How "The Blob" affected groundfish distributions in the Gulf of Alaska

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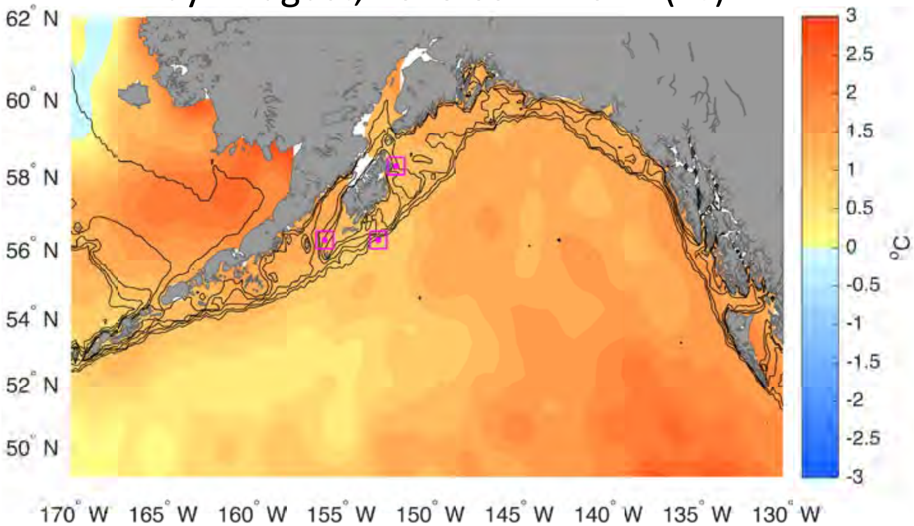
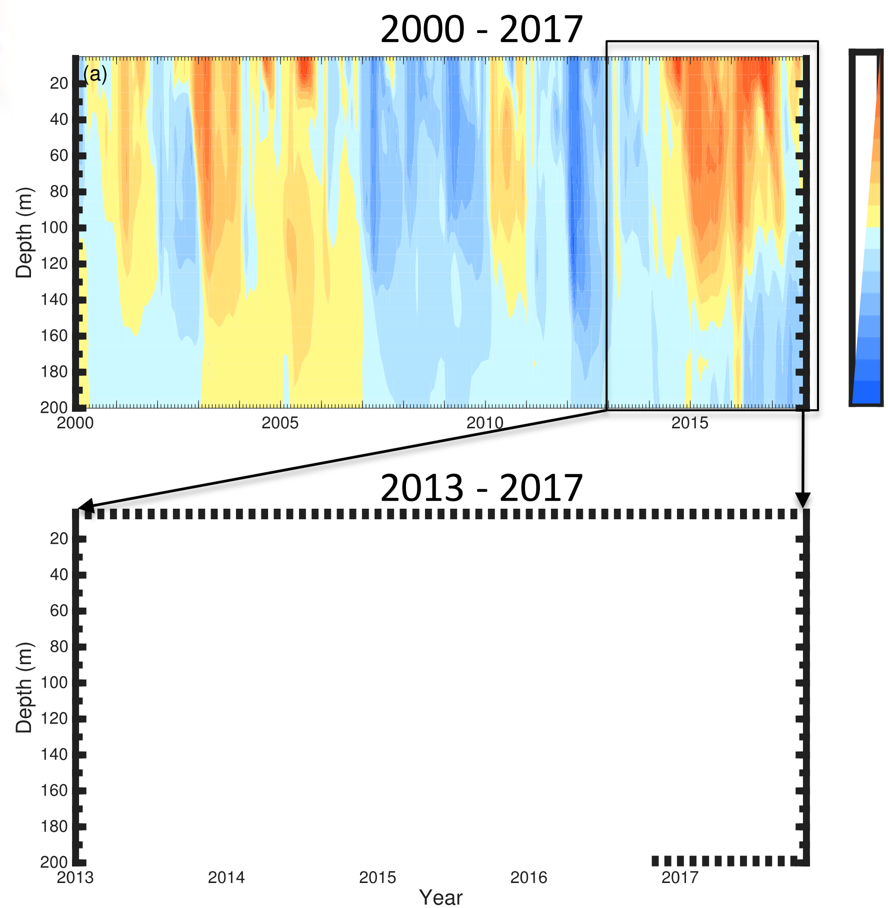
NOAA/NCEP Climate Forecast System Reanalysis

May– August, 2015 SST Anom. (^{o}C)

