Archival tag deployments by IATTC with tropical tunas in the EPO

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Inter-American Tropical Tuna Commission

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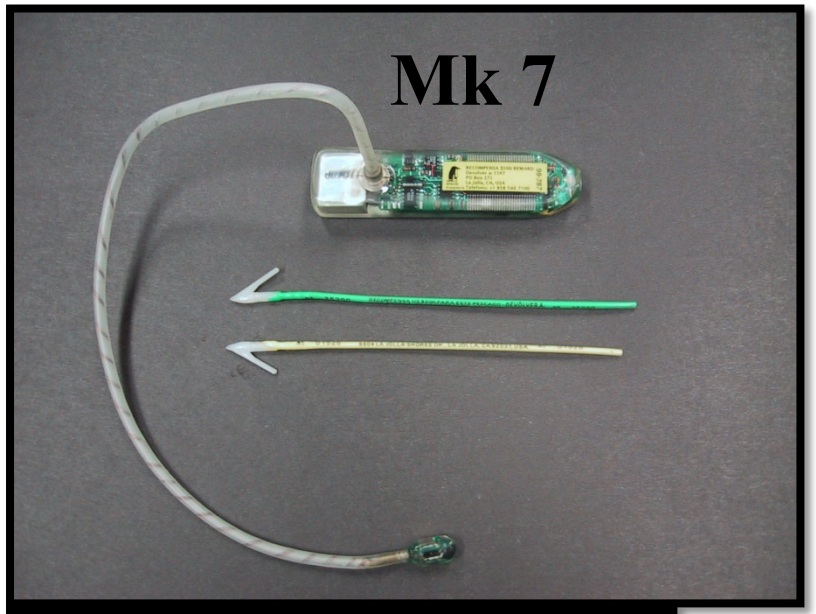
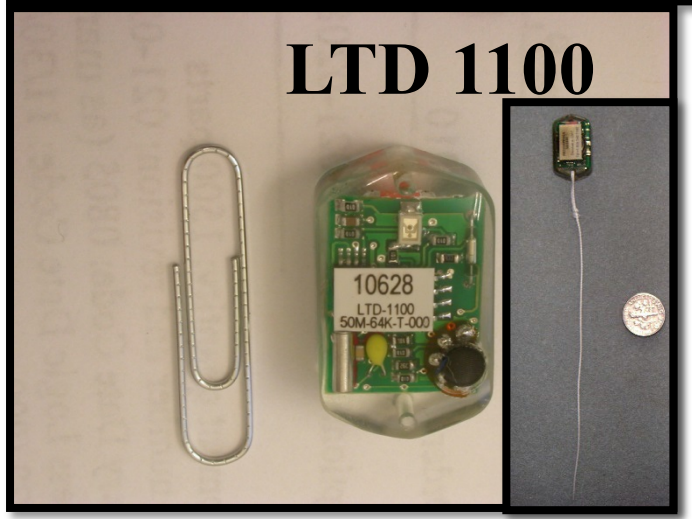
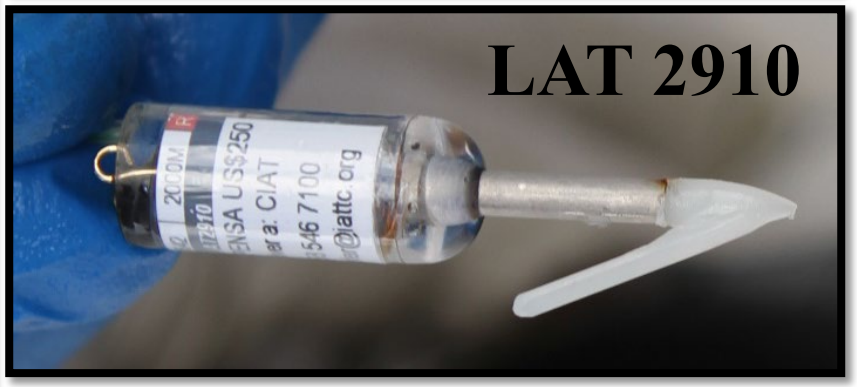
INTRODUCTION

- Archival tagging at IATTC began with the inception of the bigeye tuna tagging project in 2000
- Prior to commencing archival tagging, we sought the advice of veterinarians and other scientist involved in internal implantation of tags to help develop protocols to ensure safe handling and release
- Based on this advice it was decided that a knotless net/scoop would be employed to quickly and safely land fish
- Safe handling procedures also included the use of antiseptics on incisions, tags, new sterile scalpels for every surgery, and gloved hands for perforating the coelomic lining
- Initially only BET were tagged, but in 2002 IATTC began tagging YFT and Skipjack
- The objectives of these studies were to gather knowledge on behavior, habitat, movements, and stock structure throughout the EPO
- Numerous tag types have been used including Wildlife computers Mk7 and Mk9, and Lotek wireless LTD2310, TD1100, LAT2810, and LAT2910 archival tags
- To date, a total of 2,234 tunas with archival tags have been released

