

# ***EVOSTC ANNUAL PROJECT REPORT***

*Project Number: 080814*

*Project Title: Seabird predation on juvenile herring in Prince William Sound*

*PI Name: Dr. Mary Anne Bishop and Dr. Katherine Kuletz*

*Time period covered: FY08*

*Date of Report: September 2008*

*Report prepared by: Neil Dawson, Mary Anne Bishop, and Katherine Kuletz*

*Project website: [www.pwssc.org/research/biological/seabirds/SeabirdOnHerring.htm](http://www.pwssc.org/research/biological/seabirds/SeabirdOnHerring.htm)*

## **Work Performed and Preliminary Results:**

During FY2008, surveys of seabird distribution and abundance in Prince William Sound (PWS) were performed on four cruises: 5-12 and 26-30 November 2007, 24-29 January 2008 and 16-24 March 2008. Combining surveys from all 2007/2008 winter cruises, we surveyed a total of 874 km (178 km<sup>2</sup>). For the 2008/2009 winter, seven cruises are planned that will include seabird surveys. What follows is: a) a brief summary of work performed; and b) a preliminary analyses.

Surveys in early November 2007 and March 2008 were conducted simultaneously with hydroacoustic surveys for herring (EVOS 080830 R. Thorne, PI). These cruises focused on bays in PWS known historically to hold large overwintering aggregations of juvenile herring (Fig 1). A second vessel sampled fish in and around the acoustic transects to determine species composition and age of fish schools.

Seabird data from these cruises were converted into densities (birds/km<sup>2</sup>) for each species or species group. Seabird densities were calculated by bay, per transect and per km of transect line to enable analysis at different spatial scales. Data has been uploaded into Arcmap and seabird distributions mapped. The hydroacoustic and fish school composition data have been obtained for March and November 2007 cruises, but not for March 2008. We expect to receive the March 2008 hydroacoustic herring data from PI Thorne by late September 2008. We have categorized hydroacoustic transects into density of fish for depth bands of 0-5m, 6-20m, 21-50m, and >50m. These data are being analyzed to determine the spatial associations of each bird species with fish species, age-class, and school characteristics.

To substantiate the survey data, we also conducted focal observations of foraging seabirds, to verify which fish they are eating. However, winter weather and long travel times between bays limited observation opportunities. We will make focal observations a higher priority during cruises in winter 2008/09. Observations of foraging seabirds will be supplemented during field work for a complementary North Pacific Research Board study on marbled murrelet body condition that we will be conducting during the 2008/2009 winter.

Although the focus of this project is to survey seabirds and match their distribution with hydroacoustic data, we are also collecting unique winter data on seabird distribution and behavior throughout PWS. We collected data while on transit between bays to evaluate seabird habitat use outside of the bays. We have also placed bird observers on cruises run by NOAA's Auke Bay Lab (Humpback Whale predation on herring, EVOS 070830, S. Rice, PI). The whale cruises provide valuable insights into how the seabird distribution changes throughout winter and the additional data will aid in identification and characterization of foraging hotspots. The data from the whale cruises will also allow comparison of relative seabird densities over large areas throughout the period which juvenile herring may be vulnerable to predation. These data will augment our focus on the early and late winter periods, which may not be representative of conditions for the entire season. The whale cruises will also provide an opportunity to evaluate whether or not Humpback Whales in PWS facilitate foraging of seabirds by driving fish to the surface, as has been suggested in other regions.