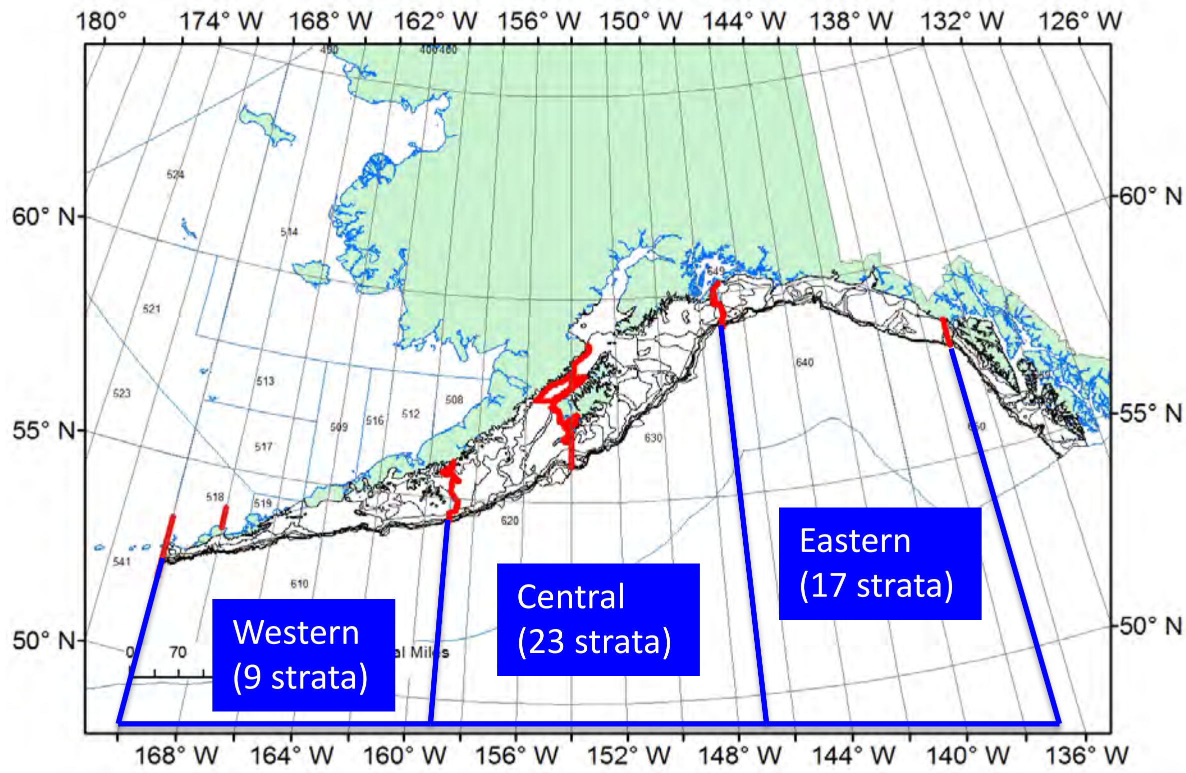


Anomalously warm ocean conditions in the NE Pacific Ocean during 2014-2016 (“The Blob”)

- During the period of 2014-2016, the NE Pacific experienced the strongest SST warming ever recorded (Bond et al. 2015).
- Within the topmost 100 m, a region of ~2X10^{6} km^{2} was more than 2.5^{o}C warmer with a peak anomaly exceeding 3 standard deviations compared to the long-term mean averaged from 1981-2010.
- Warming extended to ~300m.