TAG TYPES







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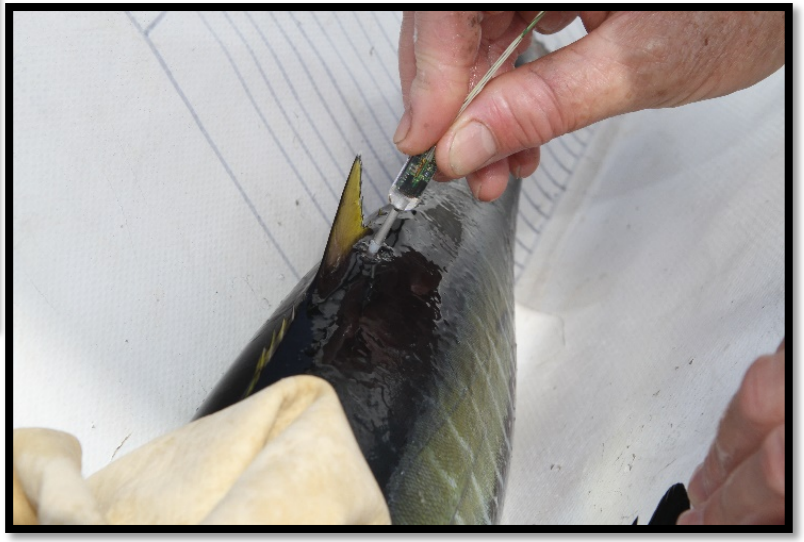
BIGEYE TUNA TAGGING - TAGGING METHODS



BIGEYE TUNA TAGGING - THE VESSELS

Her Grace, Ao Shibi Go, Gutsy Lady 4, and the Double D (not shown)

