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Migration Behavior Changes of Juvenile North Pacific Albacore linking to Environmental Variability

Yi Xu, Steven Teo, Stephanie Snyder, and Suzanne Kohin

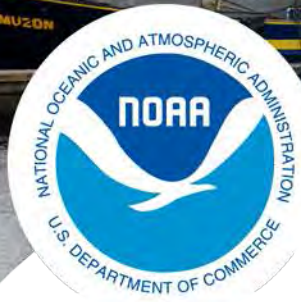


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PICES 2015 Annual Meeting
Qingdao, China, October 15th, 2015

About us



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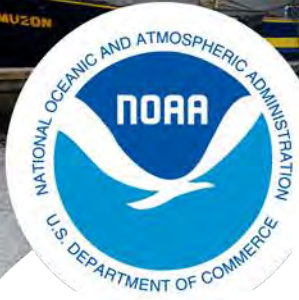
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We generate science necessary for the conservation and management of living marine resources in the California Current, Pacific Ocean and in Antarctica.

About the Species



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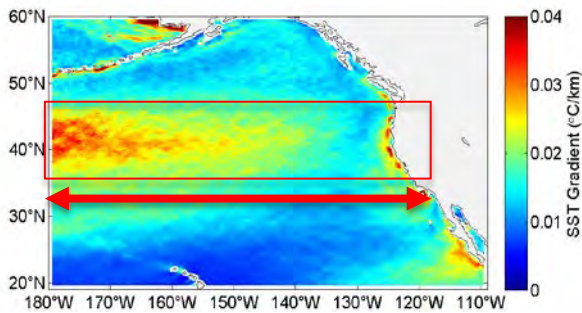
- Highly migratory
- Juvenile age 2-5, size 57-110cm
- Good omega-3 sources
- Sushi/sashimi
- Canning
- Currently healthy stock status



Background & Objectives

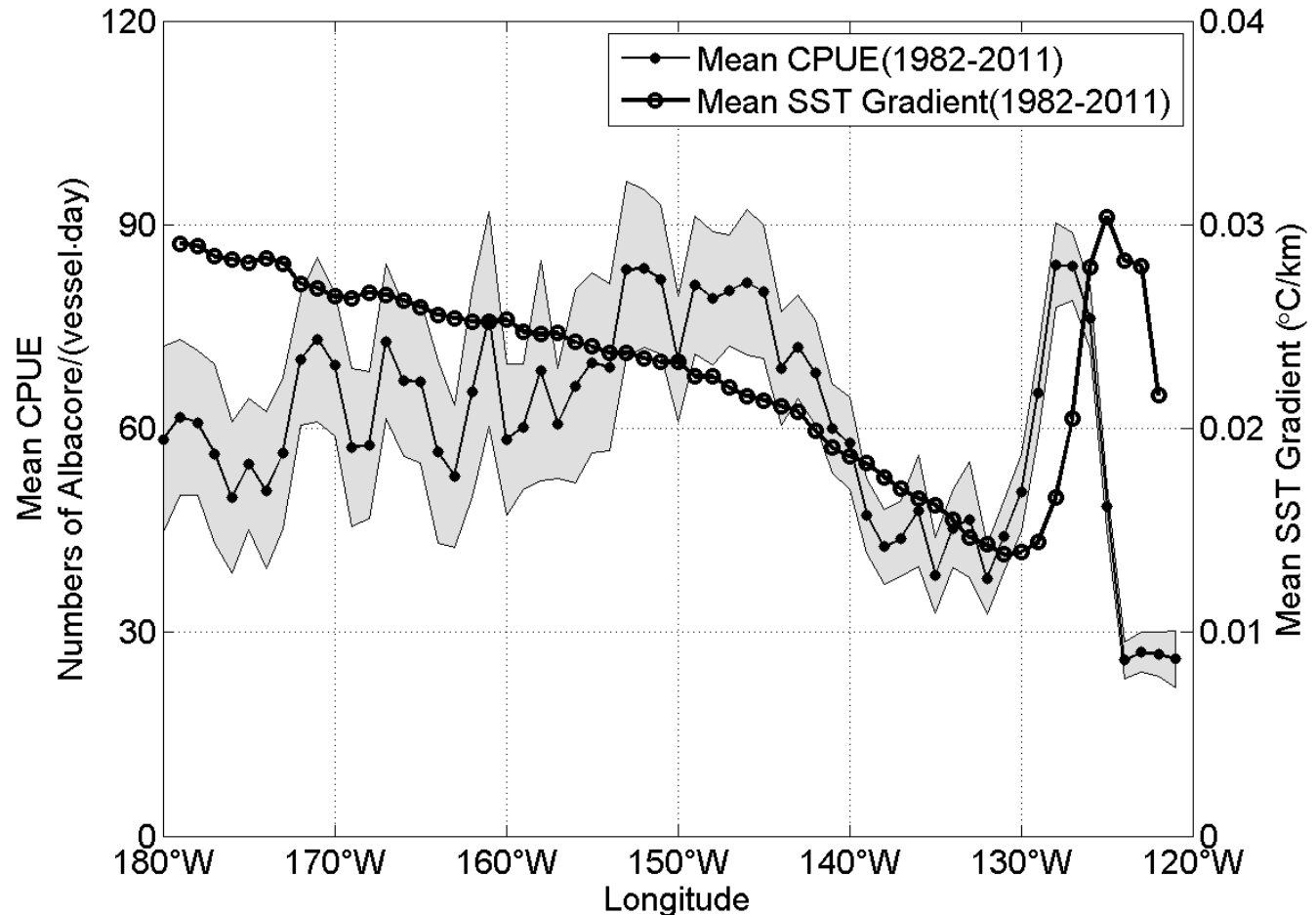
- The albacore surface fishery (troll and pole-and-line) is the most important commercial tuna fishery on the US and Canada West Coast.
- **Previous research study** showed that albacore distribution is associated with **sea surface temperature gradient and SST front** over large spatial (northeast Pacific) and temporal scales (30 years, 1982-2011). Higher CPUE were observed at places with greater SST gradient longitudinally. (Xu et al., 2015, Progress in Oceanography, In Press)
- **Our objective** is to study albacore **behavior changes (movement, diving, ambient water and body temperature changes, etc)** in different study areas identified by SST gradients and fronts, using archival tagging data.

Longitudinal changes in mean SST gradient & CPUE



SST gradient decrease from west to east, reaching min@130W, before rapidly increase near the coast.

Albacore CPUE generally has higher value in the transition zone, and reaching min@132-135W, and rapidly increase near the coast.



Data

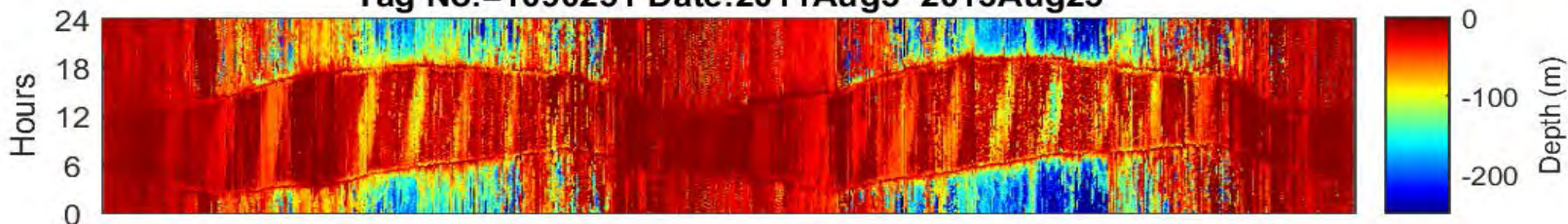
- Archival tags (manufactured by Wildlife Computers, USA and Lotek Wireless, Canada)
- 920 tags were deployed in 2004-2014 (123 tags in 2015)
- 29 recoveries (recover rate 3.2%)
- 13 albacore crossed all interested regions
- Time, light level, depth, body temperature, and water temperature were measured and recorded from the tags.