## Study Area

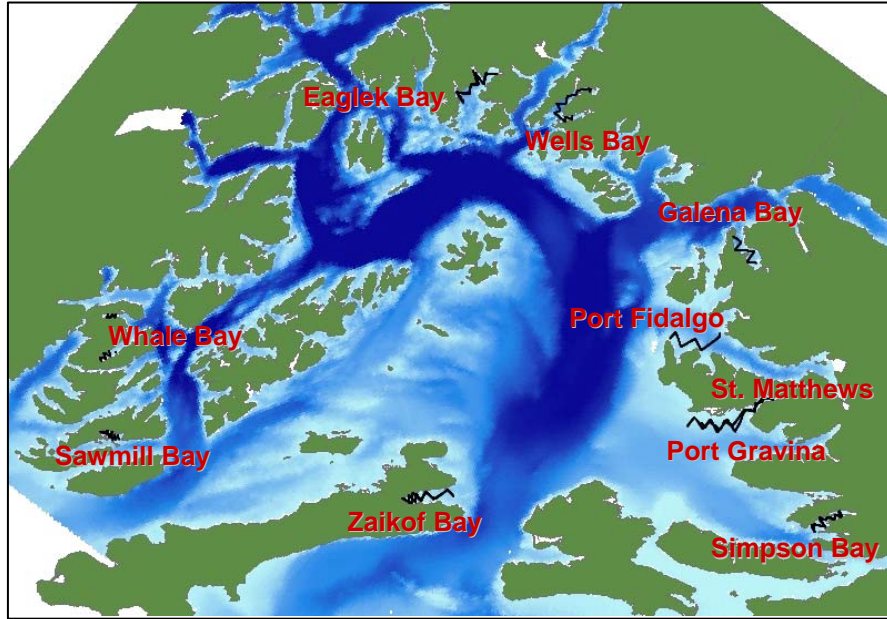


Figure 1. Prince William Sound study area, showing locations of herring hydroacoustic and seabird survey tracklines, in March and November 2007, and March 2008. Humpback Whale and seabird track lines varied by cruise.

## Seabird Distribution in PWS

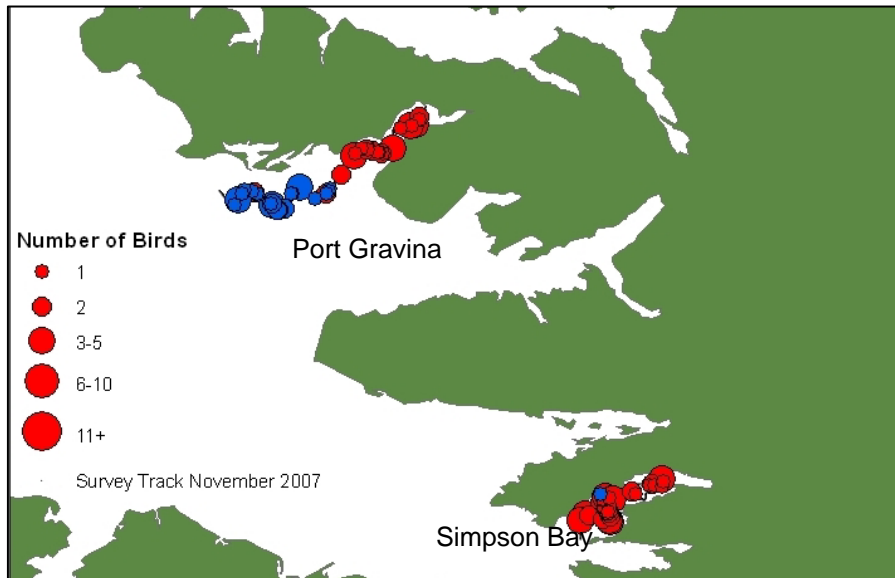


Figure 2a. Abundance of Marbled Murrelets (red) and Common Murres (blue) along hydroacoustic transects, in Port Gravina and Simpson Bay, November 2007.



Figure 2b. Abundance of Glaucous-winged Gulls (green), Common Murres and Marbled Murrelets on hydroacoustic transects in Zaikof Bay, November 2007. Note the absence of murrelets and murres.

The distributions of different species or species groups vary dramatically (Figures 2a and 2b). Distinct distribution patterns were displayed by large Gulls, Marbled Murrelets and Common Murres (3 of the most numerous seabird species; table 1). Common Murres and Marbled Murrelets appeared at times to have very little overlap in distribution (Fig. 2a). Large gulls (primarily Glaucous-winged Gulls) were found in very large aggregations but often with few murres or murrelets present (Fig 2b). The distributions of these bird species appeared to reflect preferences for different herring age and size classes. Marbled Murrelets were strongly associated with juvenile herring (age 0-2). Common Murres were most often encountered in deeper waters with aggregations of adult herring (age-3 or older). Glaucous-winged Gulls were opportunistic and fed in areas with large fish concentrations, regardless of herring age/size class (see Fig. 6 below). The gulls may rely on diving ducks, loons and cormorants to drive fish to the surface, making them available for foraging. Similarly, we found that the Black-legged Kittiwake, a small gull and the 3<sup>rd</sup> most numerous PWS seabird in winter, did not show a clear association with fish of a certain age and may be more dependent on food being available at the surface.

Table 1. Population estimates for seabird groups in PWS in March 2005 (McKnight et al. 2006).