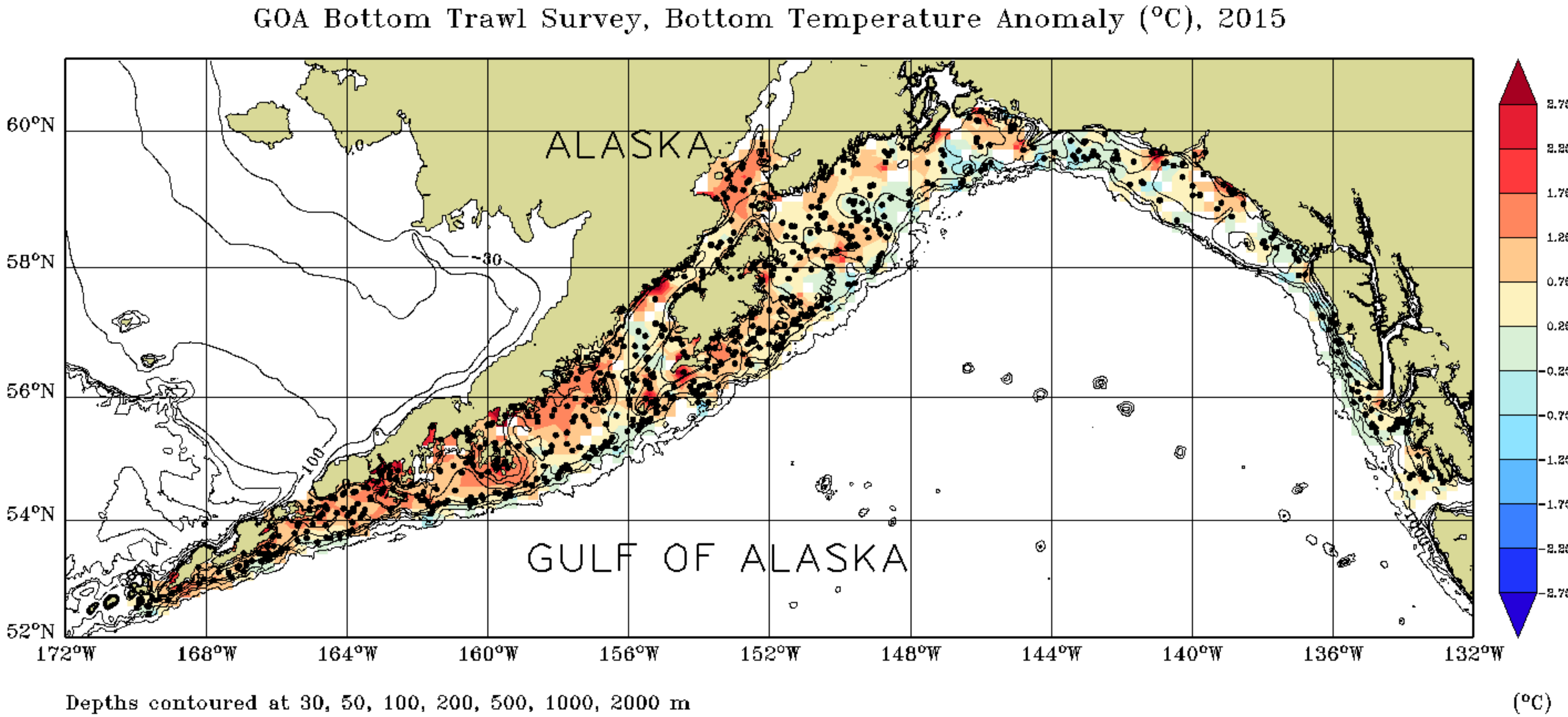


AFSC Bottom Trawl Survey



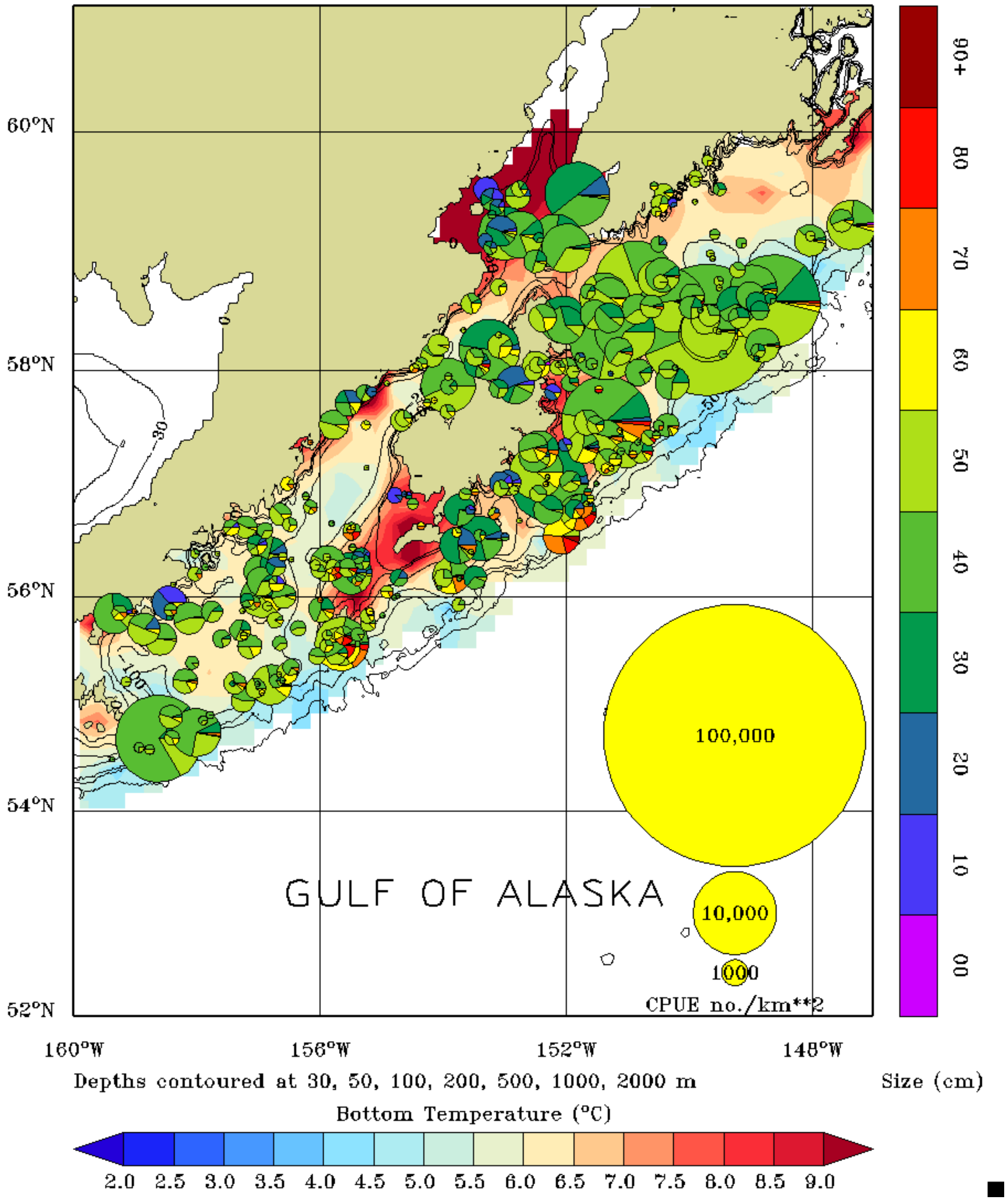
Courtesy of Wayne Palsson

- A dataset of fish abundance (CPUE; # per km^2), bottom temperature (^{o}C) and bottom depth (m) from ten summers of 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, and 2015 was analyzed.
- Six fish species: Pacific cod, arrowtooth flounder, Pacific ocean perch, walleye pollock, northern rock sole, and southern rock sole.
- Fish were binned by size (an interval of 10 cm) to account for ontogenetic differences.

