Effects of Warm and Cold Years on Flathead Sole *Hippoglossoides elassodon* spawning in the Southeast Bering Sea

Steven M. Porter
Recruitment Processes Program, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center
NOAA Fisheries, 7600 Sand Point Way NE, Seattle, Washington 98115, USA

Lorenzo Ciannelli
College of Earth, Ocean, and Atmospheric Sciences,
Oregon State University, Corvallis, Oregon 97331, USA

The objective of this study was to determine how warm and cold conditions affected the distribution and abundance of Flathead Sole eggs spawned in May in the southeast Bering Sea (Fig. 1).

Introduction

In the recent past the eastern Bering Sea has alternated between periods of warm (2001-2005) and cold (2007-2013) conditions during the spring. Warm conditions had reduced sea ice cover, westward winds, and weak currents. Cold conditions were characterized by significant sea ice cover, winds from the north, and westward currents. Biological differences included changes in zooplankton community composition and abundance (Stabeno et al. 2012).

Flathead Sole *Hippoglossoides elassodon* are a pleuronectid that inhabit the continental shelf waters of the North Pacific Ocean from the northwest coast of North America to the Sea of Okhotsk in Asia. They are also abundant on the continental shelf of the eastern Bering Sea and spawn pelagic eggs there during the spring. Bottom water temperature can influence the spatial distribution of adult Flathead Sole, and thus affect where spawning occurs.

