

Seasonal distribution of short-tailed shearwaters and their prey in the Bering and Chukchi seas

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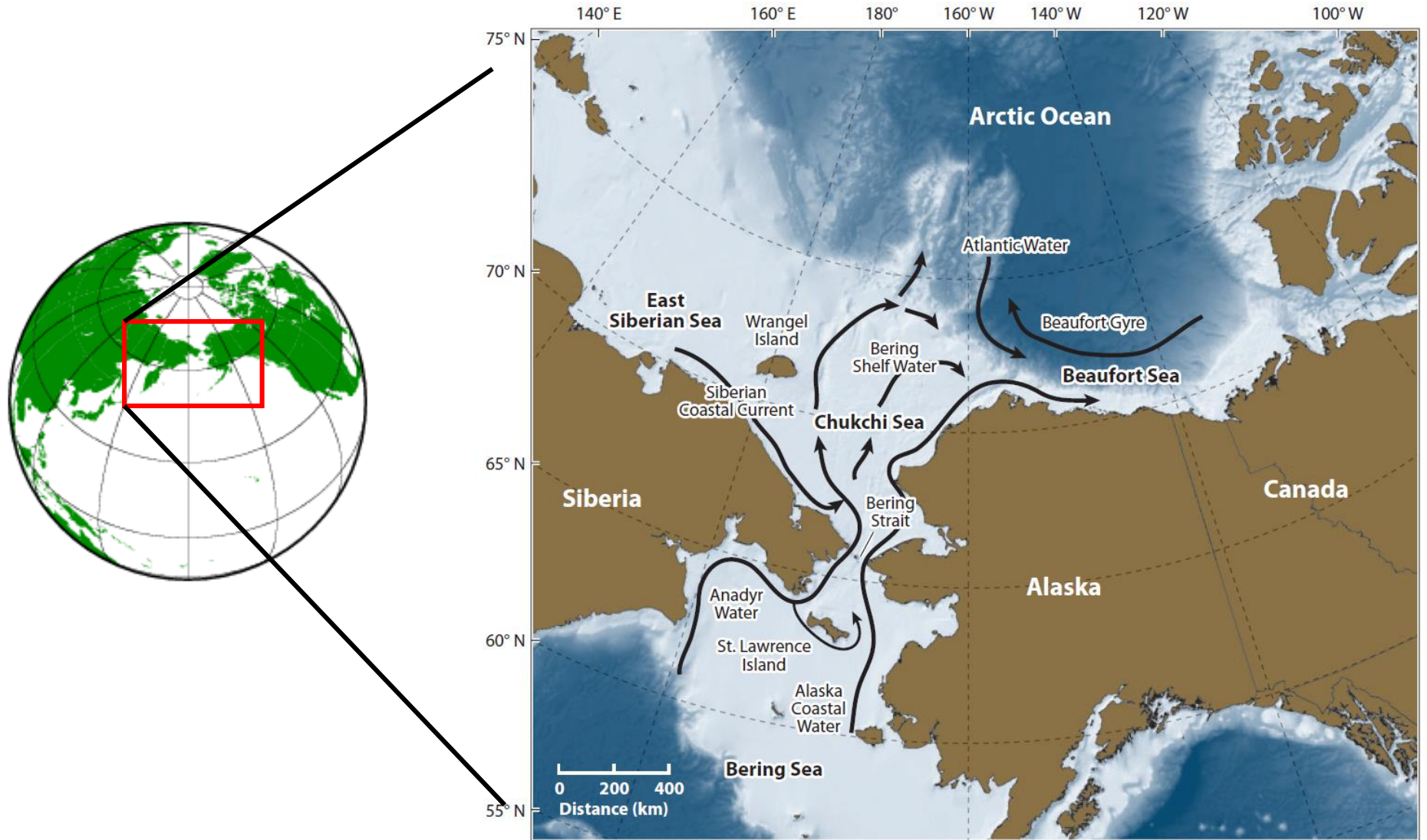
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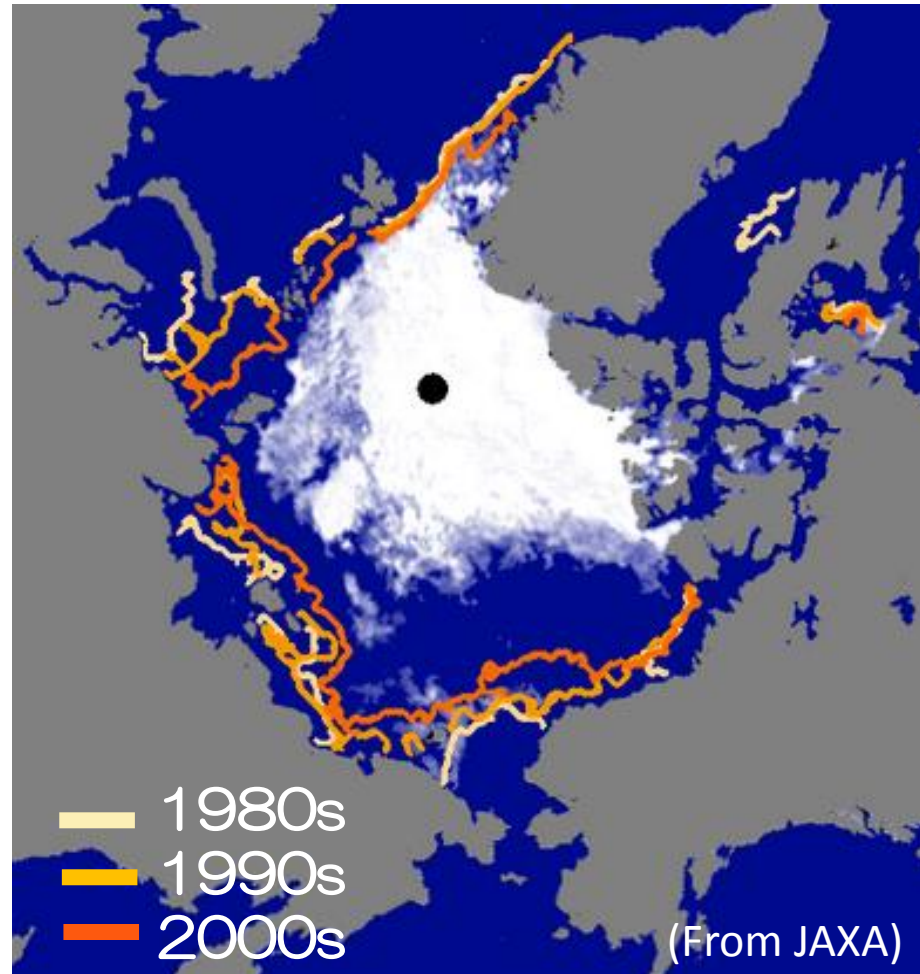
The shelf region in the Bering and Chukchi seas is one of the most productive marine ecosystems in the world