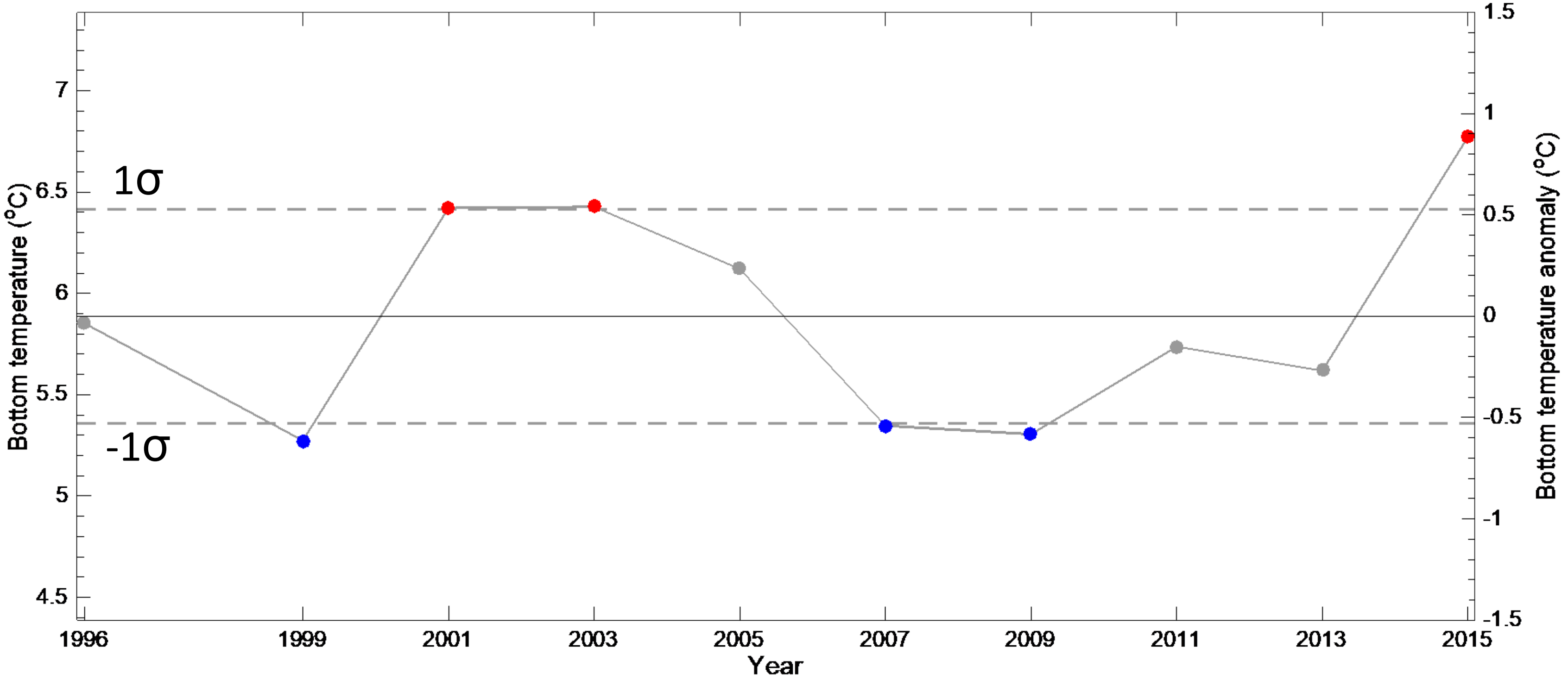


Black dots: locations of the 2015 bottom trawl stations

CGOA Bottom Trawl Survey, Pacific Cod CPUE, 2015

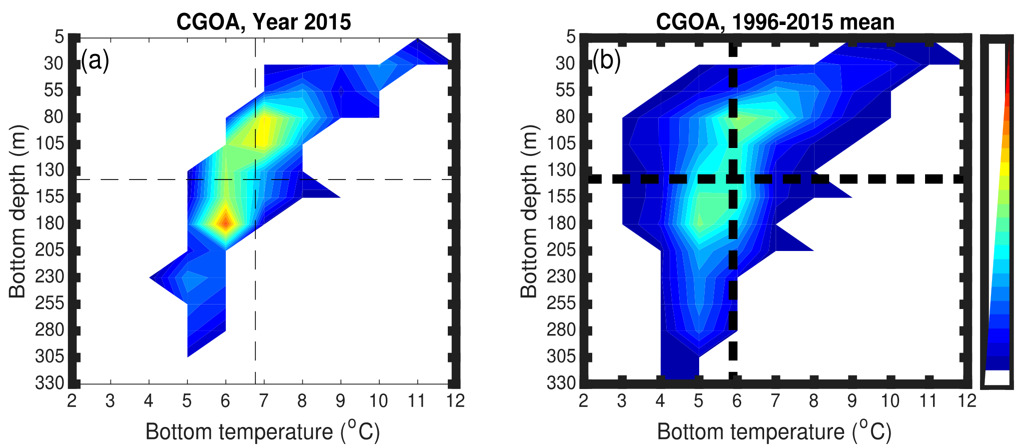


Annual mean stratum-area-weighted bottom temperatures averaged over the CGOA



In general, warm years (T > 1σ): 2001, 2003, and 2015
cold years (T < -1σ): 1999, 2007, and 2009
neutral years (-1σ ≤ T ≤ 1σ): 1996, 2005, 2011, and 2013

Joint probability density function of habitat as defined by bottom temperature and bottom depth



T_{mean}: 6.8°C
D_{mean}:137.9m

T_{mean}: 5.9°C
D_{mean}:137.4m

ΔT_{mean}: 0.9°C
ΔD_{mean}:0.5m

Joint probability density function of 50-cm Pacific cod abundance as a function of bottom temperature and bottom depth