Species Group	Number $\pm$ SE
Murre	92,777 $\pm$ 23,423
Gull	66,961 $\pm$ 12,498
Cormorant	14,654 $\pm$ 3,090
Murrelet	12,640 $\pm$ 3,899
Merganser	4,300 $\pm$ 1,875
Grebe	3,425 $\pm$ 1,260
Loon	2,348 $\pm$ 1,024
Guillemot	1,486 $\pm$ 896

## Seasonal patterns of seabird distribution

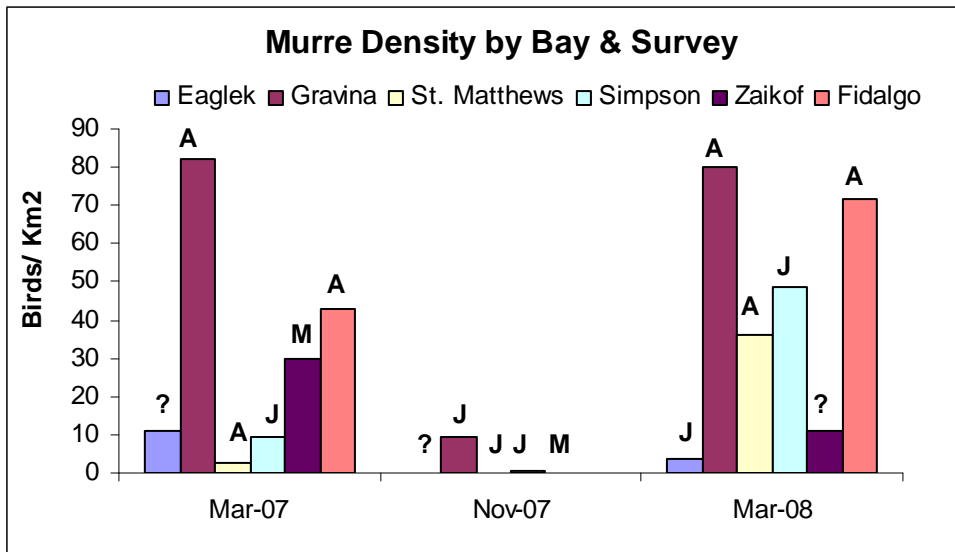


Figure 3. Density of Common Murres by bay and date. Dominant herring age classes of fish schools shown above where: A = adult, J = juvenile, M = mixed adult and juvenile, ? = unknown.

Juvenile herring concentrate in nearshore areas for up to two years before joining the adult population in deeper water (EVOS 2008). Adult herring spend the winter in central and eastern PWS before congregating to spawn in nearshore areas from March to early May (EVOS 2008). Perhaps in response to this shift in herring availability, seabirds also show clear seasonal movements in their distribution. We found a strong spatial association between Common Murres and adult herring (Fig. 3). In November, when schools of predominantly juvenile herring were found in greater densities in the bays, murres were relatively scarce. When murres were in the bays in early winter, they were usually near the bay mouth in deeper waters (Fig. 2a), where adult herring also occurred. However, in March when more adult herring were entering bays such as Port Gravina and Port Fidalgo, murres were present in large numbers compared to November (Fig. 3). Average density in bays with adult herring was 58.1 birds/km<sup>2</sup> compared to 6.6 birds/km<sup>2</sup> for bays with juvenile herring or with unknown fish composition.

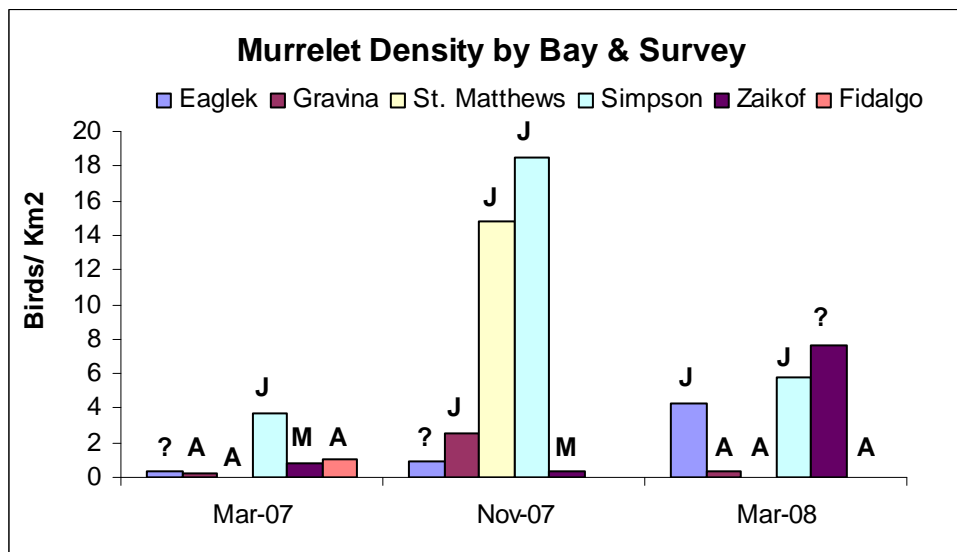


Figure 4. Density of Marbled Murrelet by bay and date. Dominant herring age classes of fish schools shown above where: A = adult, J = juvenile, M = mixed adult and juvenile, ? = unknown.

