, DR, Burnham, KP, Laake, JL, Borchers, DL, Thomas, L. 2001. *Introduction to Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press, New York City, New York, U.S.A.

Buckland, ST, Anderson, DR, Burnham, KP, Laake, JL, Borchers, DL, Thomas, L. 2004. *Advanced Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press, New York City, New York, U.S.A.

Clapham, PJ, Young, SB, Brownell, RL Jr. 1999. Baleen Whales: Conservation Issues and the Status of the Most Endangered Populations. *Mammal Review* **29:** 35-60.

Friday, NF, Waite, JM, Moore, SE, Zerbini, AN. in prep. Cetacean distribution and abundance in relation to oceanographic domains on the Eastern Bering Sea shelf.

Montevecchi, WA, Garthe, S, Davoren, GK. 2006. Biophysical influences on seabird trophic assessments. Pages 118-130 *in* I. Boyd, S. Wanless, and C.J. Camphuysen (editors), Top Predators in Marine Ecosystems: Their role in monitoring and management. Cambridge University Press, New York.

Moore, S.E., Waite, J.M., Friday, N.A., Honkalehto, T. 2002. Cetacean distribution and relative abundance on the Central-Eastern and Southeastern Bering Sea shelf with reference to oceanographic domains. *Progress in Oceanography* 55(1-2):249-262.

Redfern, JV, Ferguson, MC, Becker, EA, Hyrenbach, KD, Good, C, Barlow, J, Kaschner, K, Baumgartner, MF, Forney, KA, Ballance, LT, Fauchald, P, Halpin, P, Hamazaki, T, Pershing, AJ, Qian, SS, Read, A, Reilly, SB, Torres, L, Werner, F. 2006. Techniques for cetacean–habitat modeling. *Marine Ecology Progress Series*, 310: 271–295

Scott, BE, Sharples, J, Wanless, S, Ross, ON, Frederiksen, M, Daunt, F. 2006. The use of biologically meaningful oceanographic indices to separate the effects of climate and fisheries on seabird breeding success. Pages 46-62 *in* I. Boyd, S. Wanless, and C.J. Camphuysen (editors), Top Predators in Marine Ecosystems: Their role in monitoring and management. Cambridge University Press, New York.

Weimerskirch, H, Inchausti, P, Guinet, C, Barbraud, C. 2003. Trends in bird and seal populations as indicators of a system shift in the Southern Ocean. *Antarctic Science*, **15,** 249-256

Zerbini, AN, Waite, JM, Laake, JL, Wade, PR. 2006. Abundance, trends and distribution of large baleen whales in western Alaska and the Central Aleutian Islands. *Deep Sea Research Part I* 53: 1772-1790 doi: 10.1016/j.dsr.2006.08.00

Appendix 1: an evaluation of the power to detect trends in abundance of whales in the Bering Sea

Alex Zerbini, Nancy Friday and Paul Wade

Introduction and Methods

The purpose of this analysis is to investigate the power to detect trends in abundance of large whales in the Bering Sea, given existing abundances and respective CVs. A trend is estimated by fitting a log-linear regression through abundance data and changes in abundance are assumed to correspond to the slope parameter of the regression with an associated measure of uncertainty (the standard deviation) (Gerrodette, 1987). The detection of a change corresponds to the rejection of the null hypothesis of no change and the power of the test is the probability that a real change is detected considering the estimated slope parameter and its standard deviation for a given distribution and significance level.

The objective of the present study is to assess how much power to detect trends in whale abundance would be gained if NPRB funded marine mammal observers in one, two or three cruises during the BSIERP project. The power analysis was conducted with program TRENDS (Gerrodette, 1993). Single-tailed *t*-distribution with *n*-1 degrees of freedom (where *n* corresponds to the number of surveys) and a significance level of 0.1 was used to compute the power of detecting annual increases of 5% and 10%. Two-tailed *t*-distributions are used to assess the power to detect changes (as opposed to only an increase) of 50%/year. Note that 5% and 10% annual increase rates are chosen here as possible real increases in population size over time. An annual population change of 50%/year is biologically unrealistic if considered as population growth. This figure was used here to illustrate a scenario where different environmental conditions may cause a substantial change in whale abundance because of a shift in their distribution to a region outside of the survey area.