CPUE-$T_{centroid}$: 6.7°C
CPUE-$D_{centroid}$:135.5m

CPUE-$T_{centroid}$: 5.8°C
CPUE-$D_{centroid}$:109.4m

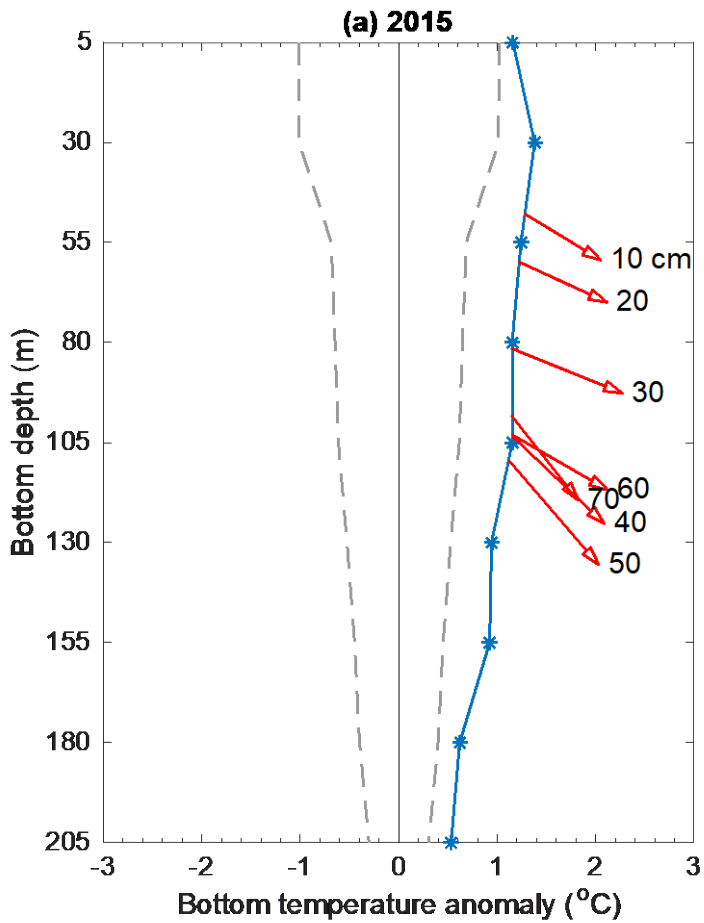
ΔCPUE-$T_{centroid}$: 0.9°C
ΔCPUE-$D_{centroid}$:26.1m

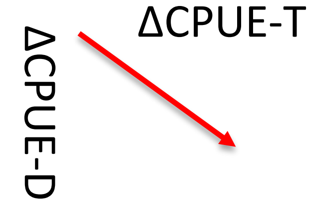
Gray shading: no available habitat
White shading: zero fish catch

Vertical profiles of habitat temperature anomalies

The Blob year 2015

Pacific cod





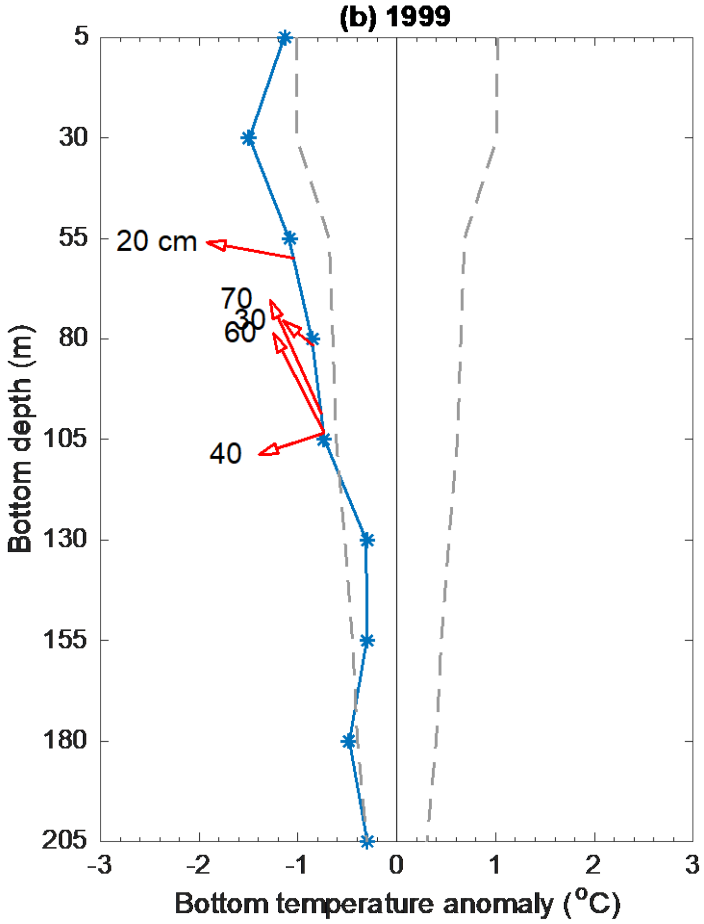
arrows: direction of changes in the CPUE-weighted centroid temperature and depth.

Pacific cod were found in deeper bottom depths in 2015

The arrows are plotted only if the vertical change in centroid depth is statistically significant at the 95% level based on the two-sided student's t-test.

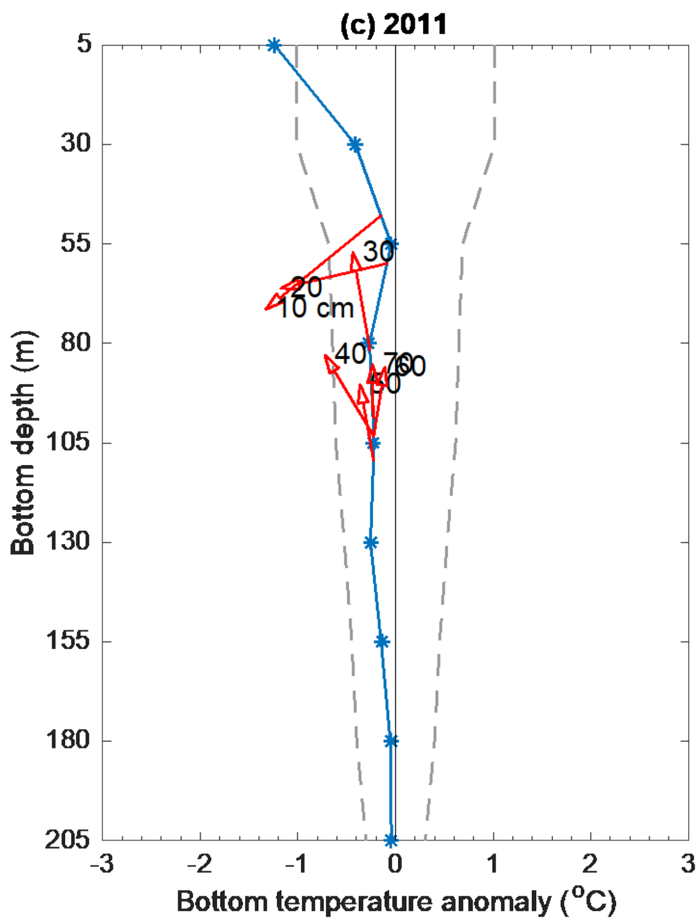
Coldest year 1999

Pacific cod



Pacific cod generally moved to shallower bottom depths, except for the 40-cm cod that reside at the depth with a relatively small temperature anomaly in 1999 neutral year 2011