Marbled Murrelets appear to be a key predator of juvenile herring in PWS. Distribution of Marbled Murrelets was very different from that of murrelets, and murrelets closely followed the seasonal movements of juvenile herring (Fig. 4). Murrelet densities were higher in early winter in bays with juvenile herring schools. Murrelets became scarce as numbers of juvenile herring decreased in late winter (Figure 4). Murrelet density averaged 7.8 birds/km<sup>2</sup> in bays with juvenile herring compared to 0.8 birds/km<sup>2</sup> in bays without juvenile herring.

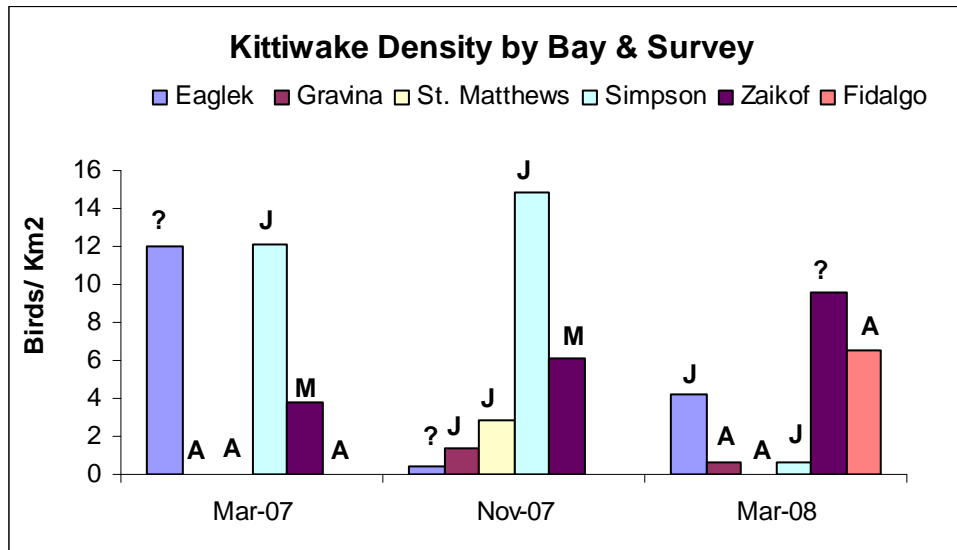


Figure 5. Density of Black-legged Kittiwake by bay and date. Dominant herring age classes of fish schools shown above where: A = adult, J = juvenile, M = mixed adult and juvenile, ? = unknown.

The distribution pattern for Black-legged Kittiwakes was less pronounced than for murrelets and murrelets (Fig. 5). Kittiwakes had a slightly higher density of 4.8 birds/km<sup>2</sup> in bays with juvenile herring, compared to the 3.1 birds/km<sup>2</sup> in bays with adult herring or unknown. The surveys that we conducted in conjunction with the Humpback Whale cruises, which covered areas outside of the bays, revealed that Kittiwake density was very low outside of the bays. During these surveys, kittiwakes were virtually absent from PWS in midwinter, although their densities were occasionally high at the beginning and end of the winter period.

In January 2008, we surveyed over 100 km of transects throughout PWS, and recorded only 3 kittiwakes, whereas March surveys conducted by USFWS found winter population estimates of approximately 15,000 (McKnight et al. 2006). Although more January surveys are necessary before making final conclusions, these preliminary results suggest that kittiwakes do not become abundant in PWS until March, and thus their predation on juvenile herring in PWS varies considerably with seasonal changes in immigration. It may be that surface food including euphaasids and zooplankton, as well as fish, may be limited in PWS in winter, and thereby influencing the abundance and distribution of kittiwakes.