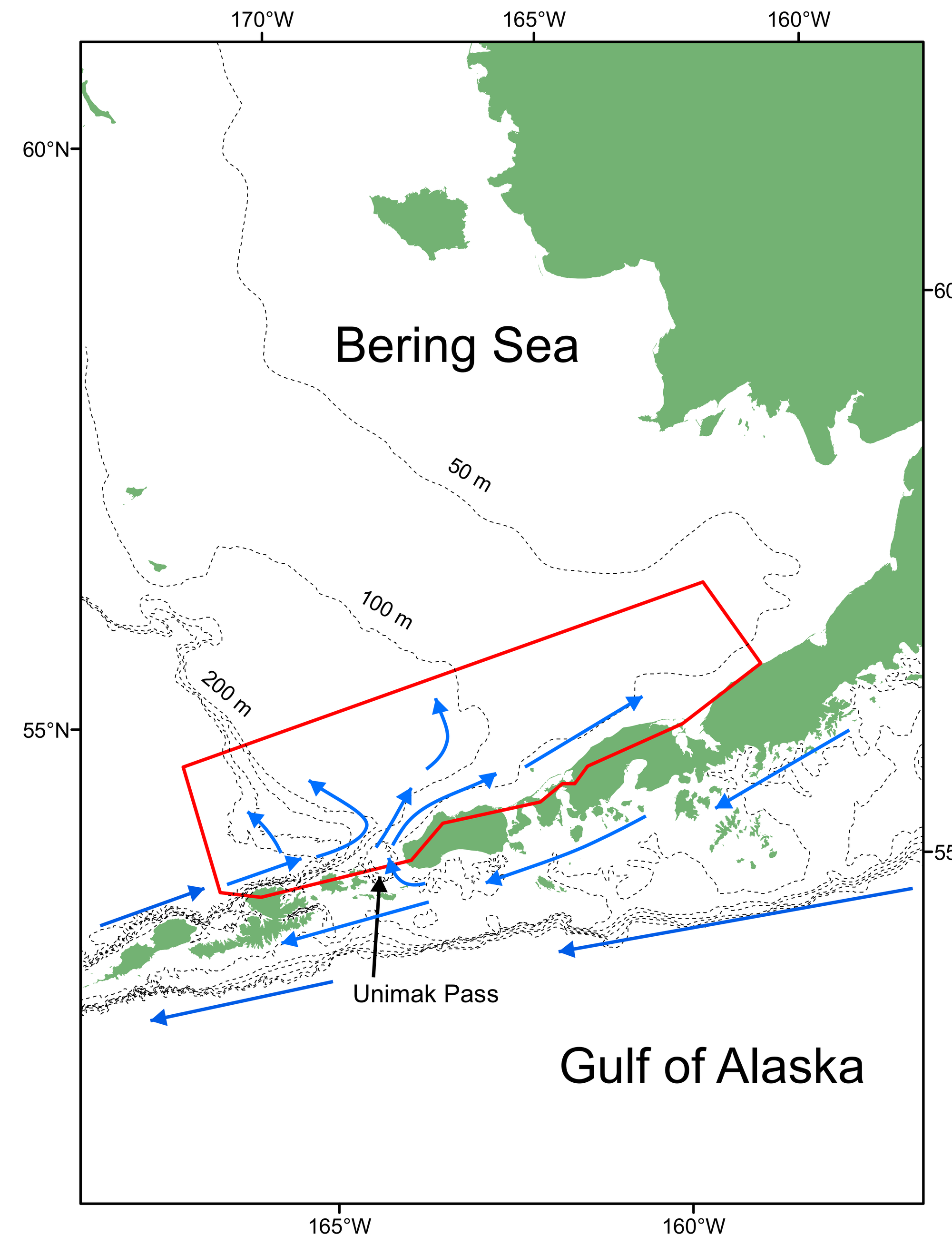