BIGEYE TUNA

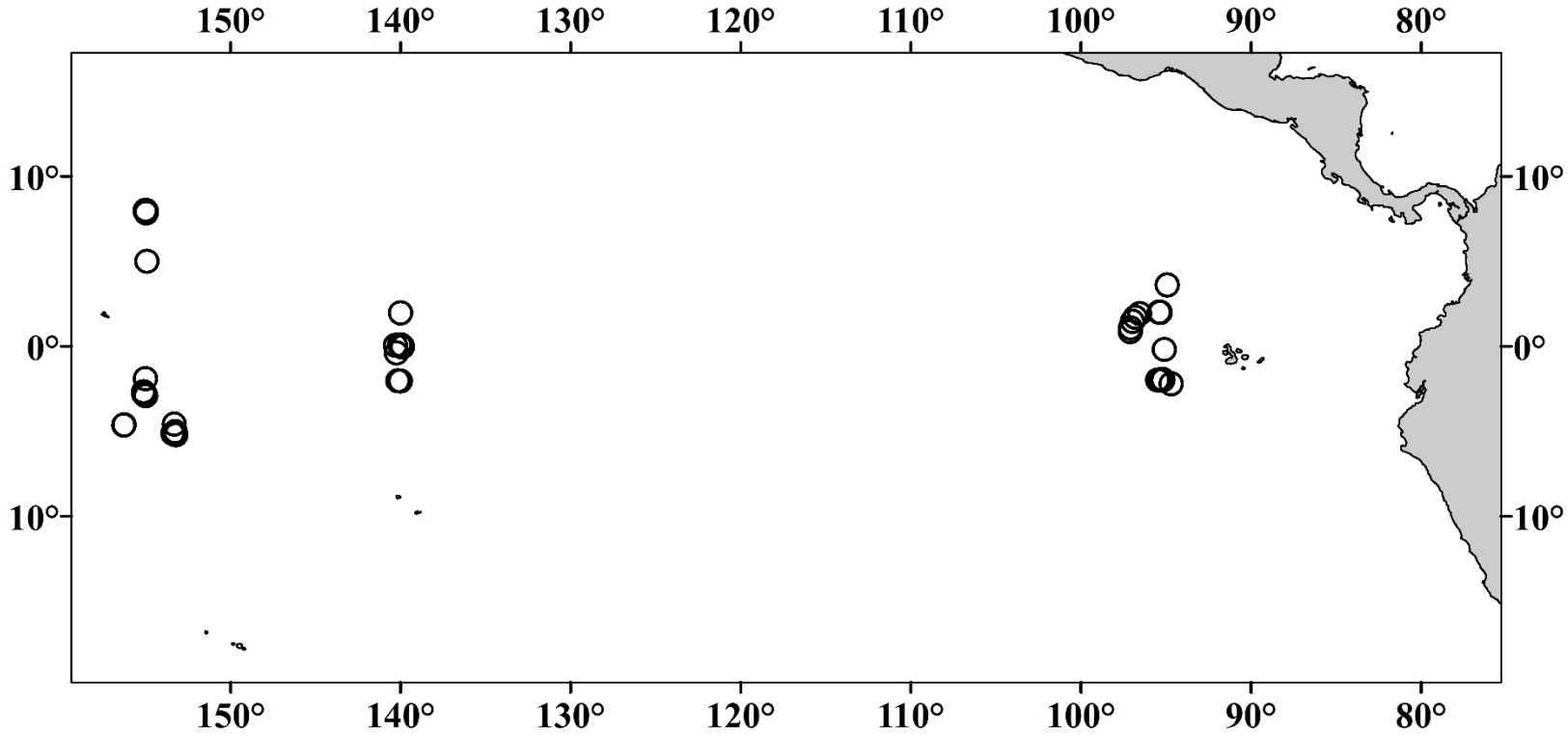
BIGEYE TUNA ARCHIVAL TAGGING

EPO BET ARCHIVAL TAGS 2000, 2002 - 2006

Bigeye Tuna		
Released	**Returned**	**% Returned**
323	**162**	**50.2**

CPO BET ARCHIVAL TAGS 2009, 2011, 2015

Bigeye Tuna		