Fin Whale

Friday et al. (in preparation) provided two abundance estimates: N_{1999}=3701, CV=0.32 and N_{2002}=435, CV=0.42. The total number of estimates possible for estimating trend in abundance of this species depends on the number of sighting surveys funded by the NPRB/BSIERP program. Three, four or five estimates can be obtained if, respectively, one, two or three NPRB/BSIERP-funded surveys are conducted. The trend estimates correspond to periods ranging from 10 (three estimates, 1999-2008) to 12 years (5 estimates, 1999 to 2010). Power to detect changes in fin whale abundance was assessed for the following options (Table 1):

1) Number of BSIERP-funded surveys: 1 year (2008), 2 years (2008 and 2009, or 2008 and 2010) and 3 years (2008-2010)
2) Expected CVs of abundance estimates were 0.2, 0.32 and 0.42. The former correspond to an assumed improved CV considering that a greater sample size will be available due to an increase in population size while the other correspond to the CVs of existing abundance estimates.

Humpback Whale

There is only one existing abundance estimate of humpback whale in the Bering Sea (Friday et al. in preparation): N_{2002} = 632, CV=0.68. Therefore, an analysis similar to the one conducted for fin whales above will have one less abundance estimate and will span through a shorter period of time: 7 to 9 years (2002 to 2008 or 2010). Table 2 provides a power analysis to detect trends in humpback whale abundance considering the same options as above, except that the expected CVs are greater (0.4 [assumed improved CV] and 0.68 [CV for existing estimate]).

Results and Conclusions

An assessment of the power to detect trends for fin and humpback whales is presented in Tables 1 and 2, respectively. Some of the conclusions we can reach by looking at these results are:

1) Results are in accordance with the study by Gerrodette (1987), which showed, among others, that power increases when estimates of abundance are more precise and annual increase rates are greater.

2) Power to detect changes in population size is relatively low for fin whale if the annual rate of population growth is 5% and one survey is conducted during the BSIERP project. Power increases if two or more surveys are funded and are at good levels (> 0.9) if the population grows at 10%/year. Power is lower to detect trends for humpback whales because there is one less survey for the species and because the CVs of the estimates of abundance are higher. For many CV and survey year cases presented in Tables 1 and 2, trends of 5 and 10%/year would only be detected using traditional statistical methods if additional surveys were carried out after the BSIERP program was finalized (that is a longer time span). However, in such cases, alternative methods (e.g. Bayesian regression) can be used instead. For this reason, additional estimates of abundance obtained during the BSIERP project would still provide valuable information and would be critical for estimates of population trends. In addition, these estimates can be used as new data points even if future trend analyses are carried out using traditional methods when post-2010 estimates are available.

3) There is much greater power to detect 50% changes in the abundance of fin whales if more than one survey is conducted. If the two surveys requested in the original broad scale large whale project component are conducted, power is higher if cruises occur in 2008 and 2010 rather than 2008 and 2009. Power is even greater if three surveys are conducted, but this would require an increase in funding.

References

Friday, N.A., Waite, J.M., Moore, S.E. and Zerbini, A.N. In preparation. Cetacean distribution and abundance in relation to oceanographic domains on the Eastern Bering Sea shelf.

Gerrodette, T. 1987. A power analysis for detecting trends. *Ecology* 72: 1889-1892.

Gerrodette, T. 1993. TRENDS: Software for a power analysis of linear regression. *Wildlife Society Bulletin* 21: 515-516

Table 1 – Power to detect trends in abundance of fin whales (Power >= 0.5 is italicized).