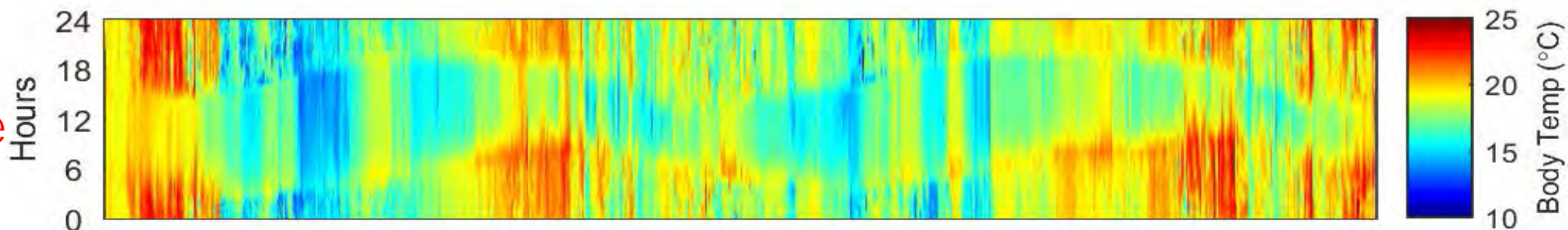
Raw Data

Tag No.=1090251 Date:2011Aug3~2013Aug25

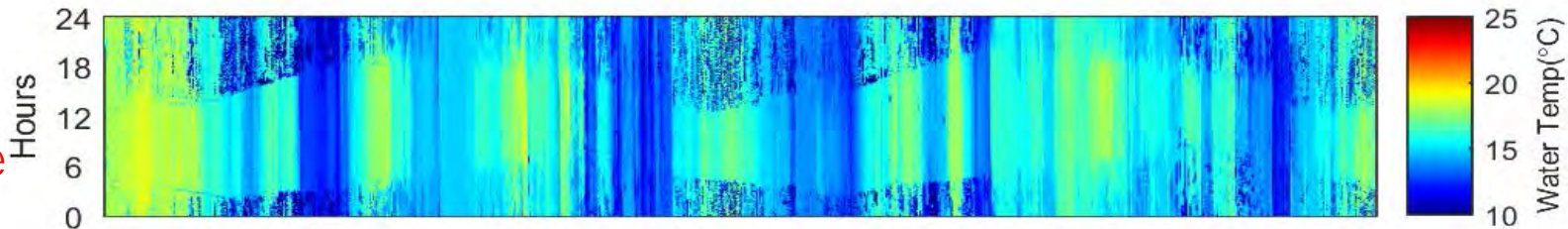
Depth



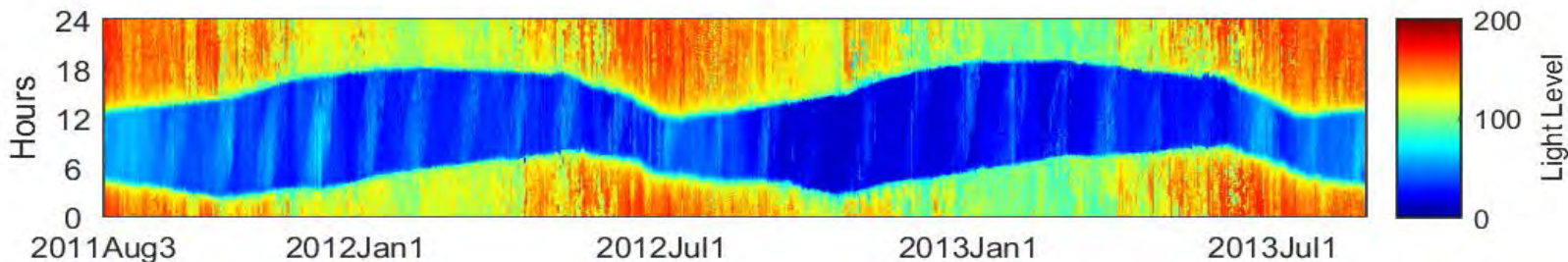
Body Temperature



Water Temperature

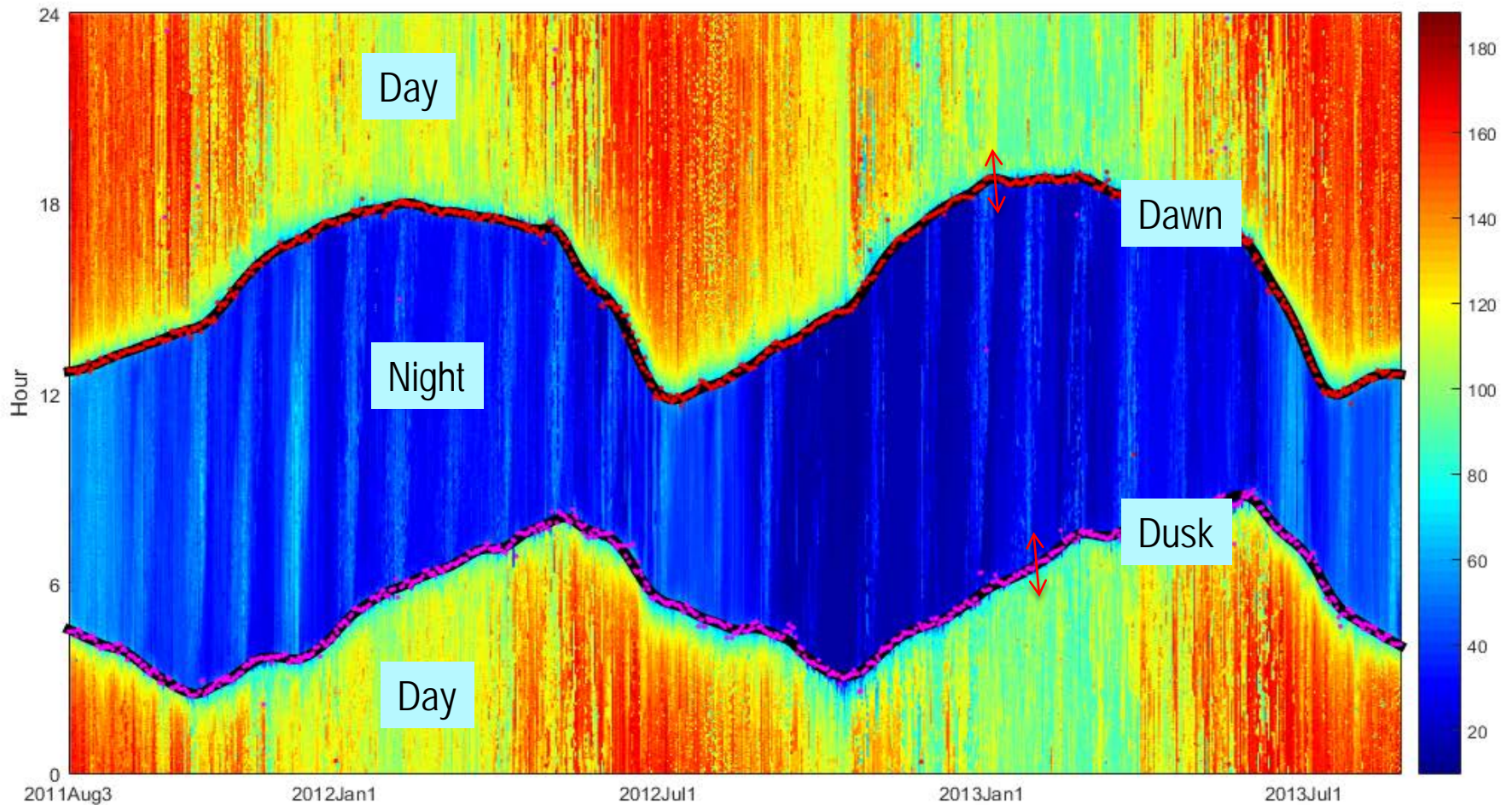


Light Level



Estimate Sunrise/Sunset from Light level

$$\text{sunrise: } \max\left(\frac{d\text{LightLevel}}{Dt}\right) \quad \text{sunset: } \min\left(\frac{d\text{LightLevel}}{Dt}\right)$$



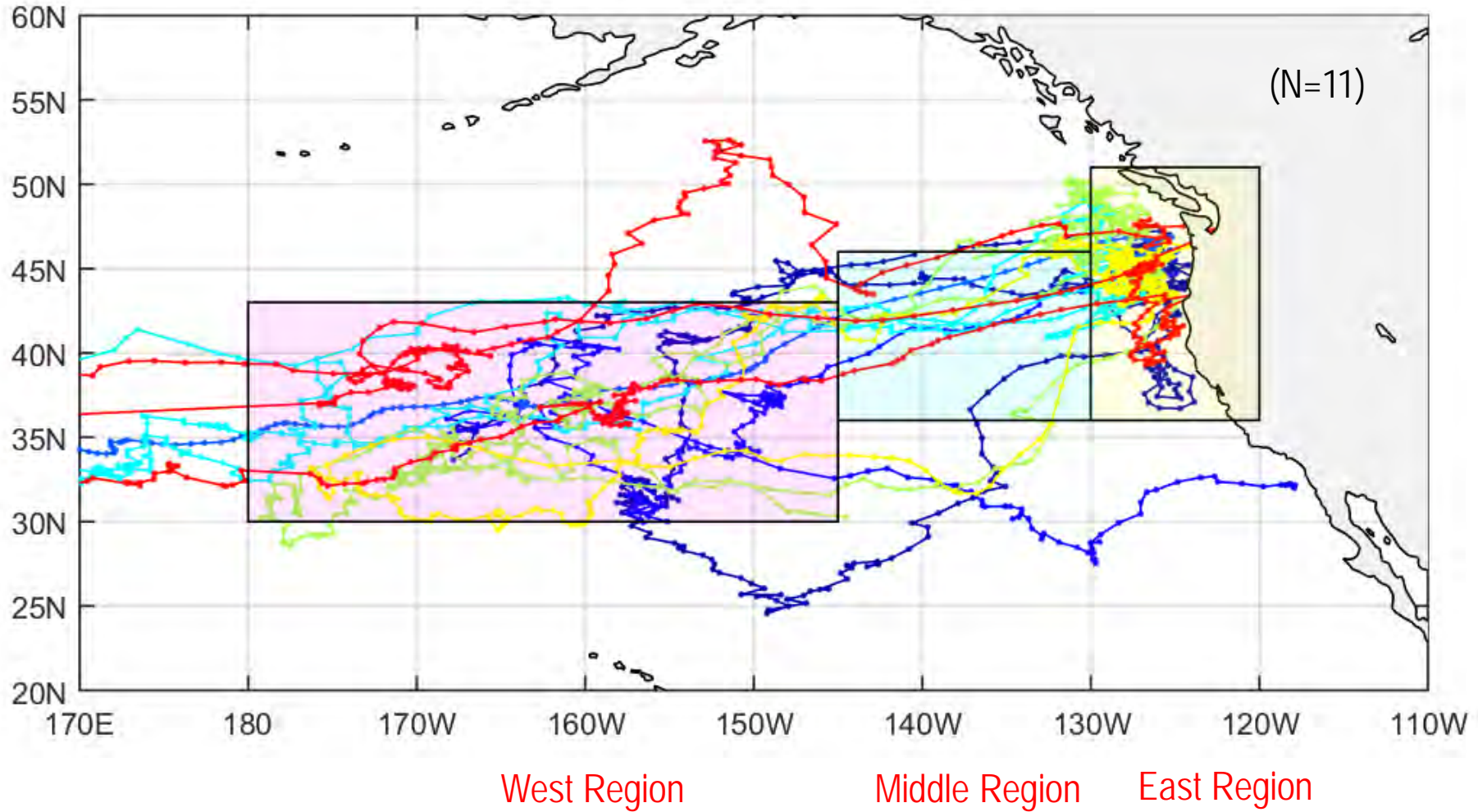
Summary of tags

Tag number	Type	Release			Recover			Days at liberty
		Date	Latitude	Longitude	Date	Latitude	Longitude	
B2381	Lotek	2004/07/01	44.53	-125.63	2005/09/01	45.53	-125.97	428
B2398	Lotek	2004/07/01	44.52	125.62	2005/09/19	45.85	-126.50	446
B2393	Lotek	2004/06/30	44.71	-125.76	2006/05/27	30.30	-144.58	697
0490306	Wildlife	2004/09/13	45.03	-125.28	2005/12/06	33.70	-167.83	450
0690063	Wildlife	2006/08/07	46.10	-124.87	2007/06/29	32.00	-117.92	327
0690065	Wildlife	2006/08/07	46.07	-124.87	2007/05/27	32.5*	-140.1*	294
0690078	Wildlife	2006/10/06	46.11	-125.14	2008/06/26	13	-172	630
D1045	Lotek	2006/08/06	46.02	-124.95	2008/06/16	31.21	-139.34	681
A0394	Lotek	2011/08/03	44.82	-126.35	2012/08/15	46.77	-125.22	379
1090269	Wildlife	2011/08/04	44.85	-126.34	2013/06/26	35.23	143.68	693
A0396	Lotek	2011/08/03	44.89	-126.38	2013/06/16	35.25	145.25	684
1090251	Wildlife	2011/08/03	44.80	-126.35	2013/08/24	46.06	-126.41	753
1190241	Wildlife	2011/10/08	46.51	-124.99	2014/09/03	N/A	N/A	1061

(N=13)