## Spatial Overlap with Marine Mammals

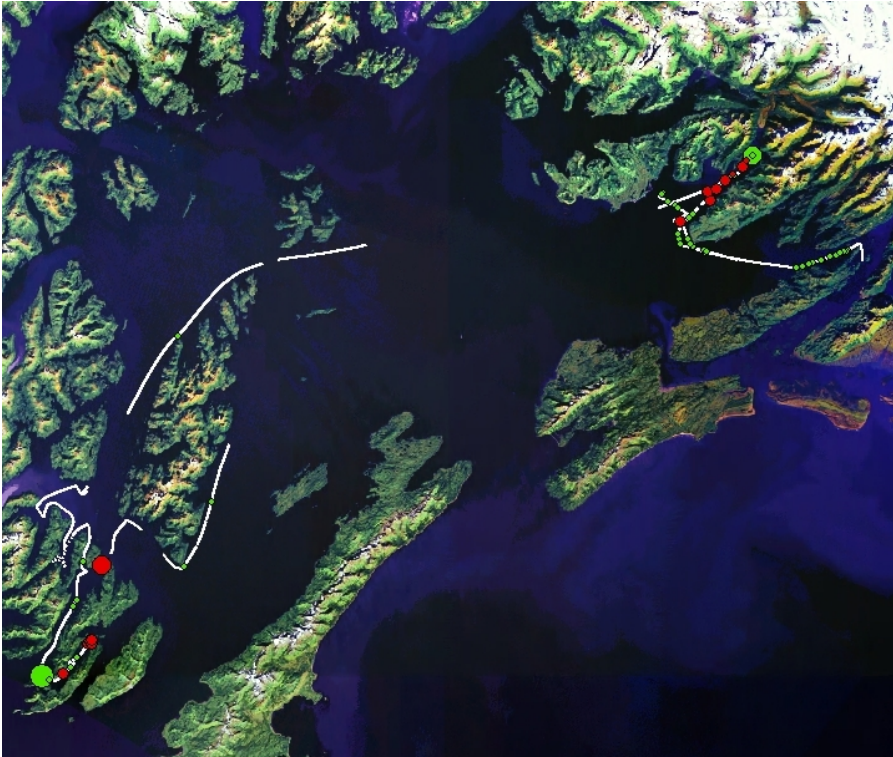


Figure 7. Distribution of loons (green) and Humpback whales (red) January 26-30, 2008.

The distribution of loons, a deep diving seabird group, was linked to the distribution of Humpback Whales (Fig. 7). While bays were indeed hotspots relative to deeper, open waters, high levels of activity were not entirely restricted to the bays. The mouths of bays, as well as narrow passages and channels between islands such as Elrington Passage and Orca Narrows, were used by high numbers of the deeper-diving seabirds (such as murre, loons and cormorants) and Humpback Whales. These kinds of physical features also provide potential wintering habitat for adult herring (EVOS 2008). Interestingly, surveys conducted in very deep waters (> 150m) were characterized by comparatively low levels of bird and whale activity.

## Seabird Response to Fish Densities

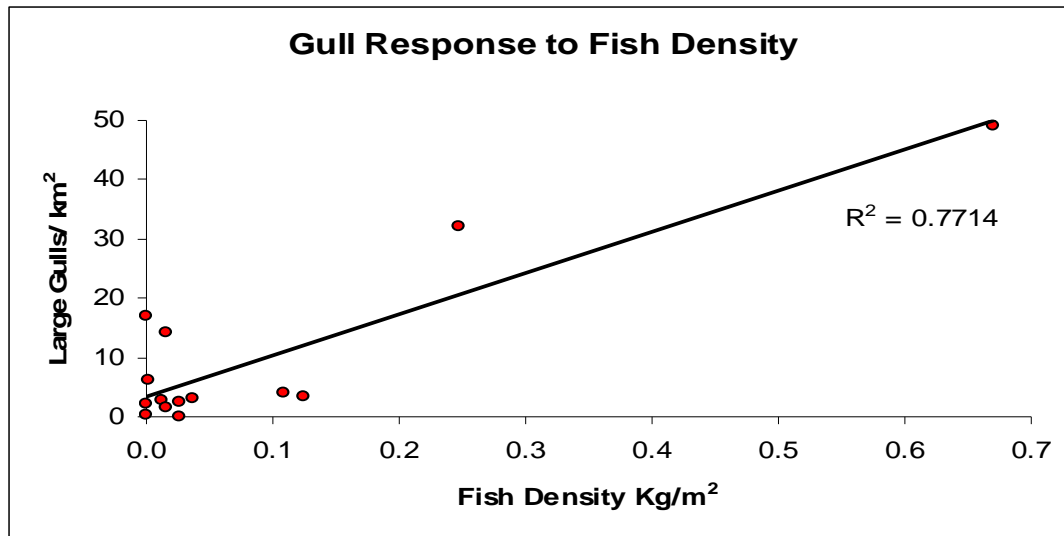


Figure 6. Relationship between densities of large gulls (Glaucous-winged and Herring) and fish observed during hydroacoustic surveys in March and November 2007. Gull densities were positively related to fish densities ( $R^2=0.77$ ,  $P<0.001$ ).