Released	**Returned**	**% Returned**
375	**78**	**20.8**

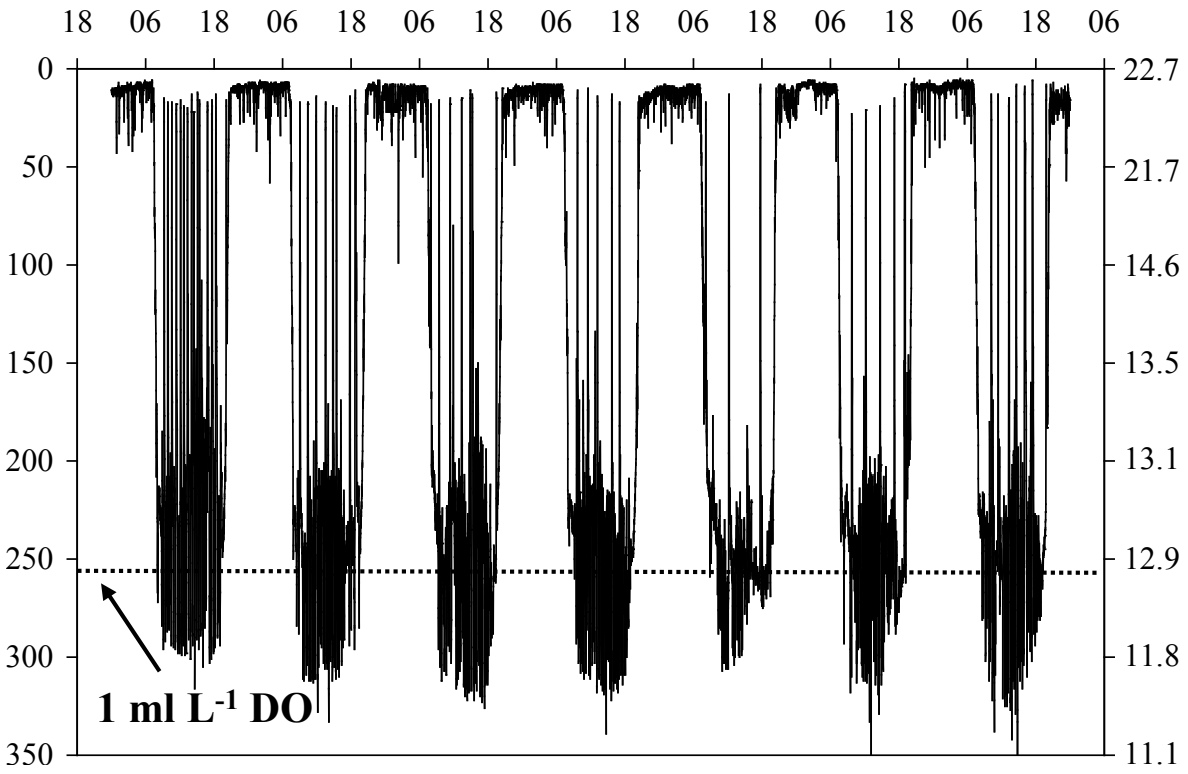


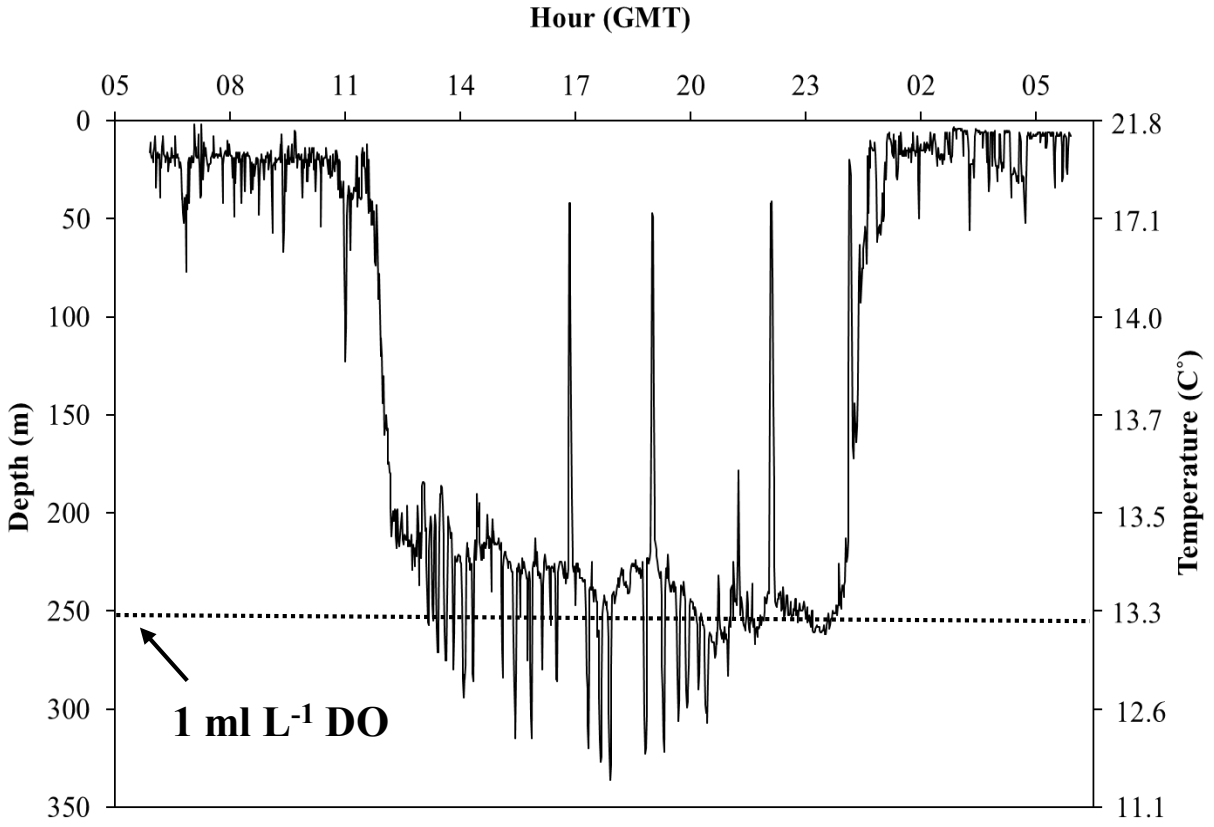
BIGEYE TUNA

- Define 3 distinct behavior type, including associative behavior, by age and size classes