Daily Estimated Geolocations

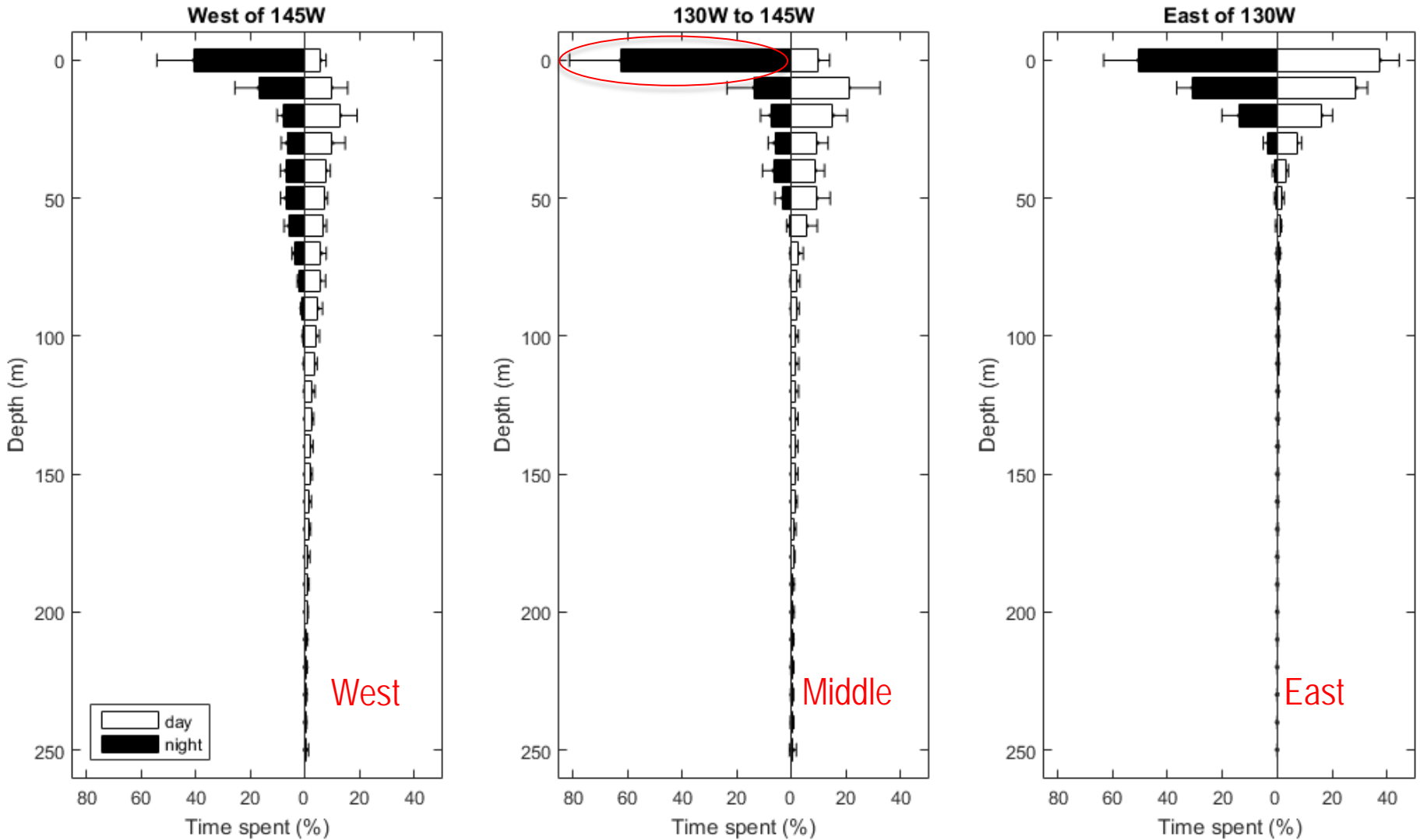


Results

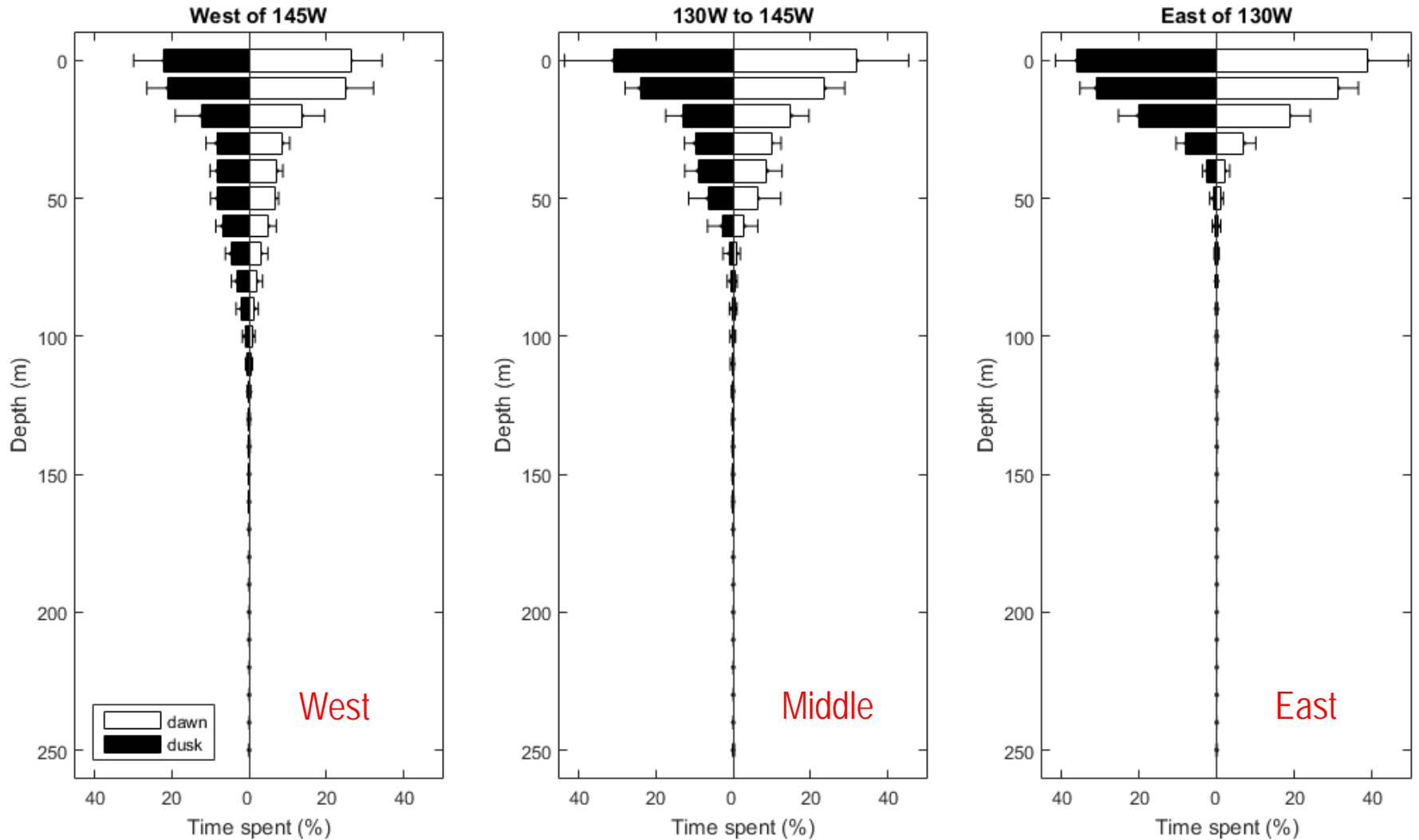
- Percentage of time in vertical water columns (day/night)
- Percentage of time in vertical water columns (dawn/dusk)
- Ambient Water Temperature
- Body Temperature
- Average Horizontal Daily Speed
- Average Cumulative Vertical Daily Speed