Nutrient-rich Pacific waters flow over the shelves from the northern Bering Sea into Arctic Ocean

(Grebmeier et al. 2006, Grebmeier 2012)

Reductions in sea-ice coverage has been a major concern in Arctic region



Reductions in sea-ice cover are significant on the Pacific side of the western Arctic, including Chukchi Sea

(e.g. Perovich and Richter-Menge, 2009)

Changes in distribution and abundance of marine top predators

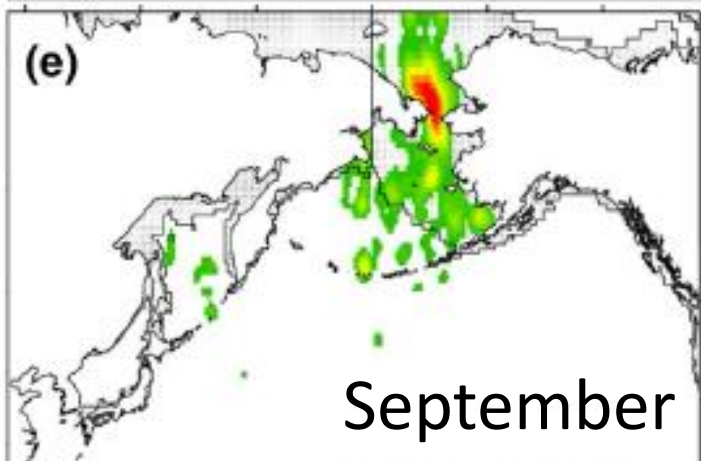
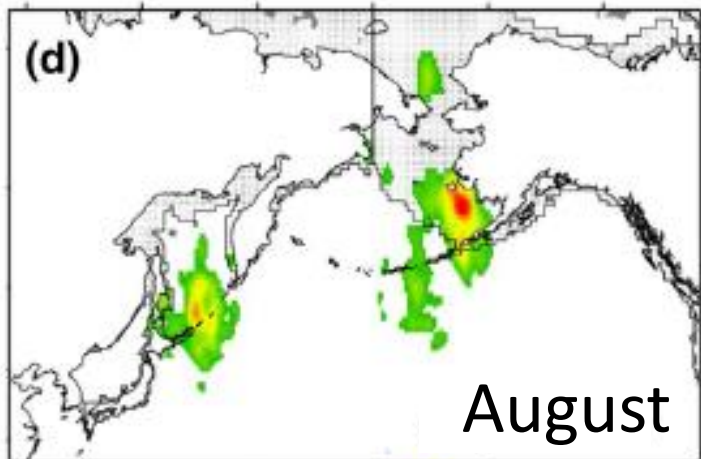
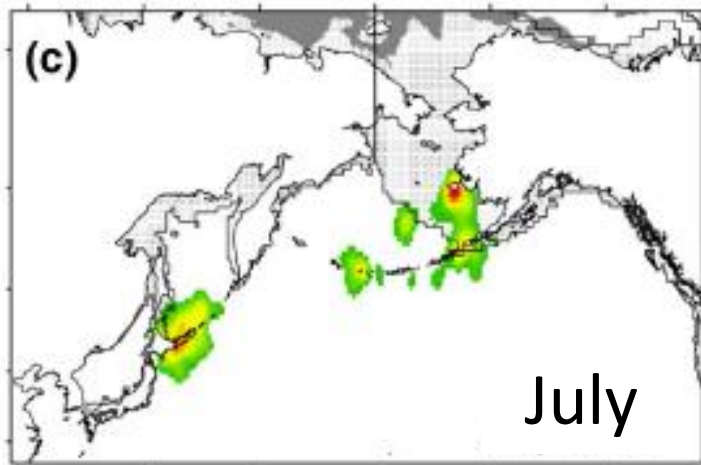
Species	Region	Main findings	Reference
Gray whales (<i>Eschrichtius robustus</i>)	Northern Bering Sea	Expand foraging range to the north coincided with decreases in amphipods	Moore et al. 2003
Spectacled eiders (<i>Somateria fischeri</i>)	Northern Bering Sea	Declines in numbers coincided with declines in clam population	Lovvorn et al. 2009
Black guillemots (<i>Cephus grylle</i>)	Western Beaufort Sea	Nestling diet shifts from Arctic cod to sculpin	Divoky et al. 2015
Albatrosses (Black-footed, Laysan, and Short-tailed)	Bering Sea	Increases in the density and poleward shifts in the distribution	Kuletz et al. 2014
Northern fulmars (<i>Fulmarus glacialis</i>)	Bering Sea	Poleward shifts in the distribution coincided with poleward shifts in fish catches	Renner et al. 2013

Short-tailed shearwaters (*Ardenna tenuirostris*)

- Conduct the trans-equatorial migration
- Breed in southeastern Australia from November to March
- Spend the non-breeding period (May-October) in the northern North Pacific (Bering Sea and Chukchi Sea)
- Feed mainly on krill (*Thysanoessa raschii* and *T. inermis*)