BIGEYE TUNA

Bigeye, 117 cm, 1 – week and 1 – Day of Characteristic Diving Behavior





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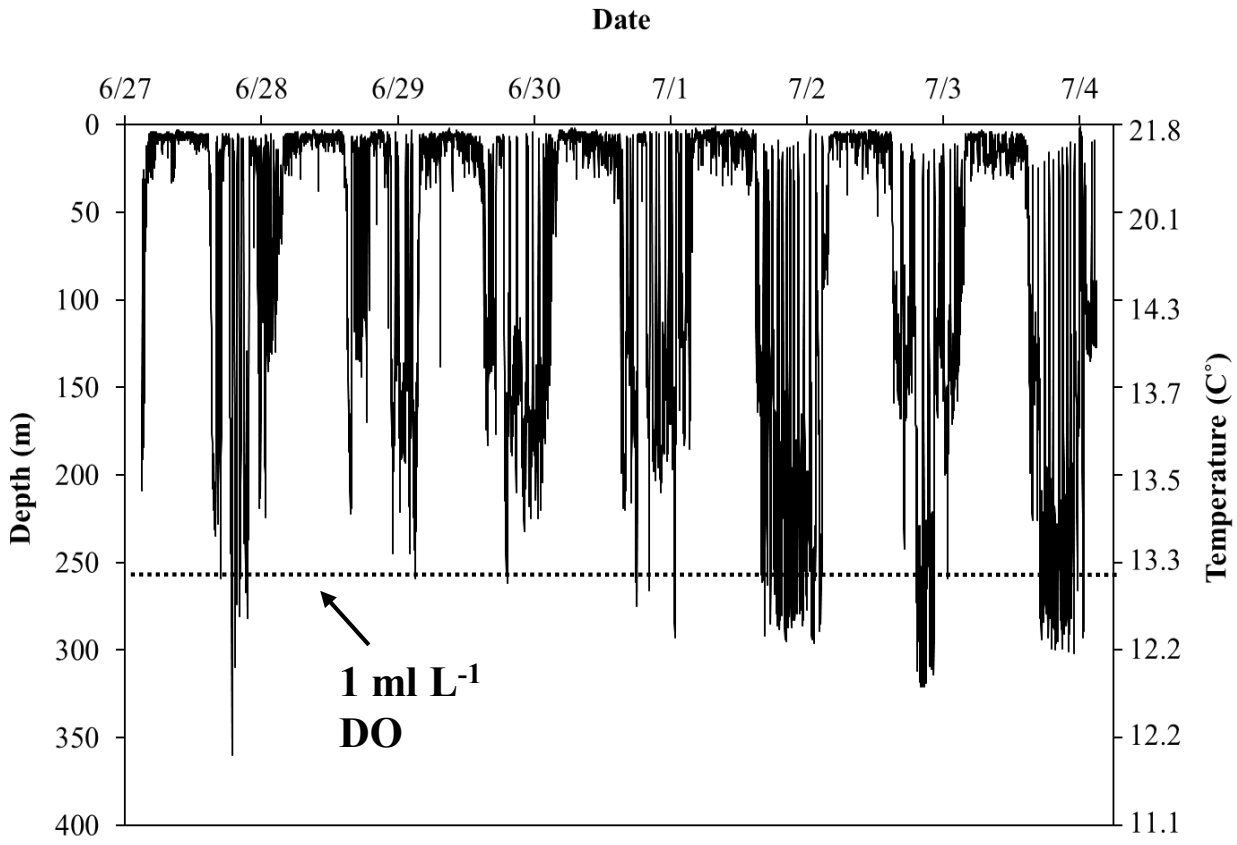
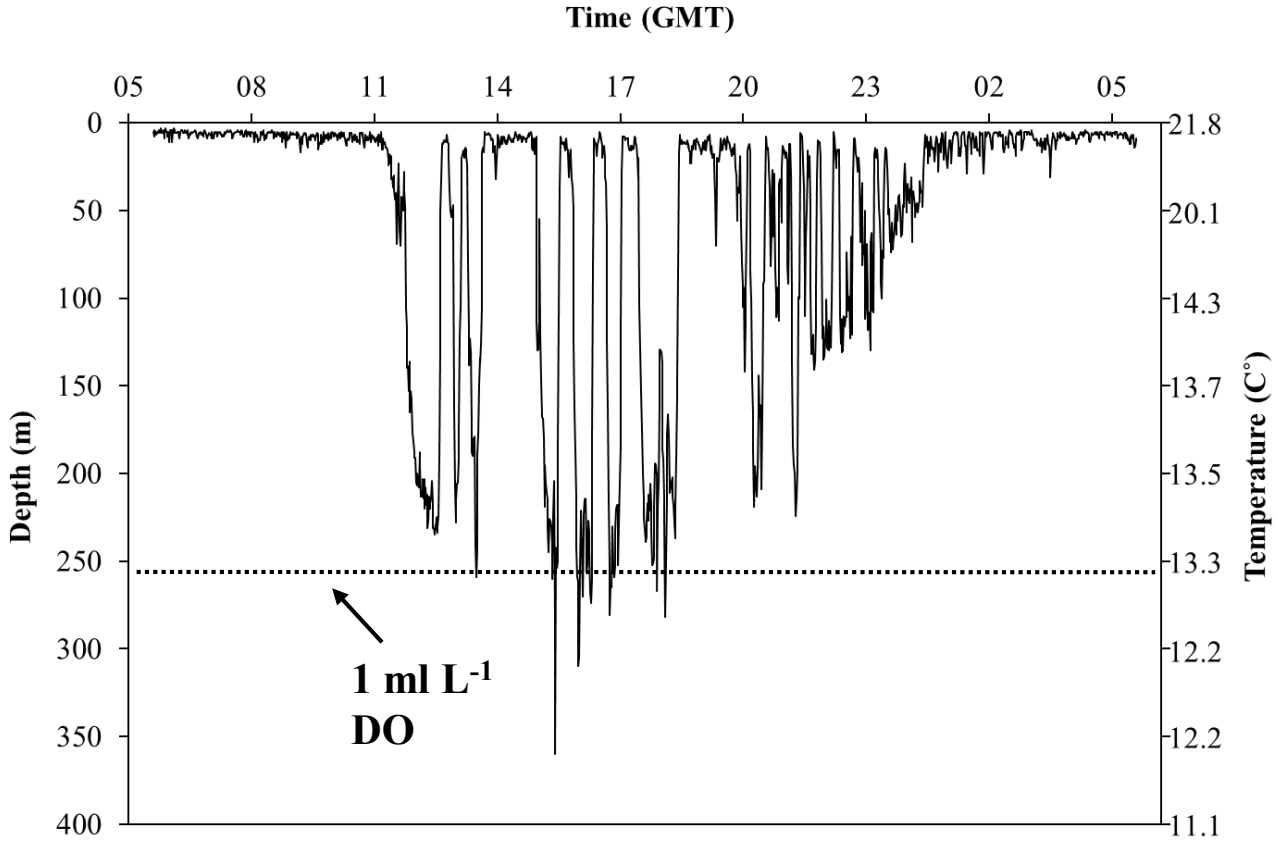
BIGEYE TUNA