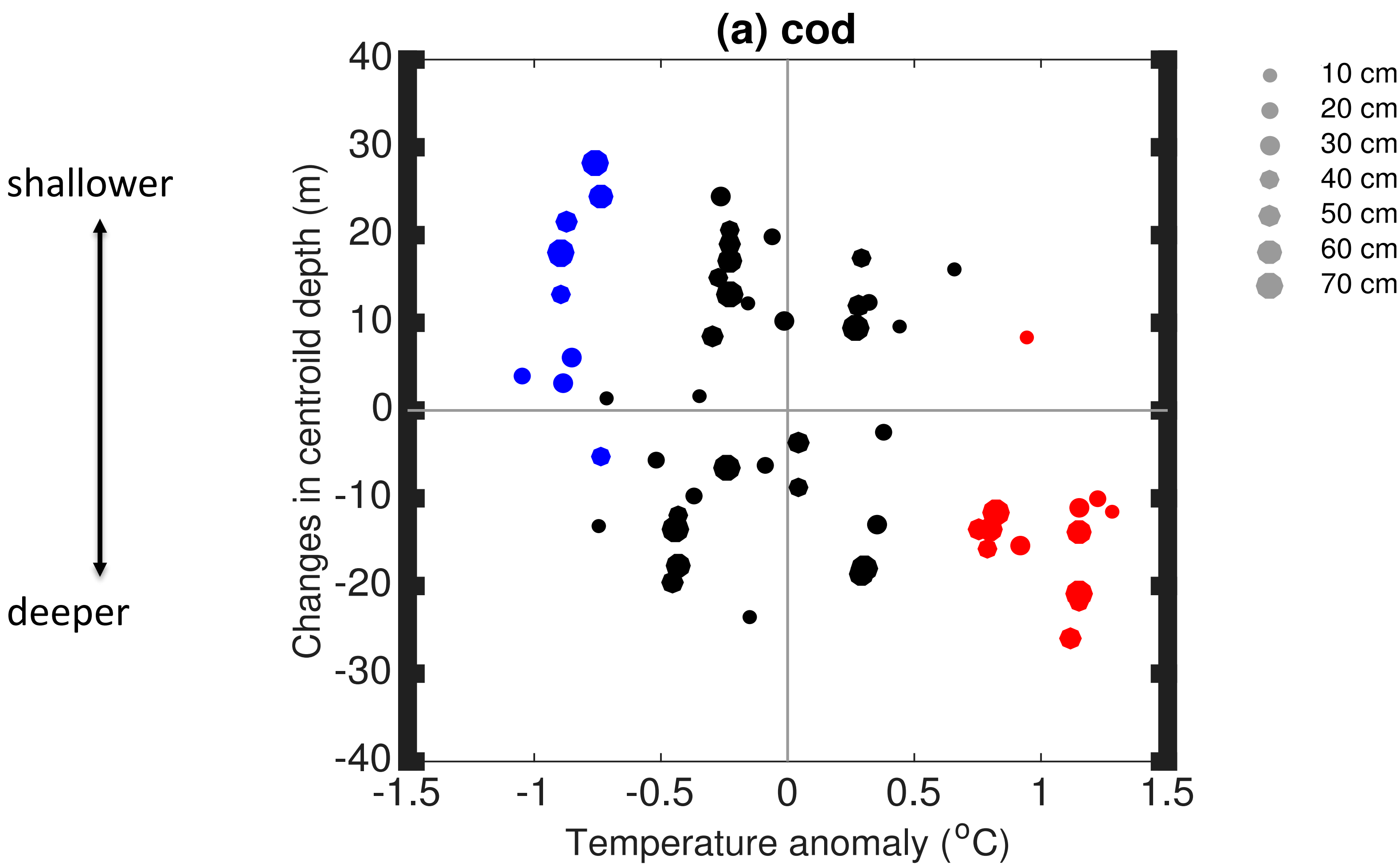
Pacific cod



10- and 20-cm Pacific cod moved deeper

≥ 30-cm Pacific cod moved shallower

Pacific cod
(Piscivorous groundfish)



In general, Pacific cod moved to deeper bottom depths in warmer years and shallower bottom depths in colder years