(Ogi et al. 1980, Schneider and Shuntov 1993, Hunt et al. 2002)



Tracked individuals move through the Bering Strait into the Chukchi Sea during **August-September**



(Yamamoto et al. 2015)

Large-scale (Bering Sea and Chukchi Sea) relationships between the distribution of short-tailed shearwaters and that of krill have not been explored

Hypothesis

The distribution of short-tailed shearwaters is related with availability of their main prey, i.e. krill

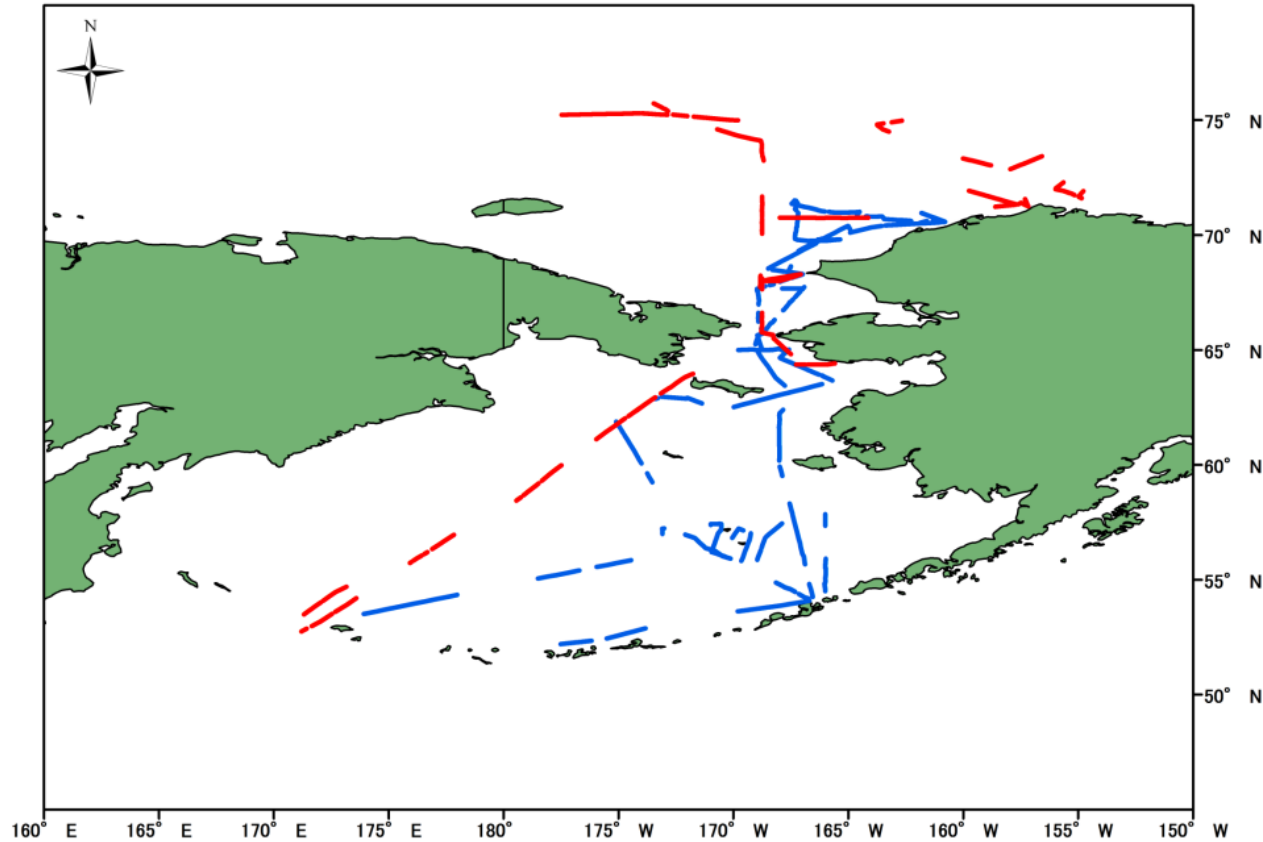
Ship-based seabird surveys



R/V Mirai

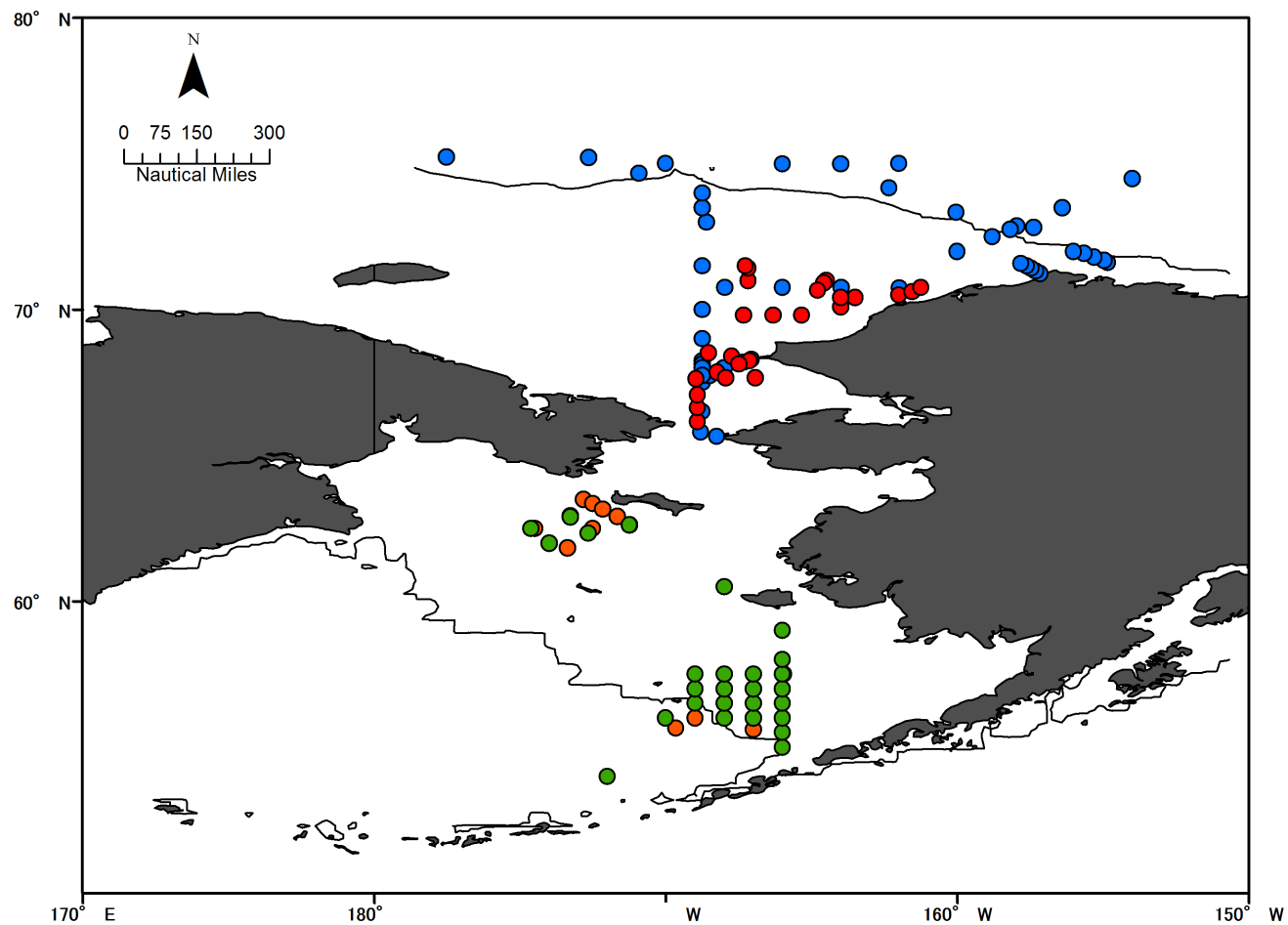


T/S Oshoro Maru



- September, 2012 onboard *R/V MIRAI* (JAMSTEC)
- July, 2013 onboard *T/S Oshoro-maru* (Hokkaido Univ.)

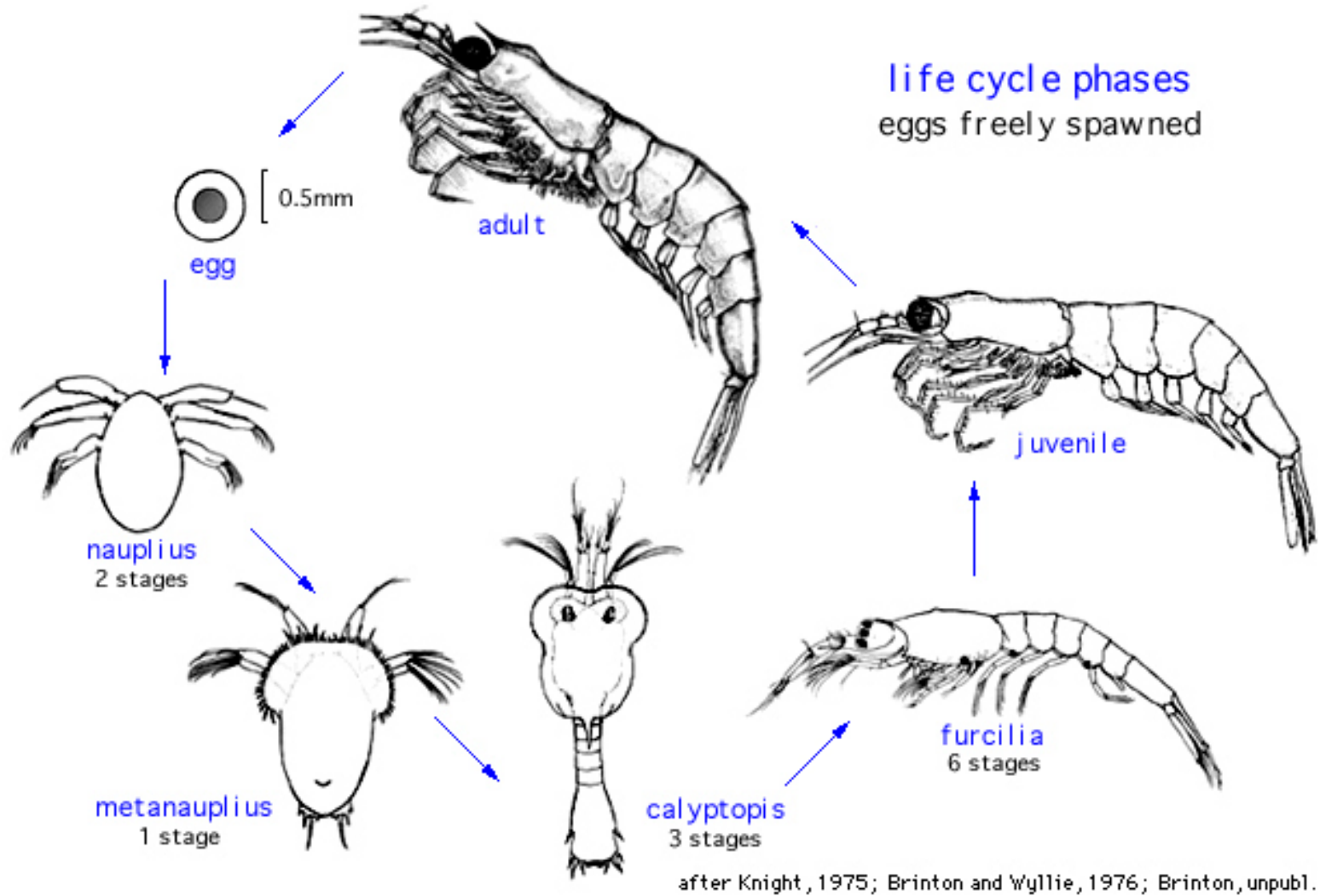
Prey sampling by net



Vertical tows with a NORPAC net at 137 stations

- 27 stations from Bering in 2007
- 33 stations from Bering in 2008
- 27 stations from Chukchi in 2013
- 50 stations from Chukchi in 2012