Bigeye, 117 cm, 1 – Week and 1 – day of Other Diving Behavior





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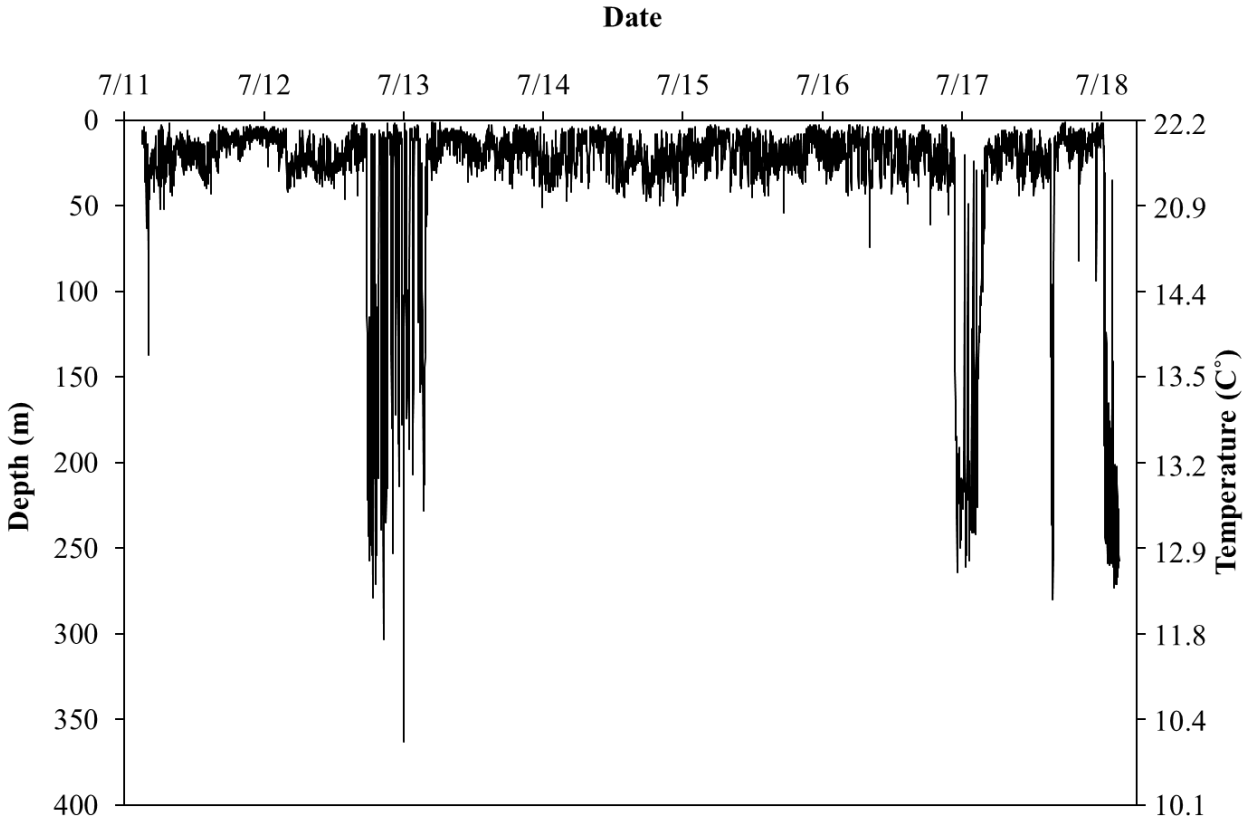
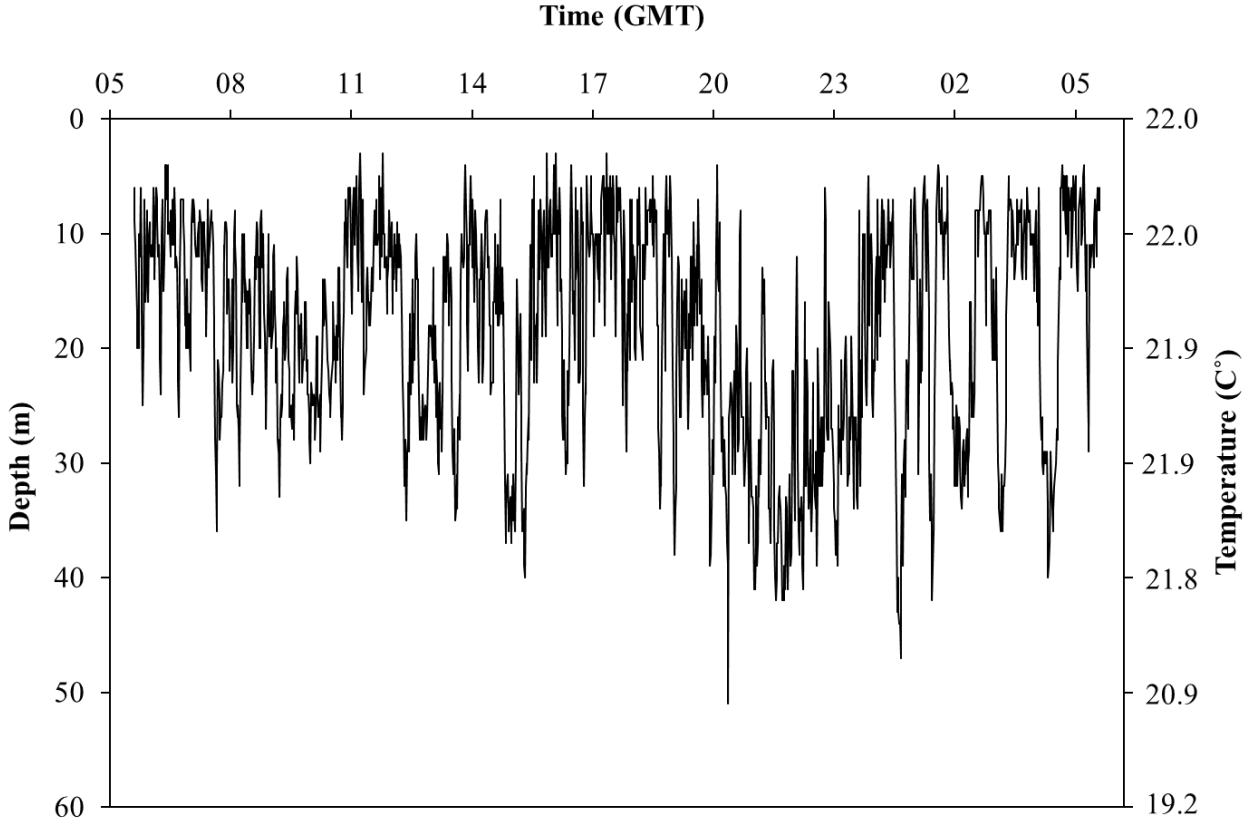
BIGEYE TUNA