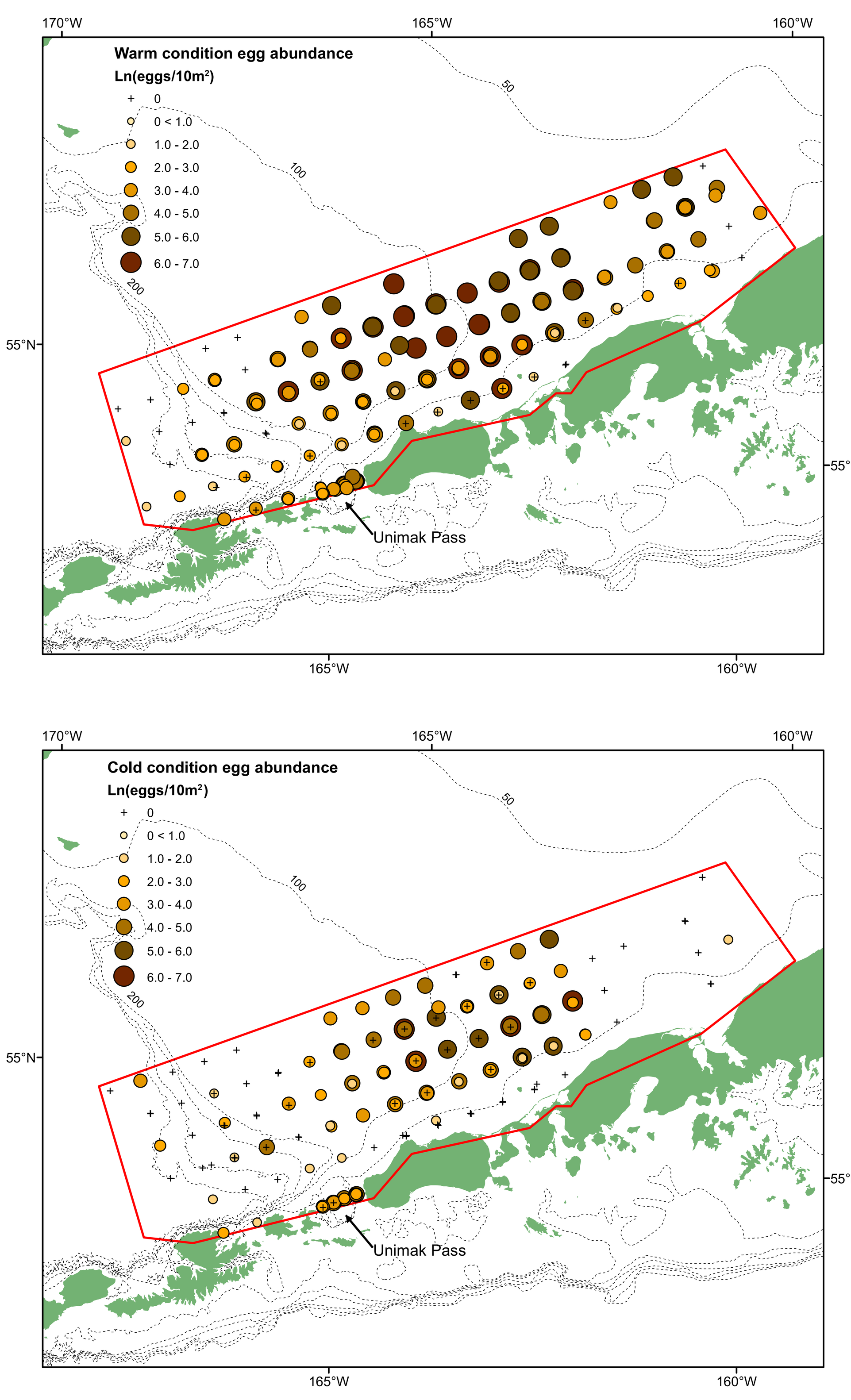