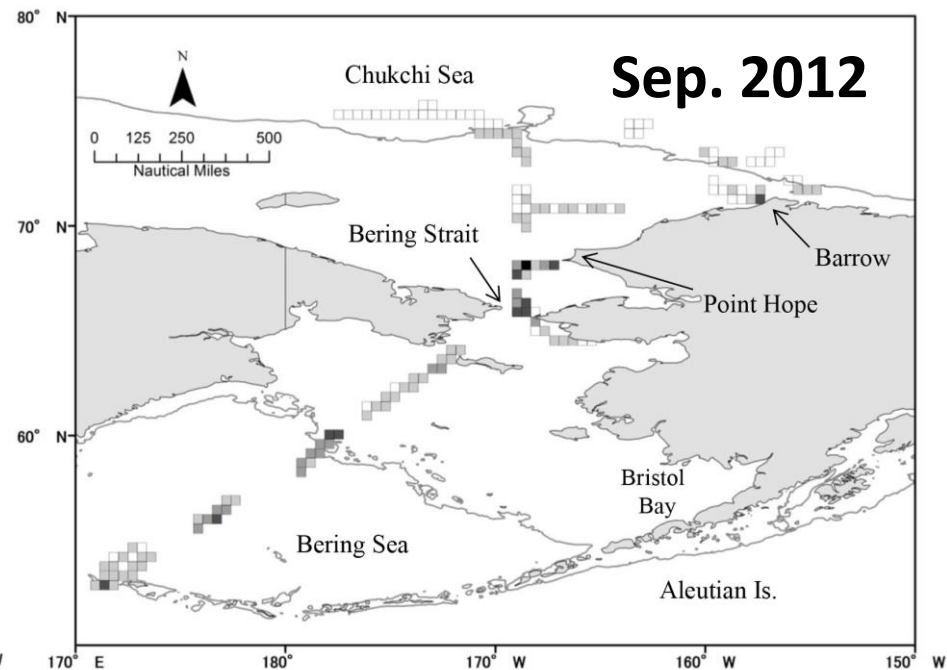
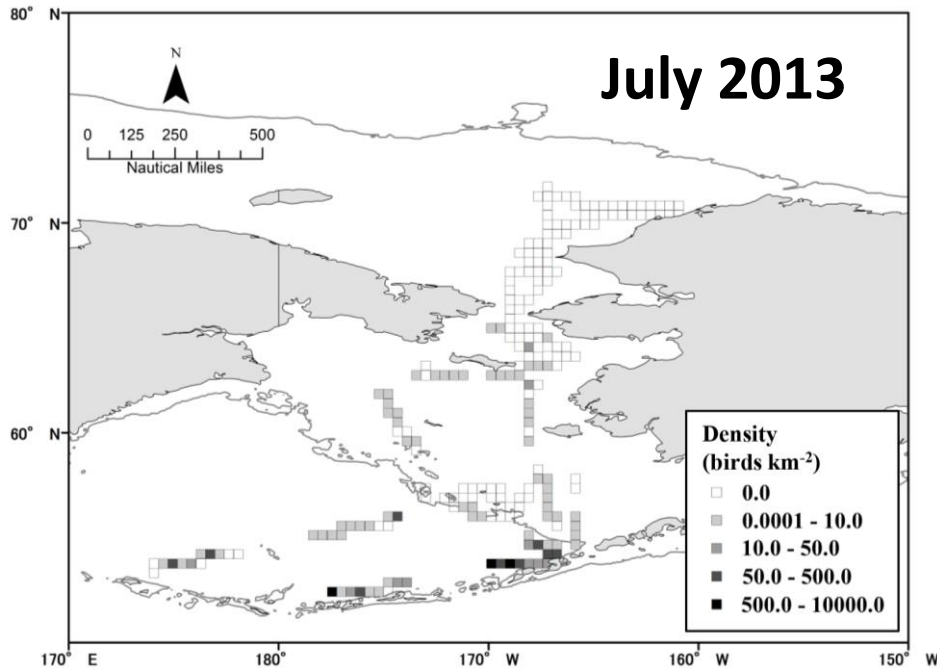
Growth stage and size of krill



- Identified the 5 stages: Nauplius(n), Calyptopis(c), Furcilia(f), Juvenile(j), Adult(a)
- Measured the Total Body Length in mm (from rostrum to tail tip)

(Brinton et al. 2000)