We found a strong association between Glaucous-winged and Herring Gulls and fish density, regardless of location and age class (juvenile or adult) of the fish present (Fig. 6). Both of these gull species are known to be opportunistic and adaptable foragers. Although they may be key predators of herring in PWS, they are not necessarily herring specialists. Their consumption of juvenile herring in winter may vary annually depending upon the relative abundance of other food. For example, in March 2008, there was a strong run of Eulachon, *Thaleichthys pacificus* in rivers around the Copper River Delta. While the run occurs annually, it varies considerably in strength and timing. The abundance of gulls in PWS at this time dropped dramatically compared with previous surveys. Density of gulls in the bays was 8.4 birds/km<sup>2</sup> in March 2007, 13.9 birds/km<sup>2</sup> in November 2007, and just 3.5 birds/km<sup>2</sup> in March 2008.

## Model Results: Selection of Foraging Area by Seabirds

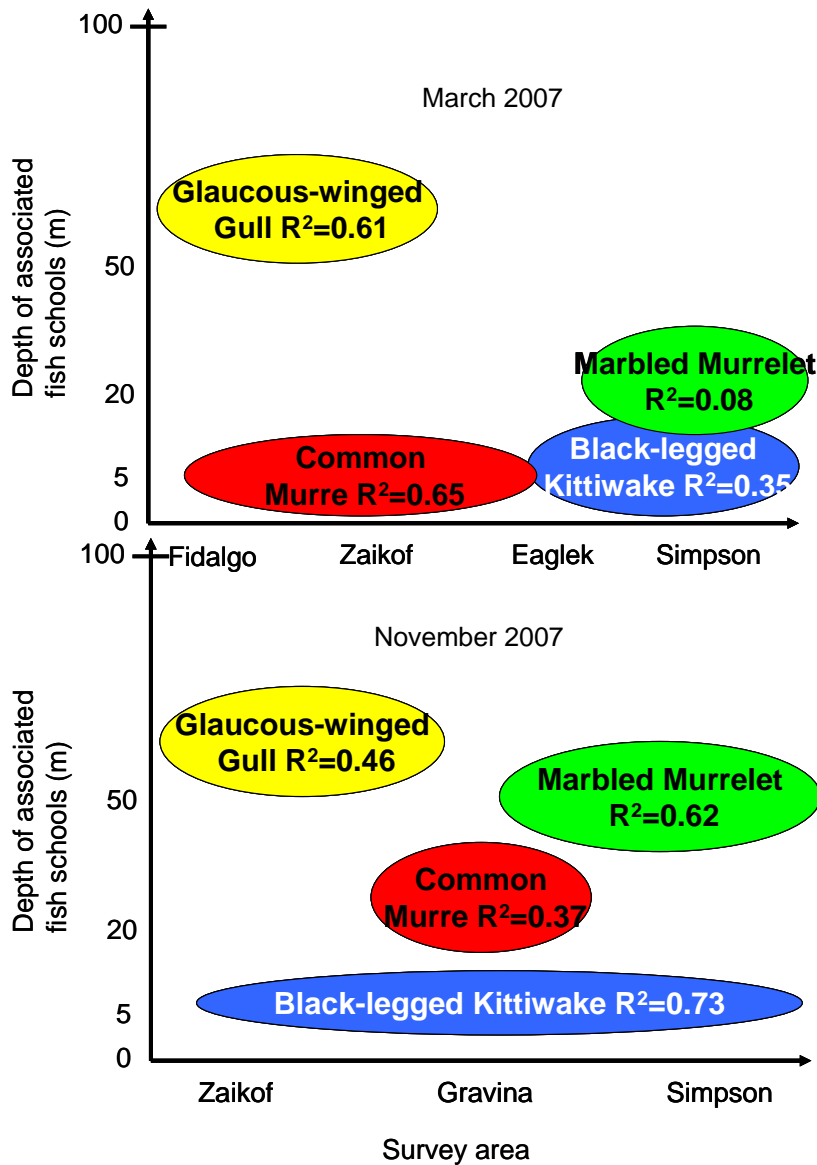


Figure 8. These two diagrams summarize model results (detailed in table 2) illustrating bird distribution by survey area and depth of associated fish prey (primarily adult or juvenile herring). Width of bubble reflects favored bays. March 2007 and November 2007.