Mean Percentage of Time Spent at Depth during Day/Night

n=11

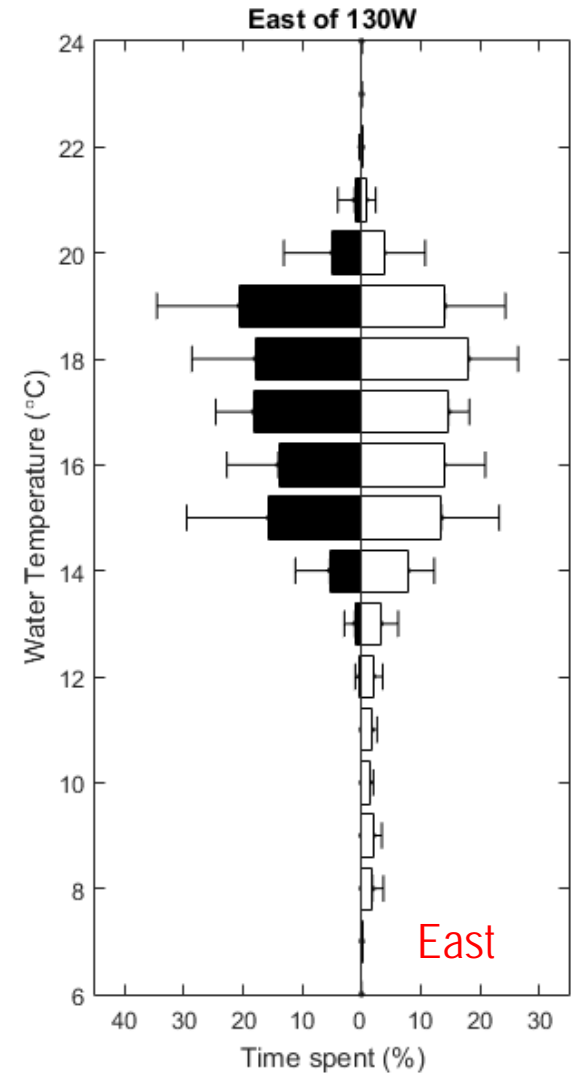
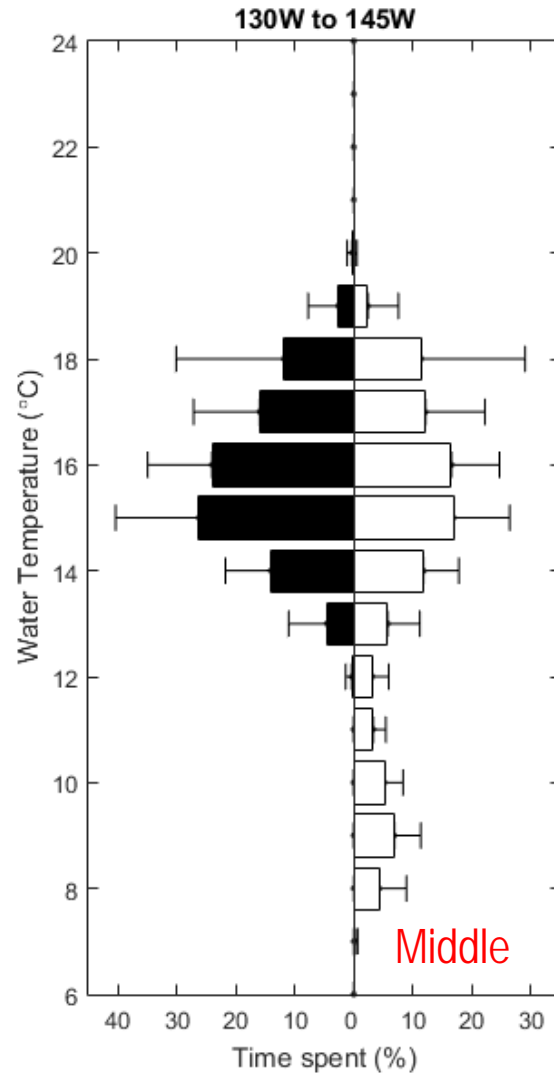
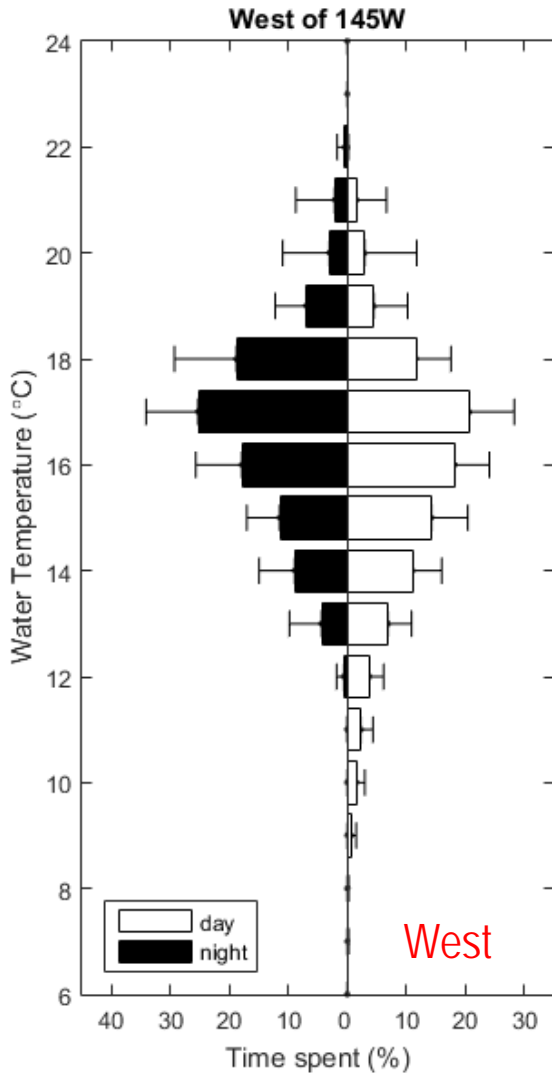