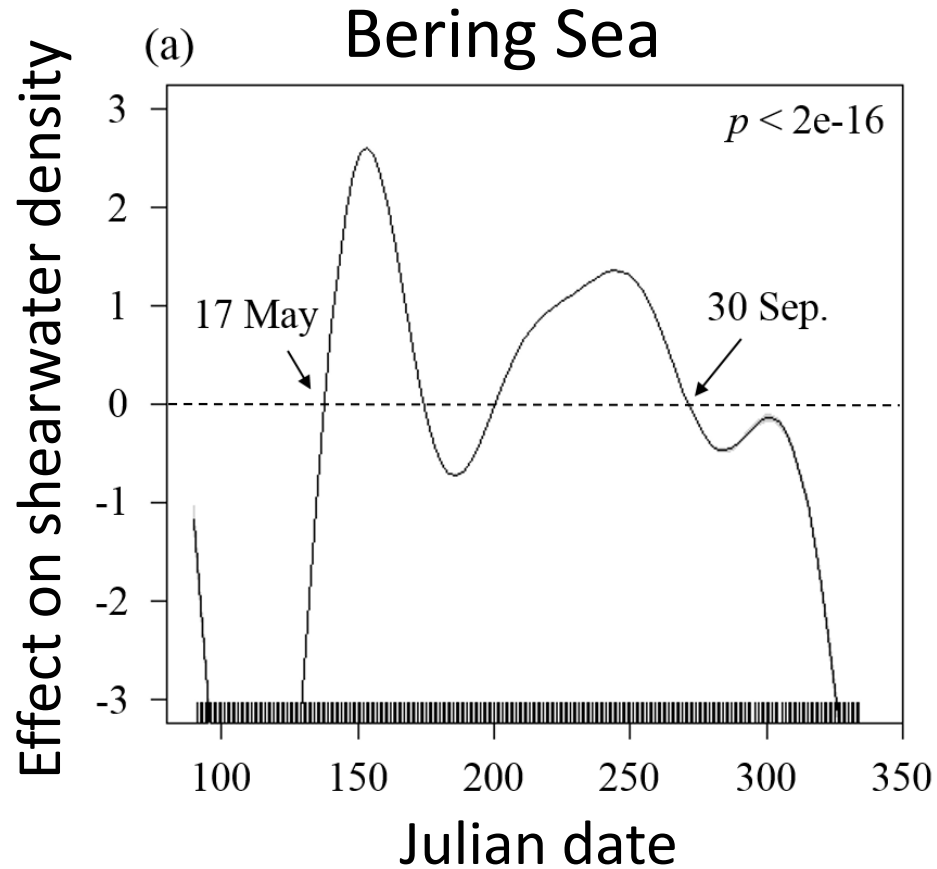
Shearwater density (birds km⁻²)



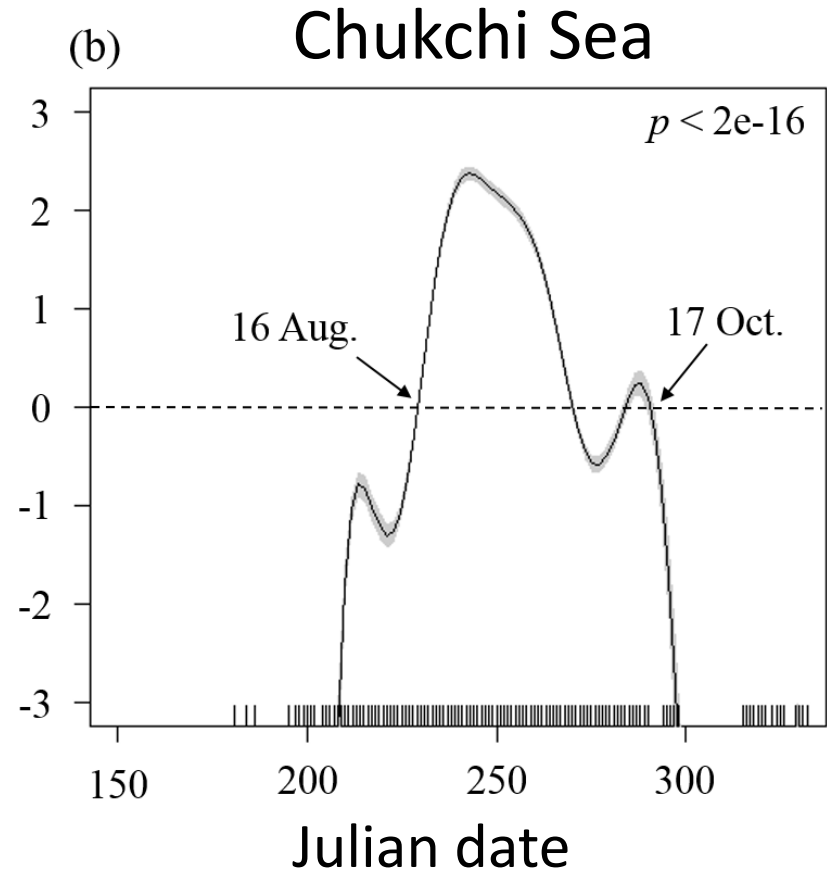
- ✓ In July, shearwaters were distributed only in the Bering Sea
- ✓ In September, they were widely distributed in the Bering Sea and Chukchi Sea

Seasonal changes in shearwater density from NPPSD

(All sampling years, 1975 through 2012 were combined)