Bigeye, 117 cm, 1 – Week and 1 – day of Associative Behavior





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BIGEYE TUNA

- Define 3 distinct behavior type, including associative behavior, by age and size classes
- Evaluate ontogenetic changes in both behavior and habitat

BIGEYE TUNA

Daily classification of behavior types for 96 bigeye tuna, by age class

			Characteristic			Associated			Other		
Age Class	Fish	Days	% Days	Events	Duration	% Days	Events	Duration	% Days	Events	Duration
1	2	62	8.1	3	1.7	69.4	5	8.6	22.6	5	2.8
1.25	8	378	26.7	34	3.0	25.7	31	3.1	57.6	56	3.2
1.5	25	864	44.8	110	3.5	15.7	64	2.1	39.5	131	2.6
1.75	34	1877	46.7	231	3.8	14.0	118	2.2	39.3	273	3.0
2	36	2435	50.6	263	4.7	14.4	142	2.5	35.0	326	2.6
2.25	38	2532	50.2	279	4.6	17.1	143	3.0	32.8	332	2.5
2.5	32	1833	60.2	231	4.8	11.6	92	2.3	28.2	240	2.2
2.75	29	1665	61.5	202	5.1	8.6	75	1.9	29.9	219	2.3
3	27	1736	62.6	213	5.1	5.6	54	1.8	31.8	232	2.4
3.25	15	1276	57.3	159	4.6	8.8	49	2.3	33.9	172	2.5
3.5	12	845	54.8	118	3.9	5.1	23	1.9	40.1	124	2.7
3.75	3	191	75.4	27	5.3	2.6	3	1.7	22.0	27	1.6
4.0	1	102	91.2	8	11.6	0.0	0	0.0	8.8	7	1.3
4.25	1	91	85.7	10	7.8	0.0	0	0.0	14.3	10	1.3
4.5	1	89	60.7	20	2.7	0.0	0	0.0	39.3	21	1.7
4.75	1	93	87.1	10	8.1	0.0	0	0.0	12.9	10	1.2
5.0	1	88	60.2	16	3.3	0.0	0	0.0	39.8	16	2.2
5.25	1	92	79.3	12	6.1	0.0	0	0.0	20.7	12	1.6
5.5	1	29	58.6	5	3.4	3.4	1	1.0	37.9	5	2.2

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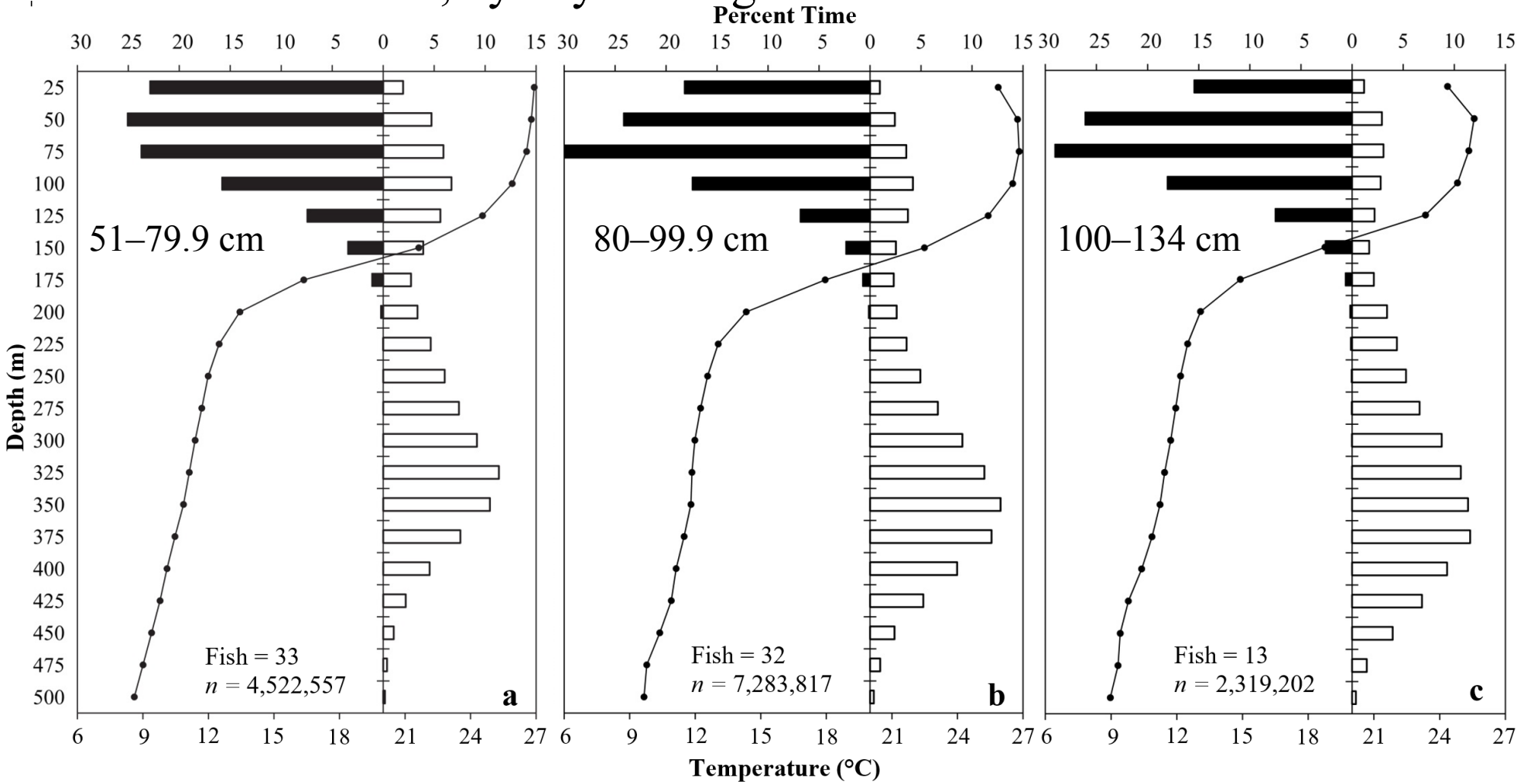
BIGEYE TUNA