Figure 1. Study area (red outline), and major currents (blue arrows).



Figures 2 and 3: Measured egg abundance during warm (top panel) and cold (bottom panel) conditions.

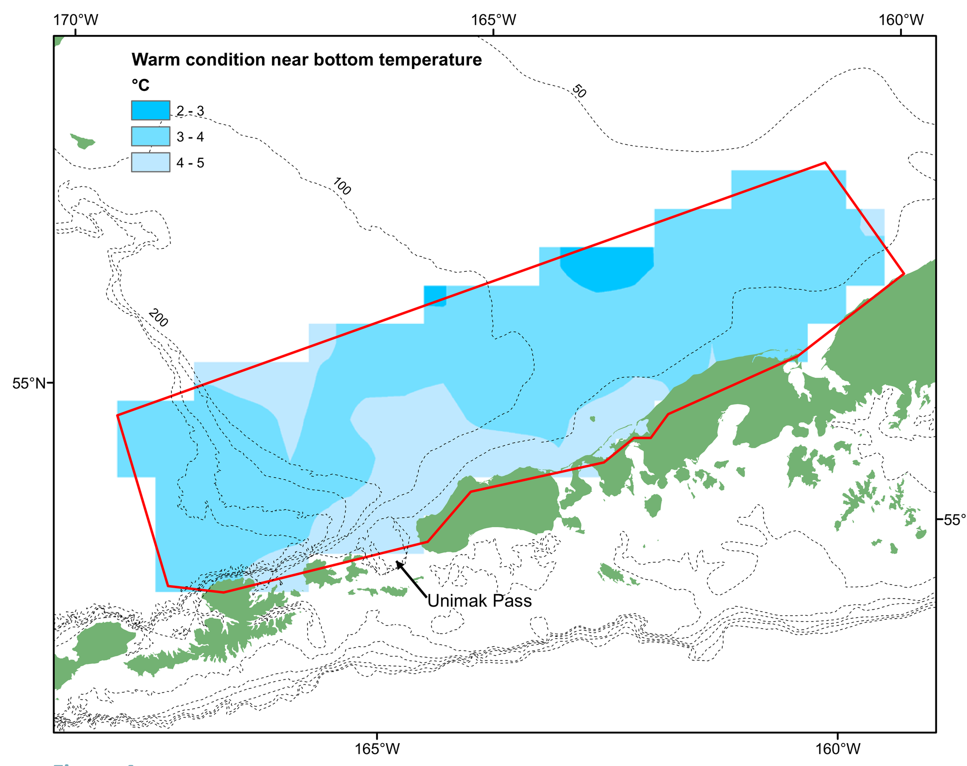


Figure 4

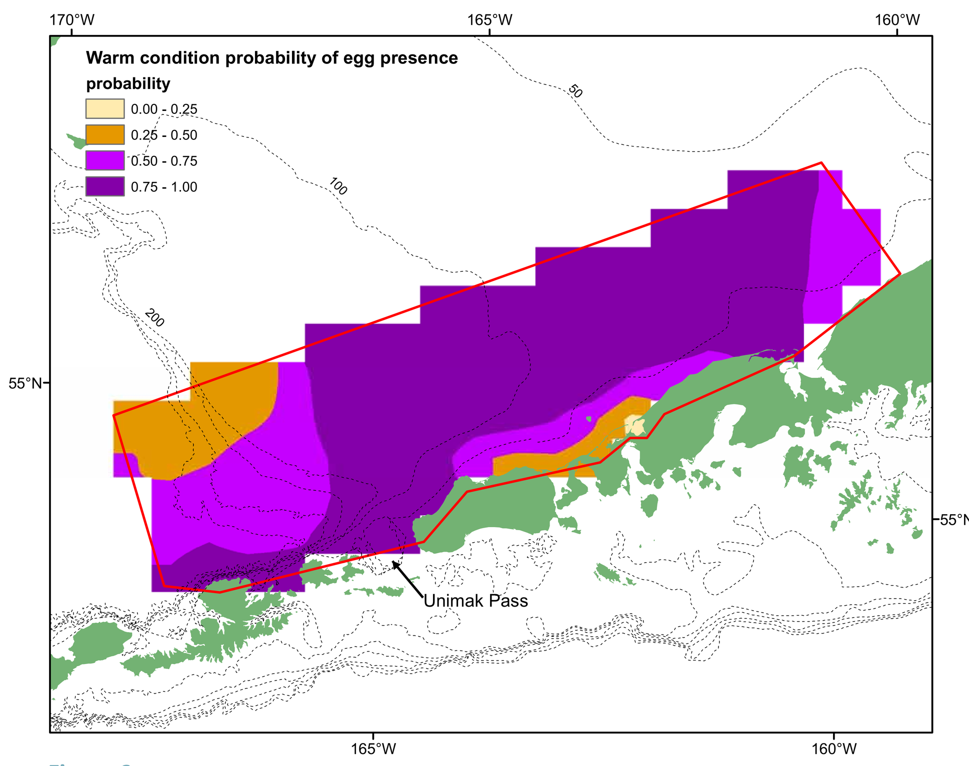


Figure 6

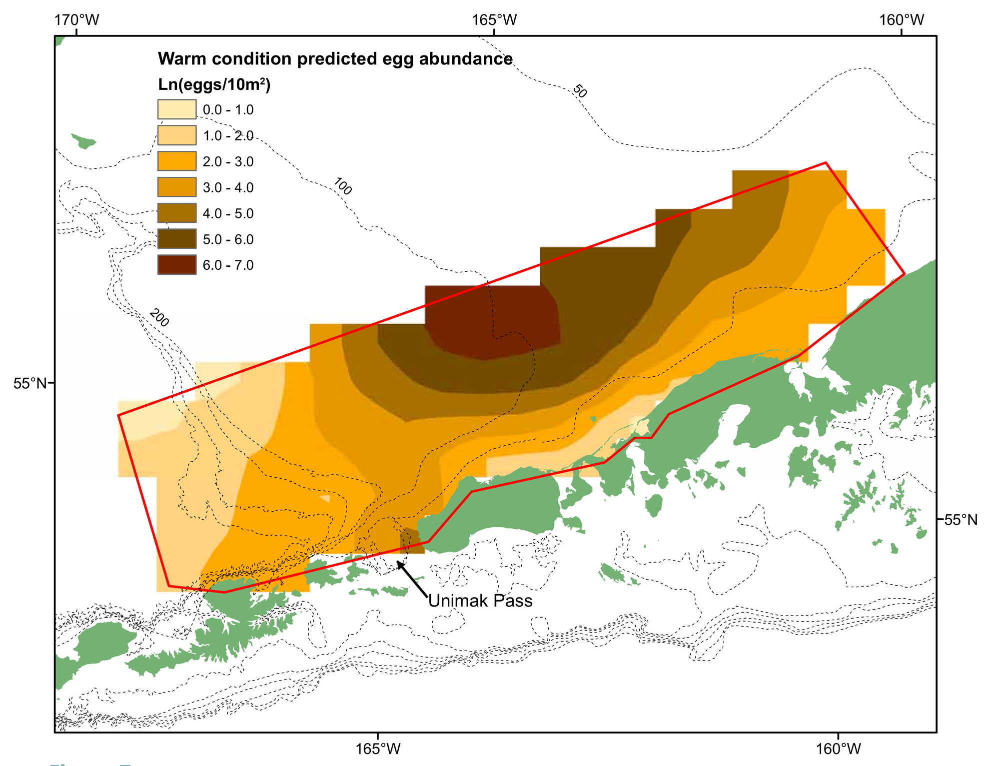


Figure 7

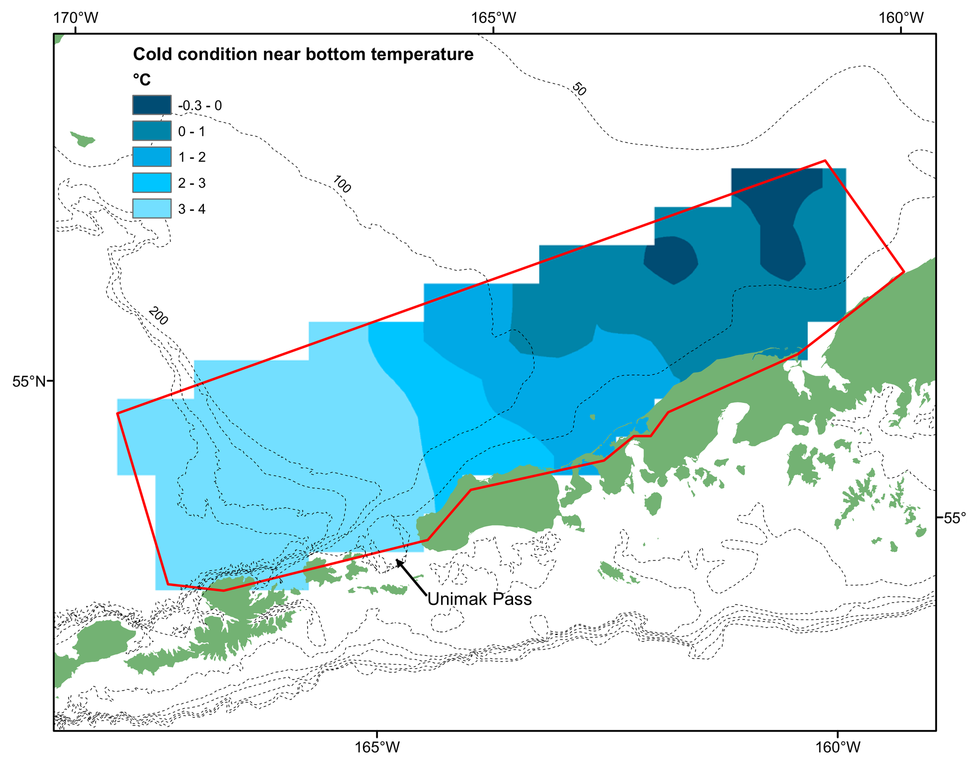


Figure 5

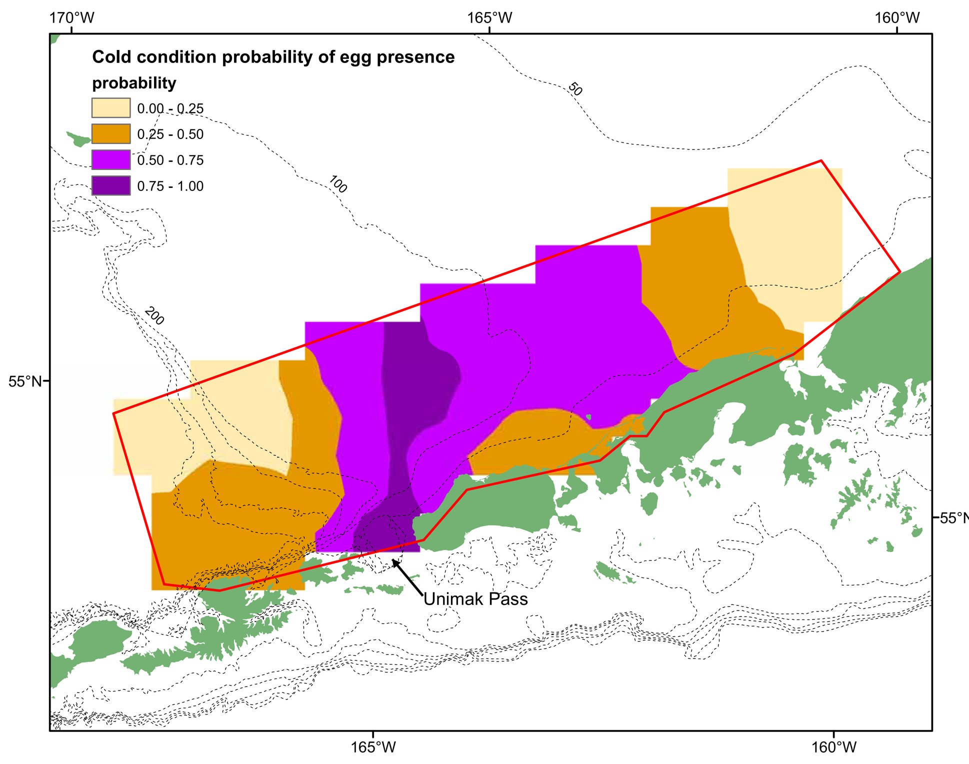


Figure 8

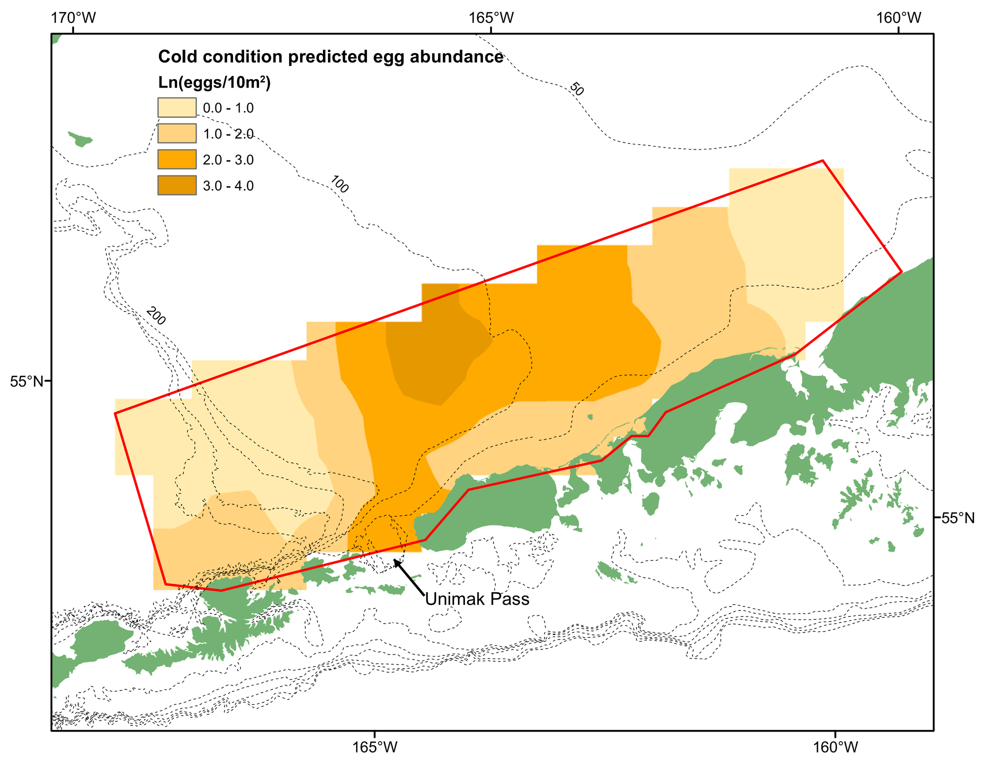


Figure 9

Methods

Egg abundance (number/10 m^2) was determined from ichthyoplankton surveys conducted during warm (2002, 2003 and 2005) and cold (2007 - 2010) conditions (sampling methodology is described in Matarese et al. 2003). Eggs were collected during May in the southeast Bering Sea from the same station locations among years (Fig. 2 and 3). Water column temperature was measured at each station using a CTD.

GENERAL ADDITIVE MODELS (GAM)

Variable-coefficient general additive models were used to account for temperature effect on egg abundance varying with location (latitude and longitude). Covariates initially tested were spawning stock biomass