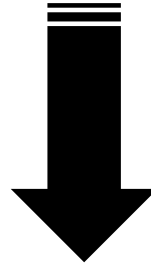


Peak in early June



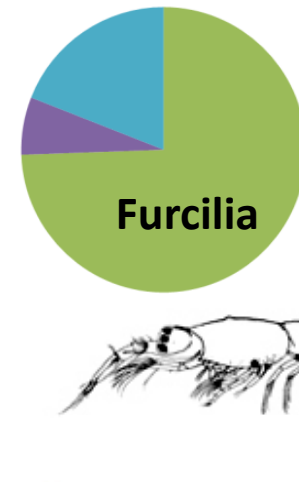
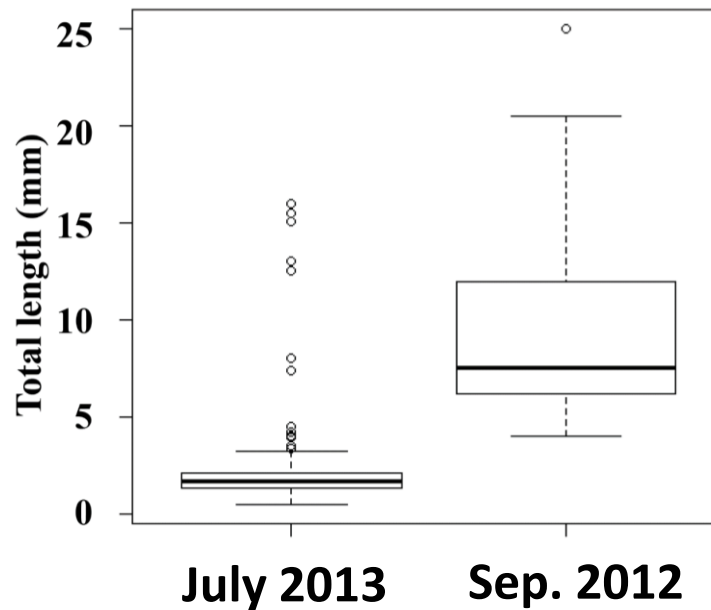
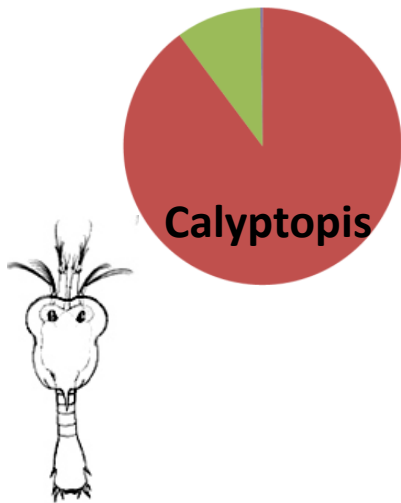
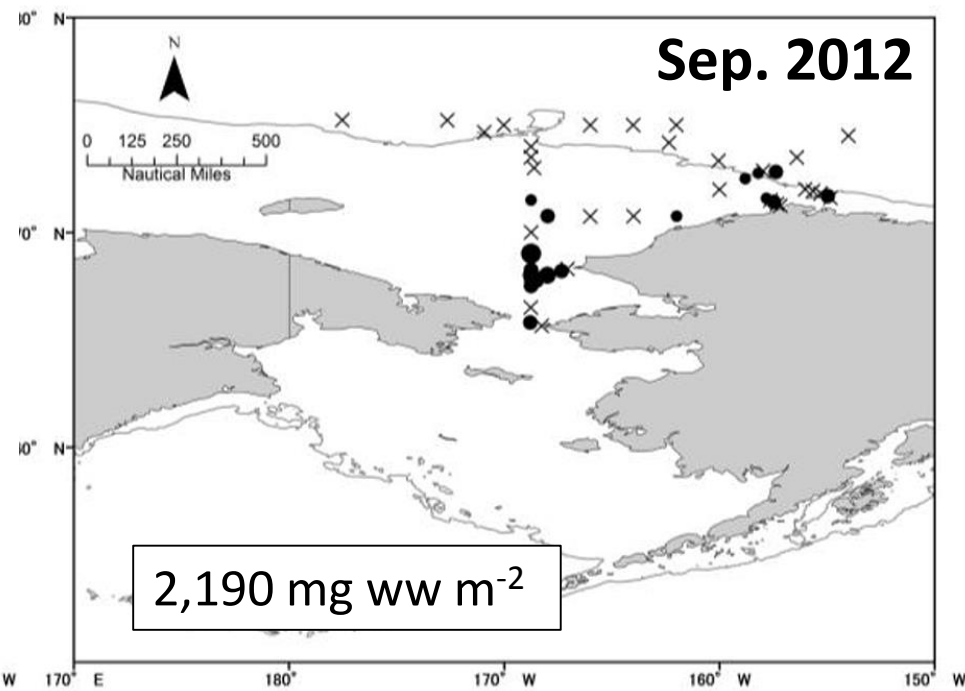
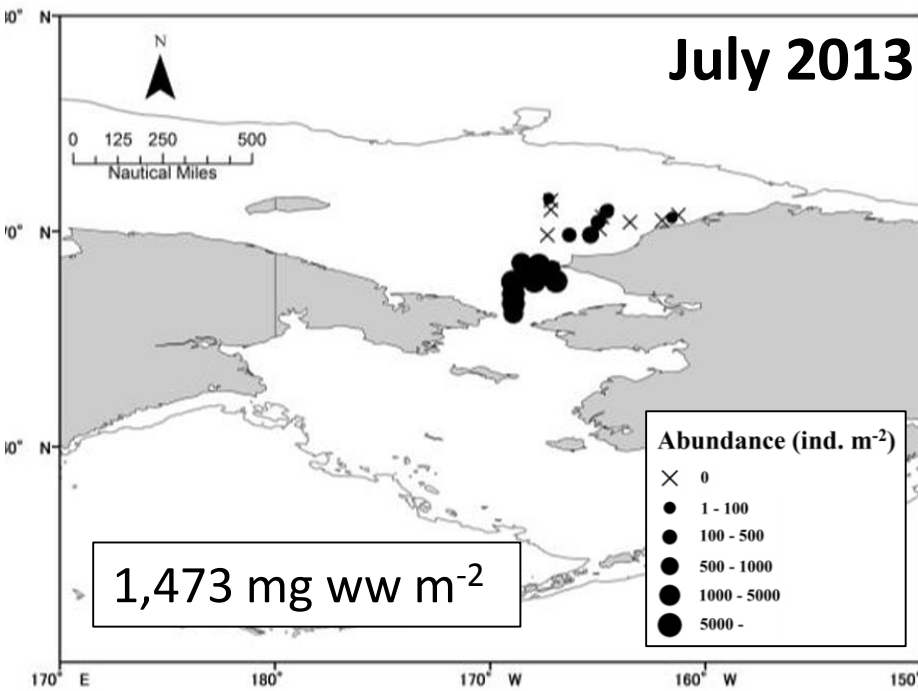
Peak in early September

Our surveys and the long-term NPPSD both showed similar seasonal changes in the distribution of shearwaters within the Bering and Chukchi seas