We ran Generalized Additive Models with a Poisson distribution and a log link function using backwards selection to explain densities of 4 seabird species by survey transect. Explanatory variables included survey areas as nominal variables, density of fish through water column, density of fish 0-5m, density of fish 0-20m, density of fish 0-50m, average depth per transect, density of other seabird species groups and presence of other seabird species groups. The model yielding the lowest Akaike's Information Criterion (AIC) was selected (Burnham and Anderson 2002). Regression trees were used to corroborate the results and further explain relationships. The same analysis was performed for every 300m<sup>2</sup> grid along the survey track with additional explanatory variables including distance to shore, bathymetric slope, aspect and shelter from prevailing easterly winds (calculated using GIS).



Table 2. Model selection results explaining variation in seabird densities by survey transect.

Species	2007 Survey	R <sup>2</sup>	Areas	Significant Variables	
				Fish Depth	Other Variables
Glaucous-winged Gull	Mar	0.61	Fidalgo	0-5m	Murre & seaduck density
	Nov	0.46	Zaikof, Gravina	All depths	Seaducks, cormorants & murrees present
Common Murre	Mar	0.65	Zaikof, Fidalgo,	0-5m	Water Depth
	Nov	0.37	Gravina	0-20m	Water Depth
Marbled Murrelet	Mar	0.08	Simpson	0-20m	
	Nov	0.62	Simpson	0-50m	Water Depth
Black-legged Kittiwake	Mar	0.35	Simpson, Eaglek	0-5m	
	Nov	0.73	Simpson	0-5m	

Seabird densities were best explained by a model containing survey area and fish density at a specific depth (Fig. 8, Table 2). Kittiwakes were particularly dependent on juvenile herring being present in the top 5m of the water column, whereas Marbled Murrelets were found where fish were within the top 20m in March and top 50m in November. Common Murres favored schools of fish located near the surface in March when adult herring were spawning but down to 20m depth in November. Although feeding on schools nearer the surface, Common Murres occurred in deeper, open water. When analyzed at a finer spatial scale of 300m<sup>2</sup> murre density was positively correlated with distance to shore and they were associated with depths greater than 40m. Glaucous-winged Gulls were linked to high fish densities regardless of the school depth. At the finer scale of < 300 m<sup>2</sup> the model suggested that Glaucous-winged Gulls were associated with congregations of seaducks, loons, cormorants and murrees. Models at this finer scale of < 300 m<sup>2</sup> included more environmental and bathymetric variables (slope, aspect, distance to shore, windshelter). However, our preliminary results thus suggest that it will be difficult to define significant relationships at scales of < 300 m<sup>2</sup>. Similar studies in other regions have found that fine-scale relationships between seabirds and prey are not well defined (Logerwell and Hargreaves 1996).

#### Literature Cited:

- Burnham, K.P., and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag. New York, New York, USA.
- Exxon Valdez Oil Spill Trustee Council. 2008. Prince William Sound Herring Restoration Plan, Draft, Issued January 10, 2008.
- Logerwell, E.A. and N.B. Hargreaves. 1996. The distribution of seabirds relative to their fish prey off Vancouver Island: opposing results at large and small spatial scales. Fisheries Oceanography, 5, 163-175.
- McKnight, A., K.M. Sullivan, D.B. Irons, S.W. Stephensen, and S. Howlin. 2006. Marine bird and sea otter population abundance of Prince William Sound, Alaska: trends following the T/V Exxon Valdez Oil Spill, 1989-2005. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project 050751), U. S. Fish and Wildlife Service, Anchorage, Alaska.

## Future Work:

Further seabird surveys will be performed in conjunction with seven cruises during the 2008/2009 winter. These include five Humpback Whale cruises (Sept, Oct, Dec, Jan, Mar) and two Hydroacoustic cruises (Nov and Mar). Below is the schedule, where  $\checkmark$  = completed survey.

Month	Seabird Surveys	
	2007/2008 Winter	2008/2009 Winters
Sep		Humpback Whale
Oct		Humpback Whale
Nov	$\checkmark$ Herring Hydroacoustic	Herring Hydroacoustic
Dec	$\checkmark$ Humpback Whale	Humpback Whale
Jan	$\checkmark$ Humpback Whale	Humpback Whale
Mar	$\checkmark$ Herring Hydroacoustic	Humpback Whale Herring Hydroacoustic

Once data have been collected and all hydroacoustic and fish school composition data received from EVOS 080830 (R. Thorne, PI), final analysis will be performed, enabling us to suggest the likely impact of seabird predation on juvenile herring. This will include developing a seabird consumption model as described in the FY09 proposal. The final report will be submitted by March 31, 2010.