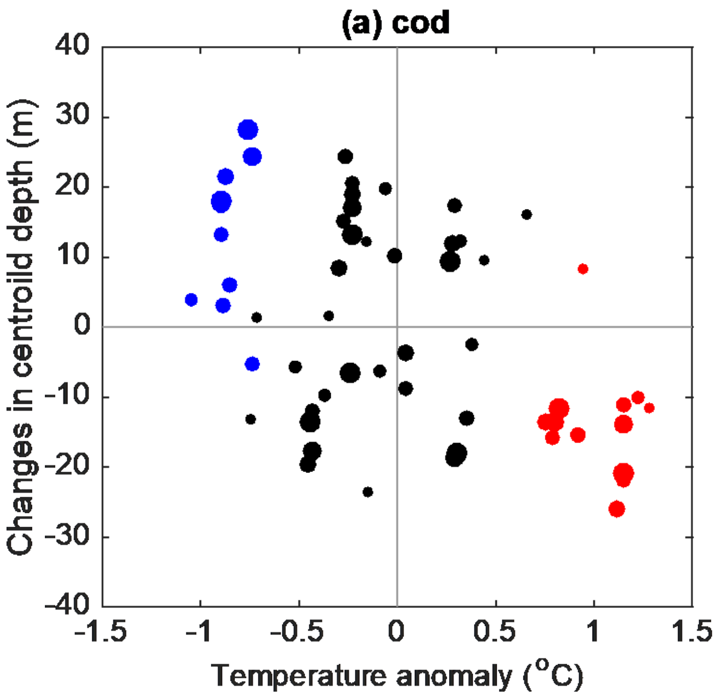
Piscivorous groundfish

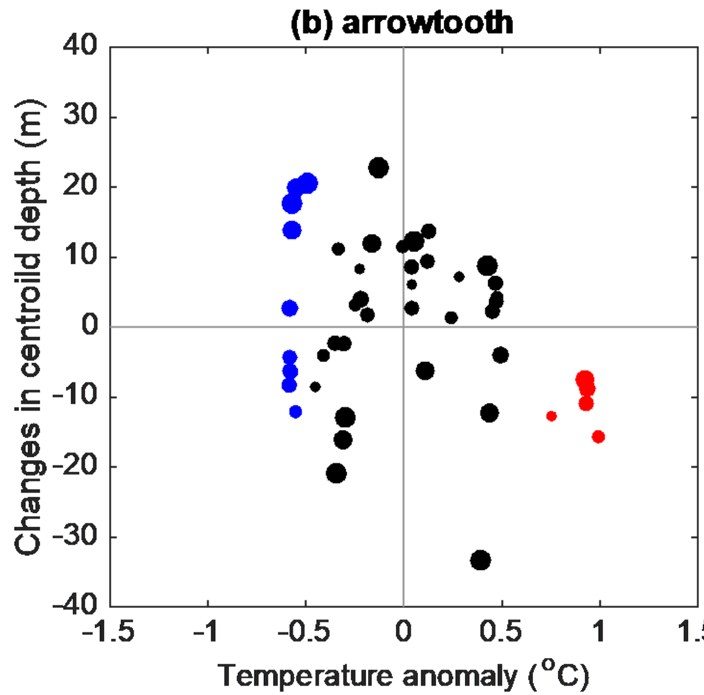
Pacific cod

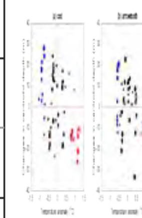
Arrowtooth flounder

shallower

deeper







- In general, Pacific cod moved to deeper bottom depths in warmer years and shallower bottom depths in colder years
- Arrowtooth flounder moved to deeper bottom depths in warmer years. However, in cold habitat, large-sized (> 40 cm) arrowtooth flounder shifted shallower while smaller ones shifted deeper

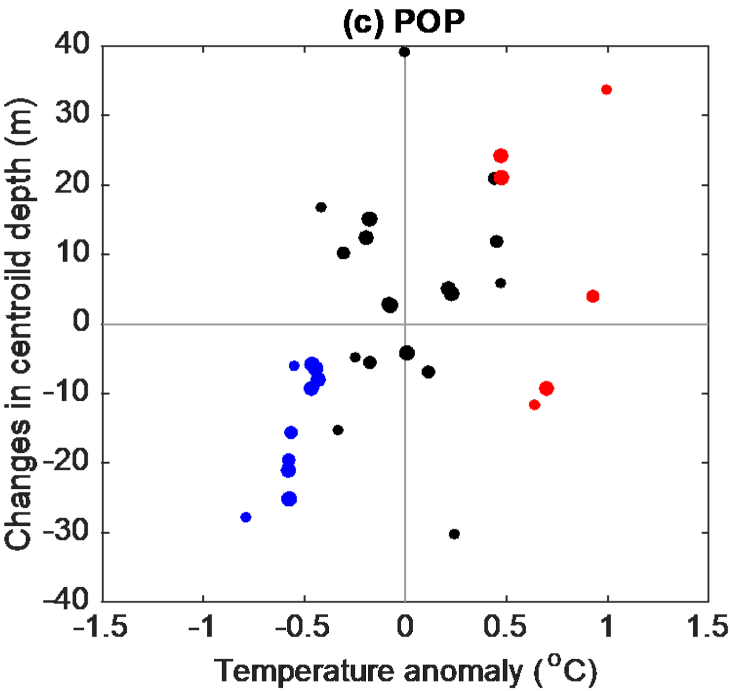
Pelagic planktivore

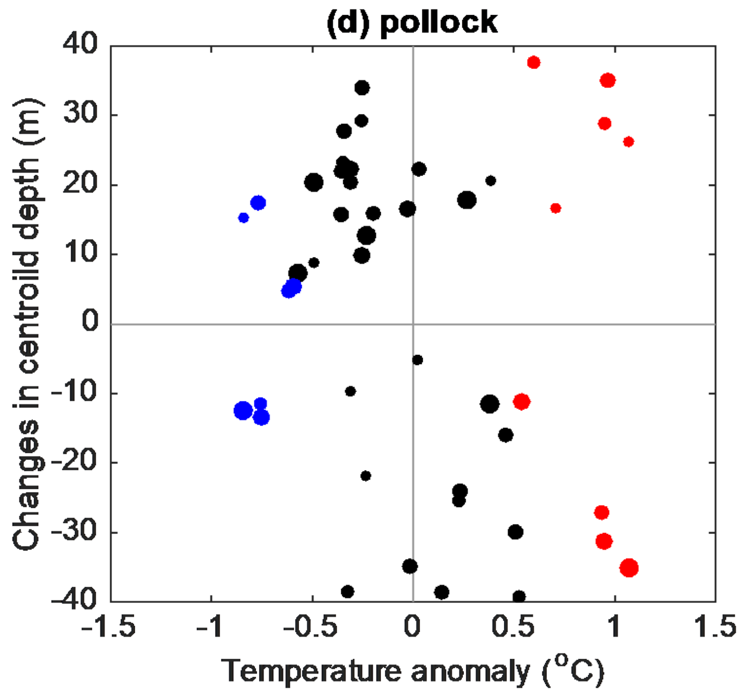
Pacific ocean perch

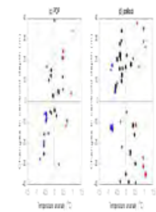
Walleye pollock

shallower

deeper







- Pacific ocean perch moved deeper in colder years
- In warmer years, smaller-sized (10-20 cm) pollock moved shallower while larger ones (> 30 cm) moved deeper