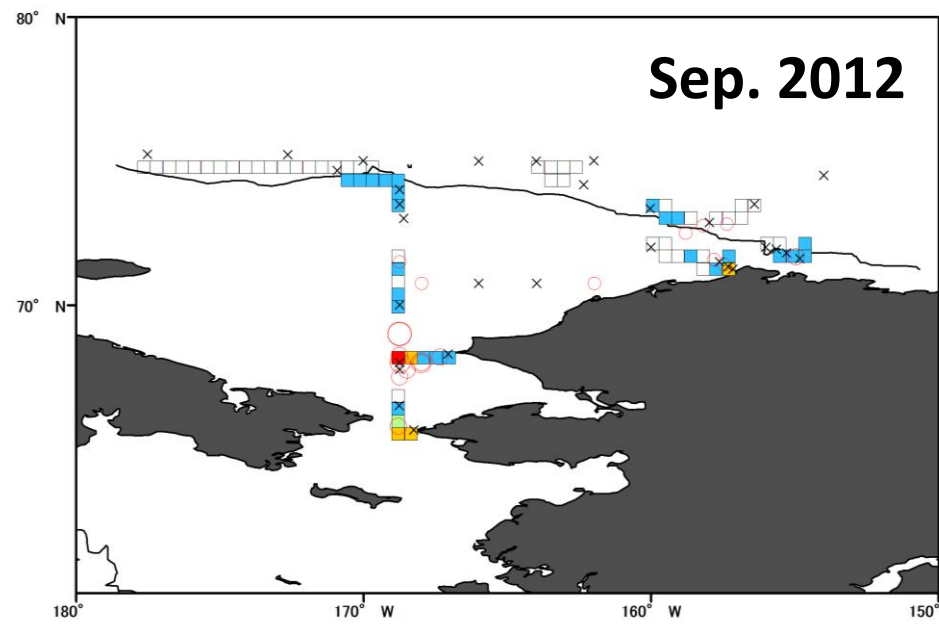
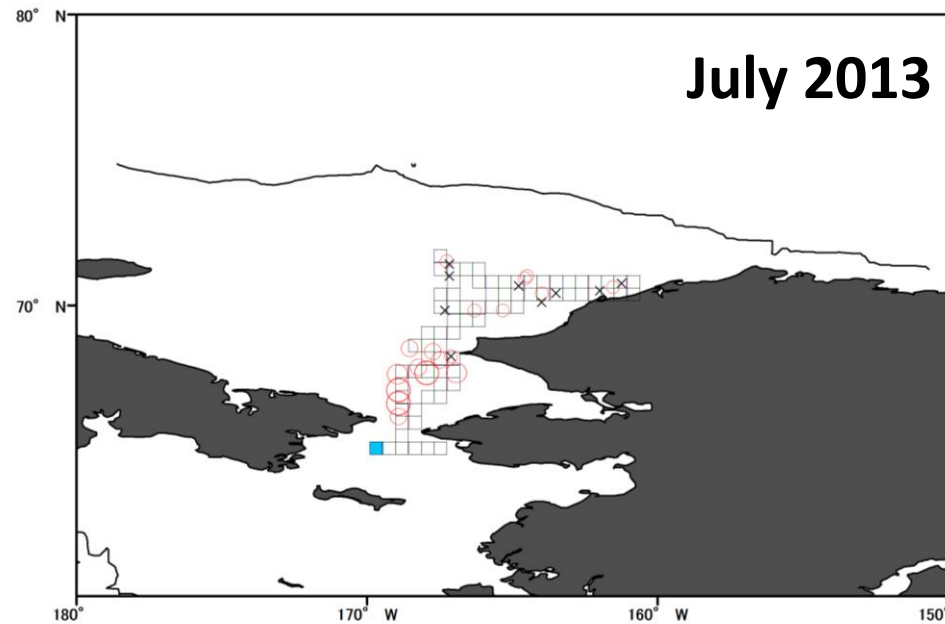
In May–July shearwaters mainly used the Bering Sea and Aleutian Islands, while in August–October they were widely distributed both in the Bering Sea and Chukchi Sea

Krill abundance and size



(Mann-Whitney's U test $p < 0.05$)

Krill and short-tailed shearwaters



Shearwater density

With large krill (> 8.0 mm)	Without large krill
179.8 ± 311.1 (16)	52.2 ± 155.6 (34)

($U = 384.5, p < 0.05$)



Summary of results

	Summer (July)	Fall (Sep.)
Bering Sea	<ul style="list-style-type: none">➤ Abundant shearwaters➤ Large-sized krill were present (mostly in the southeastern shelf)	<ul style="list-style-type: none">➤ A portion of shearwaters were present➤ Krill size and density decreased seasonally (Smith 1991, Coyle and Pinchuk 2002, Stafford et al. 2010)
Chukchi Sea	<ul style="list-style-type: none">➤ No shearwaters➤ Small-sized krill were present	<ul style="list-style-type: none">➤ Abundant shearwaters➤ Large-sized krill were present

Seasonal northward movement of short-tailed shearwaters might be associated with the seasonal increase in krill size in the Chukchi Sea

Why do short-tailed shearwaters select larger size of krill ?

① Larger krill contain more gross energy than smaller krill

(Färber-Lorda et al. 2009)

- ✓ Shearwaters need to store the energy at non-breeding area to return to their colony in the southern hemisphere by next breeding season (November)

② Larger krill, especially spawning females, are easily available for birds

- ✓ Krill migrate from the surface to depth during the day, but adult females occur at the surface (30-45 m) as high density swarms during spawning

(Hanamura et al. 1989, Smith 1991)

- ✓ Shearwaters consumed almost exclusively the krill, over 40% of which were adult females with spermatophores (Hunt et al. 1996)

Conclusions

- ❑ Krill is one of the key prey species driving distribution of top-predators in the Arctic Ocean
- ❑ Further research on the potential recruitment of krill in the southern Chukchi Sea, and on mechanisms responsible for the seasonal and interannual variations in krill abundance, be usefull in interpreting krill-eating marine top-predators