Mean Percentage of Time Spent at Depth during Dawn/Dusk

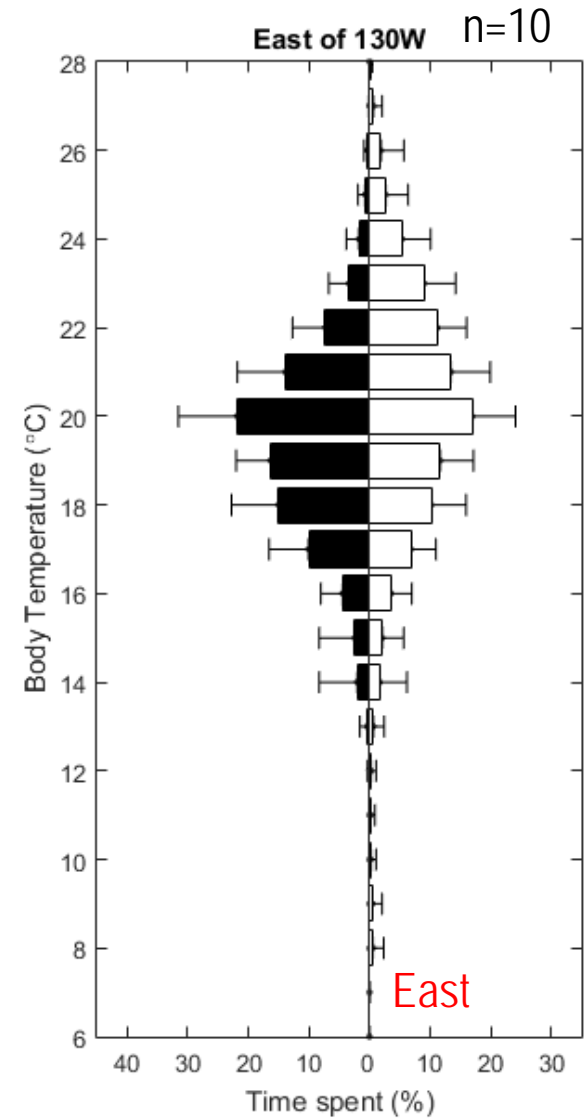
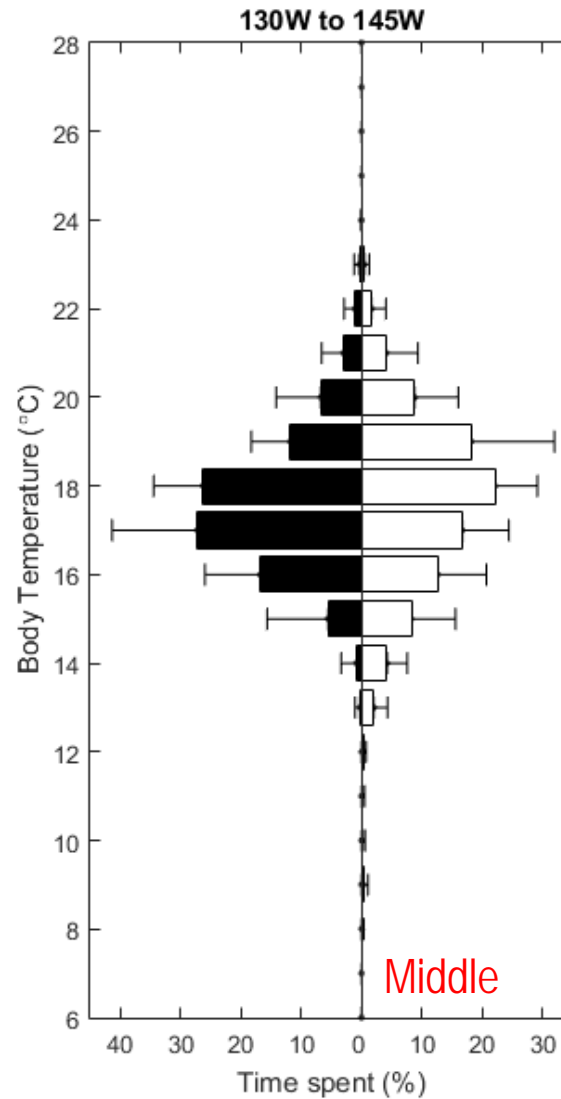
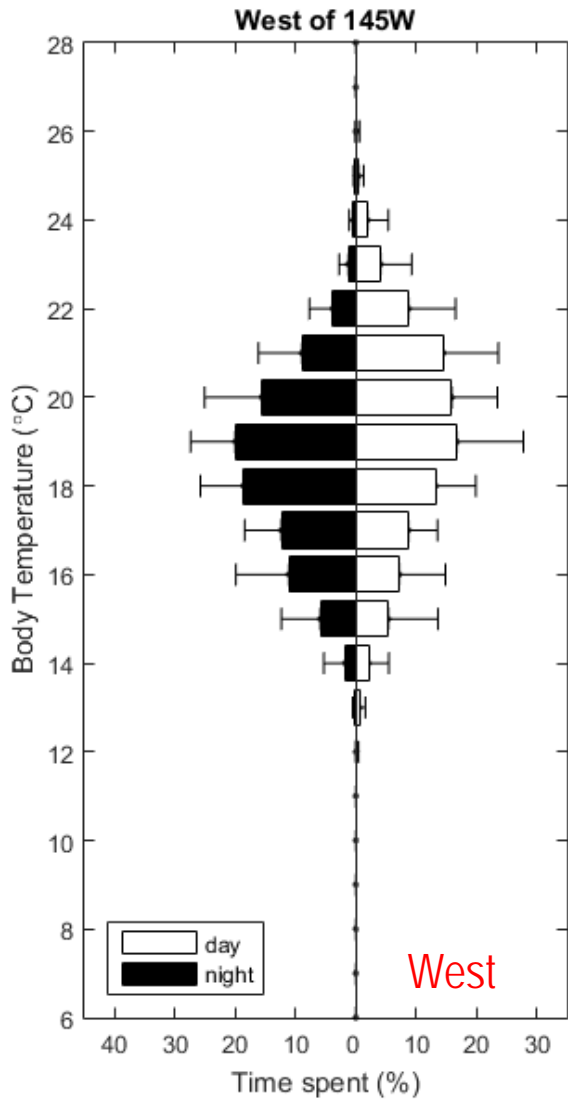


Ambient Water Temperature

n=10



Body Temperature



Average Water & Body Temperature

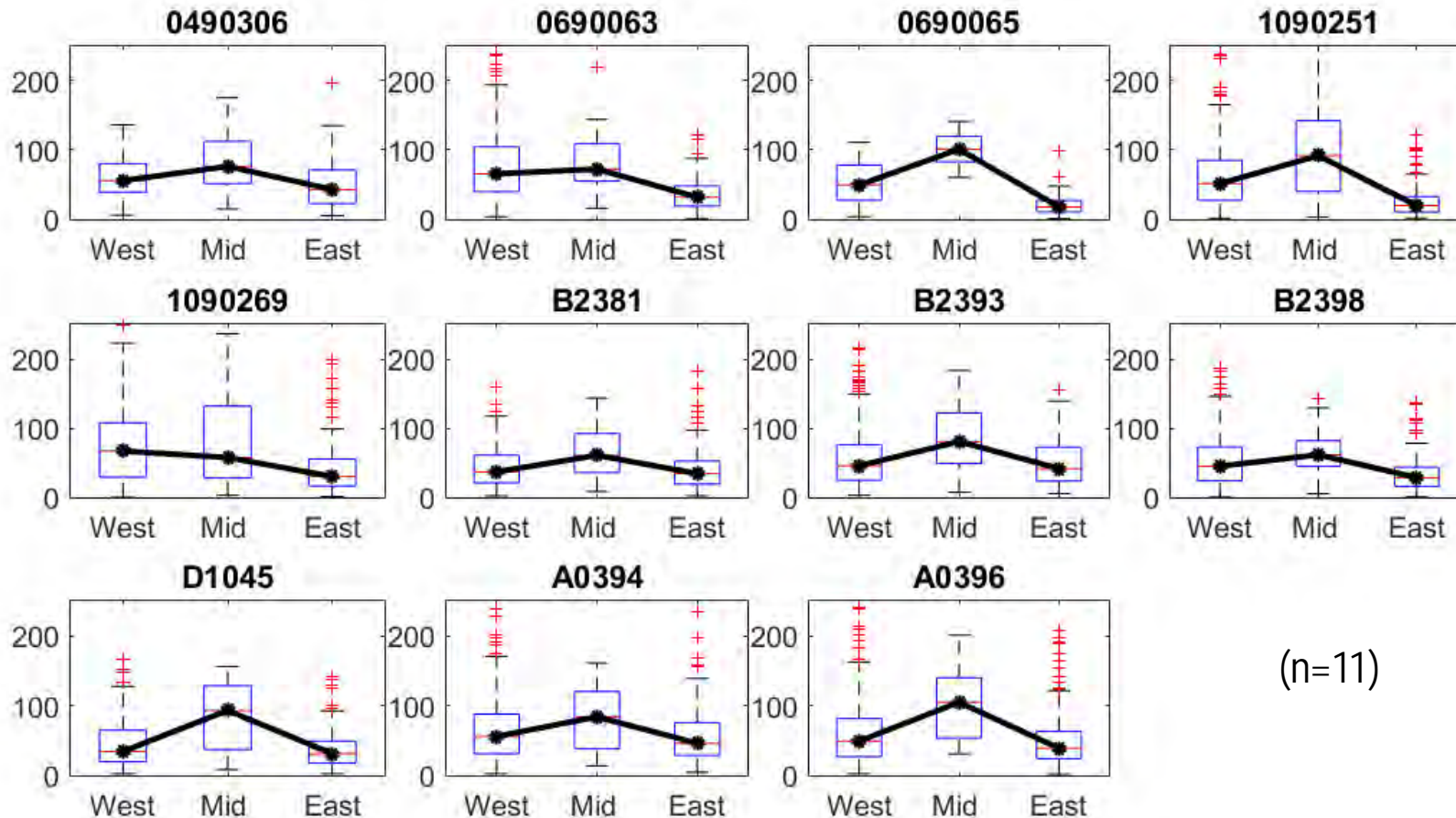
Temperature (°C) Mean±SD	West of 145W (West)	130W to 145W (Middle)	East of 130W (East)
Water (daytime)	15.28±2.00	13.89±2.57	16.67±3.41
Water (nighttime)	16.14±1.57	15.29±1.20	17.41±2.55
Body (daytime)	18.61±1.83	17.05±1.75	19.52±2.30
Body (nighttime)	17.92±1.65	17.07±1.30	18.78±1.69