We foresee at least 3 peer-reviewed publications produced from this study:

- Interactions between herring and predators during winter in Prince William Sound, Alaska. Proceedings of the International Symposium on Herring. ICES Journal of Marine Science. Expected submission date January 2009.
- Food habits of seabirds in Prince William Sound during winter. *Journal Field Ornithology*. October 2009.
- Modeling biomass consumption of juvenile herring by avian predators in a sub-arctic estuary. *Fisheries Oceanography*. March 2010.

## Coordination/Collaboration:

Our project relies on seabird surveys being performed onboard vessels associated with two EVOS projects: hydroacoustic surveys for herring (EVOS 080830, PI Thorne), and humpback whale predation on herring (EVOS 080804, PI Rice). EVOS 080830 provides our project with data from the hydroacoustic surveys and age composition of fish schools. Additional data on age composition of fish schools has been obtained from ADFG herring surveys (PI Steve Moffitt). The Humpback Whale predation on herring project provides our project with whale sightings and fish observations (jigging, dipnetting) associated with the sightings. EVOS 080811 (PWS herring forage contingency, PI Tom Kline) is providing our study with information on the condition and caloric content of year 1 juvenile herring before and after winter, data that will be used in modeling seabird consumption.

Our information on seabird predators will provide data for EVOS 080810 (PI D. Kiefer) "An Ecosystem Model of Prince William Sound Herring: A Management & Restoration Tool". Our information is being gathered in conjunction with the only juvenile herring surveys planned for PWS, and should be completely compatible with models utilizing the juvenile herring survey data. Data from our surveys will also be submitted to the North Pacific Pelagic Seabird Database (USFWS and USGS, Anchorage, Alaska)

## **Community Involvement/TEK & Resource Management Applications:**

Public presentation about the project for community education program onboard the US Coast Guard Cutter Sycamore, December 2007. (Dawson)

Project Poster with preliminary findings has been produced and prominently displayed for visitors to the Prince William Sound Science Center.

Contributed to community herring planning effort, 28<sup>th</sup> April to May 2<sup>nd</sup>. (Dawson)

## **Information Transfer:**

### **Posters and Publications:**

Dawson, N., M.A. Bishop, K. Kuletz, K. Brenneman, R. Thorne and R. Crawford. 2008. The importance of juvenile Pacific Herring *Clupea pallasii* to wintering seabirds in Prince William Sound, Alaska. Poster. Pacific Seabird Group Annual Conference, Blaine WA, 27<sup>th</sup> February-2<sup>nd</sup> March 2008.

Thorne, R.E., M.A. Bishop, N.M. Dawson, and R. Crawford. 2008. Herring and seabirds. The Breakwater, Newsletter of the Prince William Sound Science Center, Winter 2007-2008.

### **Publications in preparation:**

Thorne, R.E., M.A. Bishop, N. Dawson, K. Kuletz, and R. Crawford. *In prep.* Interactions between herring and predators during winter in Prince William Sound, Alaska. Proceedings of the International Symposium on Herring. ICES Journal of Marine Science

### **Presentations:**

Bishop, Mary Anne and Kathy Kuletz. Seabird predation on juvenile herring in Prince William Sound. EVOS Herring Working Group, October 2007, Anchorage.

Thorne, R.E., M.A. Bishop, N. Dawson, K. Kuletz, and R. Crawford. Interactions between herring and predators during winter in Prince William Sound, Alaska. International Symposium on Herring. National University of Ireland, Galway. August 26-29, 2008.

### **Website:**

A webpage has been set up on the project, available since June 2008.

<http://www.pwssc.org/research/biological/seabirds/SeabirdOnHerring.htm>

## **Budget Changes:**

For Prince William Sound Science Center (PWSSC), the estimated FY09 costs remain the same as in the FY07 original proposal except for PWSSC administrative overhead. Originally the overhead was estimated at 25.6%, however for FY09 the federally approved overhead is estimated at 28.82%.

The budget for USFWS included \$10.6k in FY10 for salary for K. Kuletz, which was time for the Co-PI to complete publications. We are adding that \$10 to FY09, to better meet publication deadlines and to keep all costs for the project within FY09.