for the eastern Bering Sea and Aleutian Islands area for each year, latitude, longitude, day of year, near bottom water temperature, and warm or cold condition. The number of stations used for warm condition was 170, and 152 for cold condition. Given the overdispersed nature of the egg data (about 30% of the data were zero) a two-step approach was used to model egg distribution (Fox et al. 2000). First we fit a binomial presence/absence model, then a model with natural log transformed egg abundance having only catches > 0 used for the response variable. Model diagnostics, such as residual plots and Akaike Information Criterion (AIC), were used to determine the covariates that produced the best model fit for each type. The product of the binomial and egg abundance models was used to estimate egg abundance throughout the study area during warm or cold conditions.

Results

Near bottom water temperatures were almost homogenous during warm conditions, ranging between 3° and 5°C (Fig. 4).

During cold conditions near bottom temperatures varied greatly, from below 0°C in the northeast to nearly 4° in the southwest (Fig. 5).

MODELED EGG ABUNDANCE

Both the binomial and egg abundance models had spawning stock biomass, day of year, near bottom temperature, and latitude and longitude as covariates. The binomial model explained 44% of the deviance, and egg catch model explained 67%.

Eggs were more abundant and were present throughout the continental shelf during warm conditions indicating that spawning most likely was occurring there (Figs. 6 and 7). The transport of eggs from the Gulf of Alaska through Unimak Pass may be greater during the warm conditions as indicated by the relatively large area of high probability of egg presence and higher abundance through the pass and into the Bering Sea (Figs. 6, 7, 8, and 9). Area of highest egg abundance contracted and shifted to the southwest during cold conditions, possibly indicating that spawning Flathead Sole were avoiding temperatures less than 2°C that were occurring in the northeast (Figs. 7 and 9). Delayed spawning due to cold conditions could have influenced egg abundance and distribution but it could not be investigated due to lack of surveys later in the spring.

Conclusion

Flathead Sole exhibit some degree of plasticity in spawning distribution related to springtime water temperature. We documented changes of both location and number of eggs spawned, and this could have potential consequences on early-life survival and recruitment of this species by affecting larval drift toward nursery areas, and spatial overlap with predators and prey.

REFERENCES

Fox CJ, O'Brien CM, Dickey-Collas M, Nash RDM (2000) Patterns in the spawning of cod (*Gadus morhua* L.), sole (*Solea solea* L.) and plaice (*Pleuronectes platessa* L.) in the Irish Sea as determined by generalized additive modeling. Fish Oceanogr 9: 33-49.

Matarese AC, Blood DM, Picquelle SJ, Benson JL (2003) Atlas of abundance and distribution patterns of ichthyoplankton from the northeast Pacific Ocean and Bering Sea ecosystems based on research conducted by the Alaska Fisheries Science Center (1972-1996). NOAA Prof. Paper NMFS 1, 281 p.

Stabeno PJ, Kachel NB, Moore SE, Napp JM, Sigler M, Yamaguchi A, Zerbini AN (2012) Comparison of warm and cold years on the southeastern Bering Sea shelf and some implications for the ecosystem. Deep-Sea Res II 65-70: 31-45.