- The average ambient water temperature is cooler in the middle region.
- The averaged body temperature in the middle region is cooler than western and eastern region.



Horizontal Daily Speed

Region	West of 145W (West)	130W to 145W(Middle)	East of 130W(East)
Average Horizontal Speed (km/day) Mean±SD	50.45±10.31	80.31±16.40	32.70±8.96



(n=11)

Data Analysis

Fit data to generalized linear mixed-effects model (GLME)

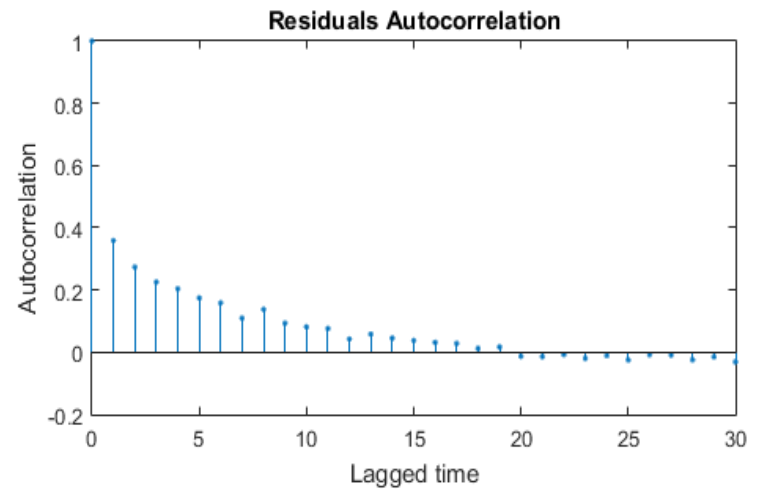
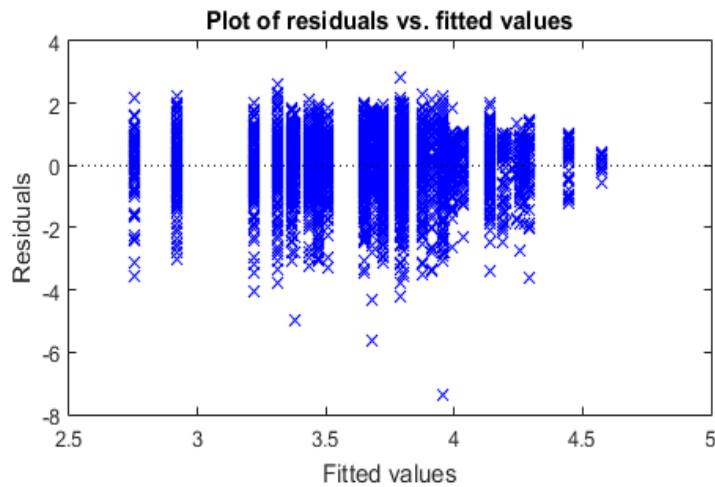
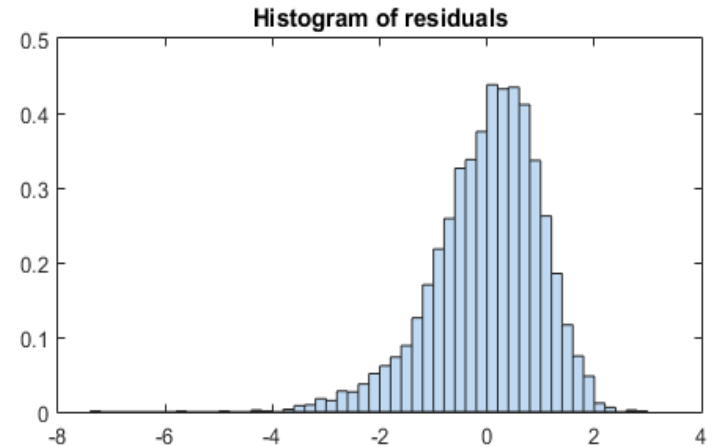
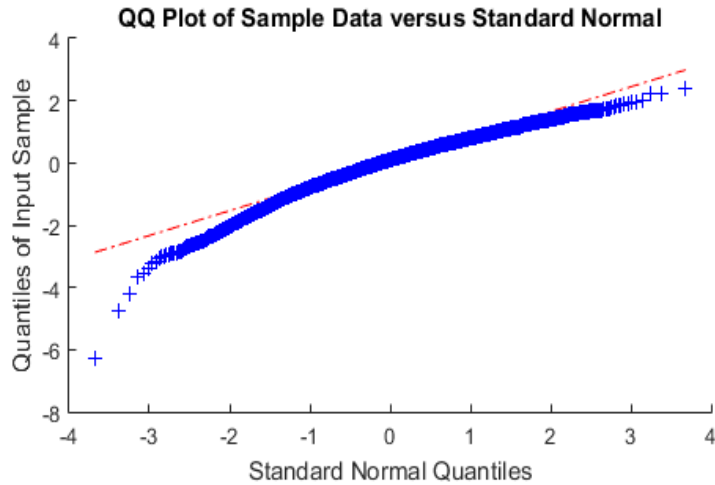
	Model Formula	Intercept	Area_mid	Area_east	AIC	BIC	Log Likelihood	Deviance	Dispersion
All Fish	log(speed)~1+area+fish	3.98	0.42	-0.35	10922	11011	-5446.9	10894	0.86
All Fish	log(speed)~ 1+area+fish+area:fish	3.99	0.28	-0.34	10811	11028	-5371.6	10743	0.85
All Fish	log(speed)~1+area+ (1 fish)	3.75	0.42	-0.35	10946	10977	-5467.8	10936	0.86
All Fish	log(speed)~1+area+ (area fish)	3.78	0.40	-0.41	10857	10921	-5418.7	10837	0.85

All the model showed similar results.