5%/yr increase			
		CV	
BSIERP Surveys	**0.2**	**0.32**	**0.42**
1 (2008)	0.36	0.26	0.23
2 (2008/9)	*0.57*	0.36	0.29
2 (2008/10)	*0.6*	0.38	0.30
3 (2008/9/10)	*0.71*	0.45	0.34

10%/yr increase			
		CV	
BSIERP Surveys	**0.2**	**0.32**	**0.42**
1 (2008)	*0.59*	0.4	0.33

2 (2008/9)	*0.90*	*0.64*	*0.50*
2 (2008/10)	*0.92*	*0.67*	*0.52*
3 (2008/9/10)	*0.98*	*0.78*	*0.62*

50%/yr change

		CV	
BSIERP Surveys	**0.2**	**0.32**	**0.42**
1 (2008)	*0.84*	*0.62*	*0.5*
2 (2008/9)	*1*	*1*	*0.94*
2 (2008/10)	*1*	*1*	*0.95*
3 (2008/9/10)	*1*	*1*	*1*

Table 2 – Power to detect trends in abundance of humpback whales (Power >= 0.5 is italicized).

5%/yr increase		
		CV
BSIERP Surveys	**0.4**	**0.68**
1 (2008)	0.2	0.18
2 (2008/9)	0.22	0.19
2 (2008/10)	0.23	0.19
3 (2008/9/10)	0.24	0.18

10%/yr increase		
		CV
BSIERP Surveys	**0.4**	**0.68**
1 (2008)	0.27	0.21
2 (2008/9)	0.3	0.23
2 (2008/10)	0.32	0.23
3 (2008/9/10)	0.41	0.26

50%/yr change		
		CV
Surveys	**0.4**	**0.68**
1 (2008)	0.4	0.24
2 (2008/9)	0.47	0.29
2 (2008/10)	0.49	0.3
3 (2008/9/10)	*0.87*	*0.54*

Budget Narrative – National Marine Mammal Laboratory, AFSC, NOAA

Personnel/Salaries:

No Personnel/Salaries are requested.

Personnel/Fringe Benefits:

No Personnel/Fringe Benefits are requested.

Travel:

Domestic: Total domestic travel costs are $38,000 and include:

- Roundtrip airfare, room and board for cetacean observer participating on REFM's pollock surveys in FY 08 and FY10 estimated at $3,000/observer with a total of $36,000.
- $2,000 in FY11 for the Marine Science Symposium.

International: No foreign travel is requested.

Equipment:

Total equipment costs are $ 27,000 and include:

- Acquisition of a laptop for data collection by cetacean observers during sighting surveys on the AFSC pollock surveys estimated at $3,000 for FY08.
- Acquisition of a pair of Big Eye binoculars at $20,000 for FY08.
- Fabrication of two aluminum stands for Big Eye binoculars at $2,000 each for a total of $4,000 for FY08.

Supplies:

No Supplies are requested.

Contractual/Consultants:

We plan to contract for sighting survey work as follows; totaling $232,960:

- One 63 day or two 33 day contracts for cetacean cruise leader(s) to lead cetacean sighting surveys during the summer Pollock assessment cruises in the Bering Sea in FY08 and FY10. Corresponding to a total of 60 survey days (30 days in each of legs 1 and 2) and three travel days. Cetacean cruise leader(s) will be hired at $22.22/hr in FY08 and $23.57/hr in FY10. Contractors will be hired through Aquatic Farms, Ltd. Total cost is $29,130 in FY08 and $30,910 in FY10 resulting in a total contractual cost of $60,040.
- Two 63 day, four 33 day, or one 63 day and two 33 day contracts for cetacean observers to conduct sighting surveys during each leg of the summer Pollock assessment cruises in the Bering Sea in FY08 and FY10 resulting in two observers per leg. Each contract will include 30 or 60 survey days and three travel days. Cetacean observers will be hired at $18.17/hr in FY08 and $19.28/hr in FY10. Contractors will be hired through Aquatic Farms, Ltd. Total cost is $47,640 in FY08 and $50,540 in FY10 resulting in a total contractual cost of $98,180.
- One 39 week, full-time contract for project management and data analysis in FY09. This person will be hired at $33.18/hr through Aquatic Farms, Ltd. Total cost is $74,740.

Other:

A total of $2,000 is requested for shipment of equipment ($1,000/survey year).

Indirect Costs:

No Indirect Costs are requested.

Total Funds requested for this institution for this component are: $299,960

Other Support/In kind Contributions for NMML:

In-kind contributions from NMML will be determined at a later date.