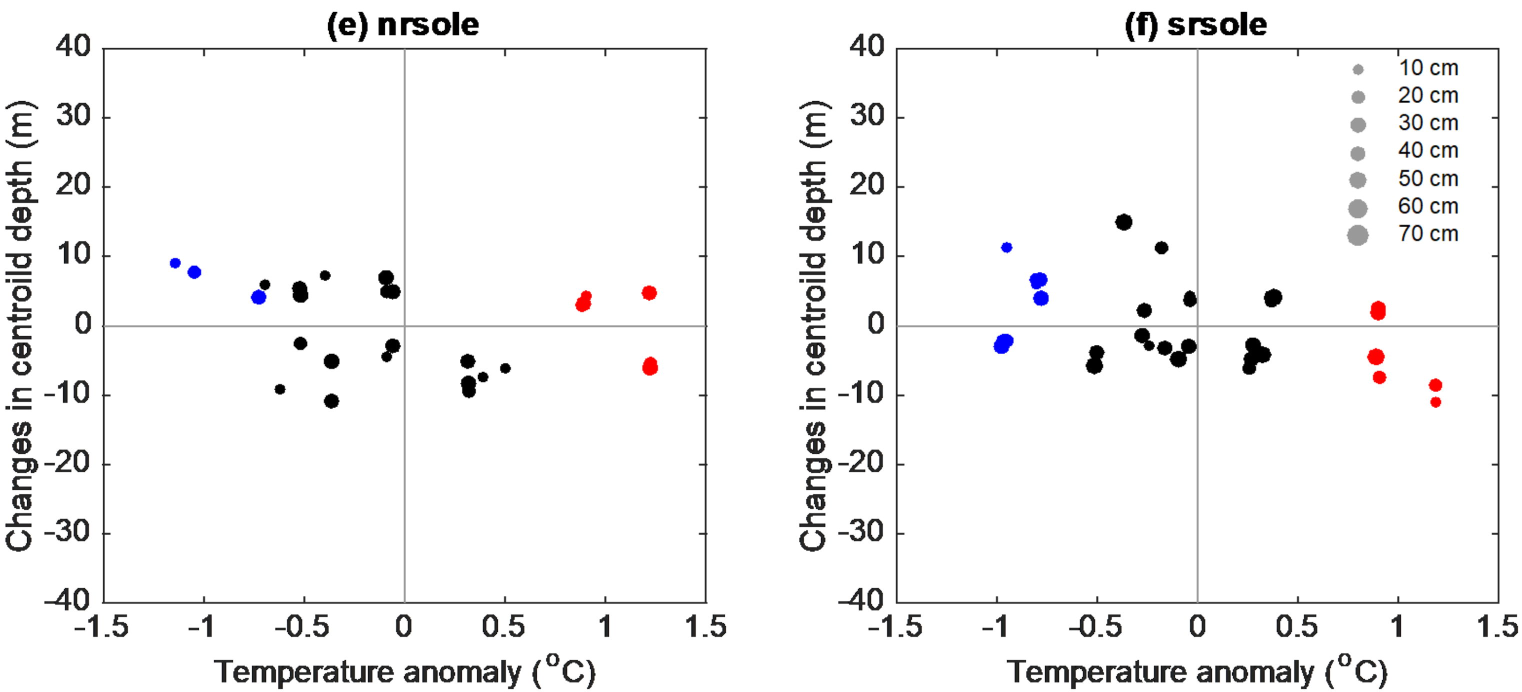
Benthivore

shallower

deeper

Northern rock sole

Southern rock sole



Northern rock sole were found in shallower waters in colder years

Summary

- It is important to account for the temperature anomalies at the depth where a species resides for a given size bin.
- The two piscivorous groundfish show similar responses to ocean warming but different responses to cooler ocean conditions. In general, Pacific cod moved to deeper bottom depths in warmer years and shallower bottom depths in colder years. Arrowtooth flounder also moved deeper in warmer years. However, in cold years, larger arrowtooth flounder moved shallower, but smaller ones moved deeper.
- The two pelagic planktivore groundfish exhibited different responses to habitat temperature changes. Pacific ocean perch exhibited an opposite response to thermal changes in habitat, compared to Pacific cod and arrowtooth flounder. They moved deeper in colder years but no clear change in depth-at-size in warmer years. In response to warmer habitat, smaller pollock (10-20 cm) were found in shallower waters and larger pollock (> 30 cm) in deeper waters. However, there was no clear change in depth-at-size in colder years.
- Northern rock sole (a benthivore) moved shallower in colder waters, but no clear movements to warmer waters were observed. No noticeable changes in depth-at-size were observed for southern rock sole.

Yang Q., E. Cokelet, P. Stabeno, L. Li, A. Hollowed, W. Palsson, N. Bond, S. Barbeaux (2018), How "The Blob" affected groundfish distributions in the Gulf of Alaska, *Fisheries Oceanography*, in review.