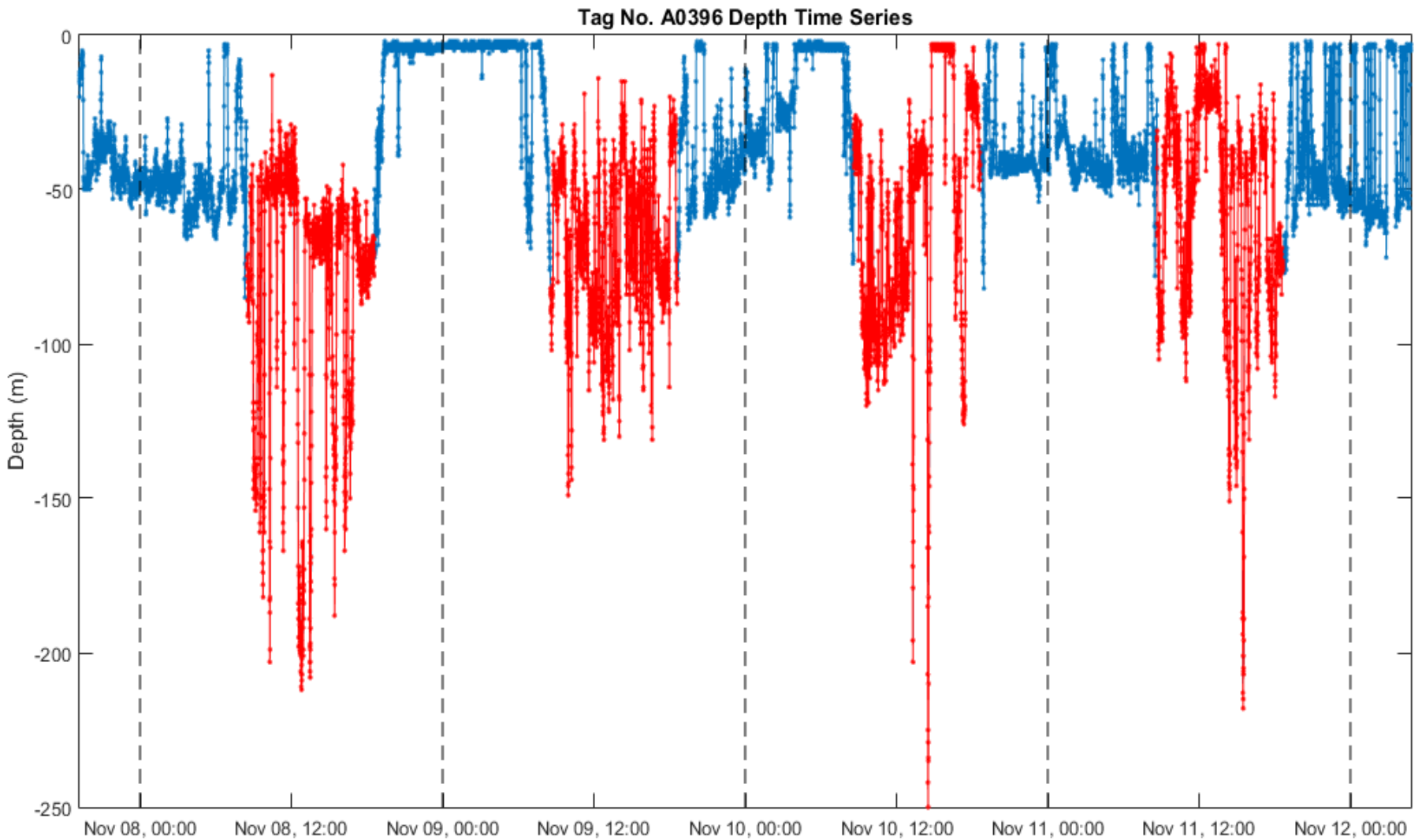
Model $\log(\text{speed}) \sim 1 + \text{area} + \text{fish} + \text{area}:\text{fish}$ shows the minimum AIC and maximum log-likelihood.

Model Diagnostics

$\log(\text{speed}) \sim 1 + \text{area} + \text{fish} + \text{area}:\text{fish}$



Cumulative Daily Vertical Speed



Average Cumulative Daily Vertical Speed

Average Speed (km/day) Mean±SD	West of 145W (West)	130W to 145W (Middle)	East of 130W (East)
Daytime	10.08±3.18	9.88±3.99	7.03±3.20
Nighttime	4.29±1.99	2.72±1.56	3.08±1.25

- The average cumulative vertical daily speed in the middle region during daytime is similar to west region and slightly higher than the east region.
- During nighttime, the average speed in the middle region is the slower than the west and east region.

Summary

Middle region characteristics:

- Albacore spent more time in surface waters during night. During daytime, albacore spend more time than the east region, and less time than the west region.
- Ambient water temperature is cooler at night. During daytime, bigger proportion in cold water may due to long distance diving.
- Body and water temperature is cooler both daytime and nighttime.
- The horizontal daily speed is faster than west and east region.
- Cumulative vertical speed during nighttime is slower.

Future work:

- Update geolocation information
- Statistical analyses
- Publication



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Qingdao, China, October 15th, 2015

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How does explicit treatment of spatial variability in environmental conditions affect simulated anchovy recruitment?

Will be presented
October 22nd, 2015

HOW DOES EXPLICIT TREATMENT OF SPATIAL VARIABILITY IN ENVIRONMENTAL CONDITIONS AFFECT SIMULATED ANCHOVY RECRUITMENT?

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Introduction

Spatial variation in environmental conditions such as temperature and food availability can greatly affect larval and juvenile fish growth and survival, and therefore ultimately affect recruitment to the population. In this study, we use a 3-dimensional (3-D) individual-based model (IBM) of Peruvian anchovy to examine how explicit representation of spatial variation in environmental conditions can affect recruitment. Peruvian anchovy is a good test case because it is well studied, it is an important ecological and commercial species, and inhabits a coastal upwelling system that is highly spatially and temporally dynamic.

Fig. 1. Peruvian anchovy large schools close to the coast of Peru.

Methods

We used two models: temperature, salinity, and zooplankton concentrations (3-D IBM) and a 2-D IBM (IBM) that used spatially averaged environmental conditions. The 3-D IBM simulated individuals as they progressed from eggs to recruitment at 10 cm. Eggs and yolk-sac larvae were followed hourly through the process of development, mortality, and movement, and larval and juvenile were followed daily through the processes of growth, mortality, and movement (advection plus behavior). A bioenergetics model was used to grow larvae and juveniles. The 2-D IBM provided very fish-like behavior: both food consumption rate as well as behavior modeled recruitment with individuals going to grid cells having optimal growth conditions. We conduct three sensitivity simulations to demonstrate how recruitment was affected by the importance of spatial variability in temperature and food.

Results

Recruitment

The 3-D and 2-D versions generally produced similar interannual patterns in recruitment (20-year) for individuals or cohorts starting months from 2004 to 2004, with the 3-D results yielding consistently higher survivorship (Fig. 3). They both captured the very poor recruitment observed during the 1999-2001 El Niño event, while both versions generated very low recruitment during the El Niño period. The recruitment predicted by the 3-D version was substantially higher (but still low) compared to the 2-D version.

Spatial distribution

With model recruitment in 1995, 1999, and 2004, we superimposed the spatial distribution of the 3-D IBM on the 2-D IBM. The October period, and larval growth in 2004 cohorts resulted in a

Growth rates

Four fish days for the October period were used to compare each day spent in the surface layer or 50 meters deep during the El Niño period. The October 1999 and high recruitment, but showed

Conclusion

We compared predicted Peruvian anchovy recruitment between the 3-D IBM and 2-D IBM that used spatially averaged environmental conditions. The 3-D and 2-D versions generated similar interannual patterns in monthly recruitment for eggs to stock, with the 3-D results yielding consistently higher survivorship. Both model versions successfully captured the very poor recruitment during the 1999-2001 El Niño event, higher recruitment in the 3-D simulations was due to higher larval survival during the larval stage resulting from individuals searching for more favorable temperatures that led to faster growth rates. The strong effect of temperature was because both model versions provided subsisting food conditions for larval and juvenile anchovies.

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