Vertical habitat utilization, by day and night between the 120°W and 180



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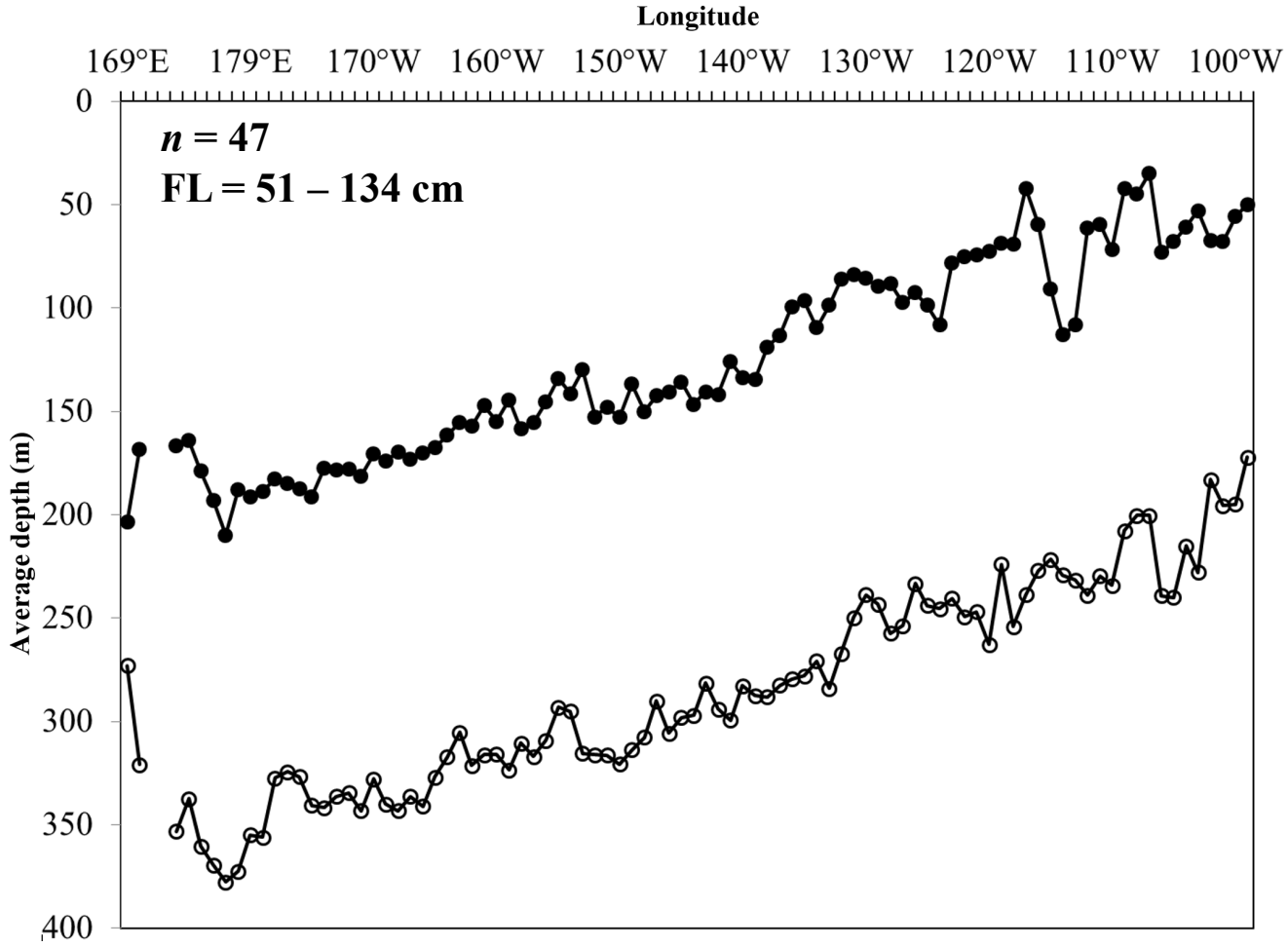
BIGEYE TUNA

Average daytime depths and the corresponding depth of the 20 °C isotherm by longitude



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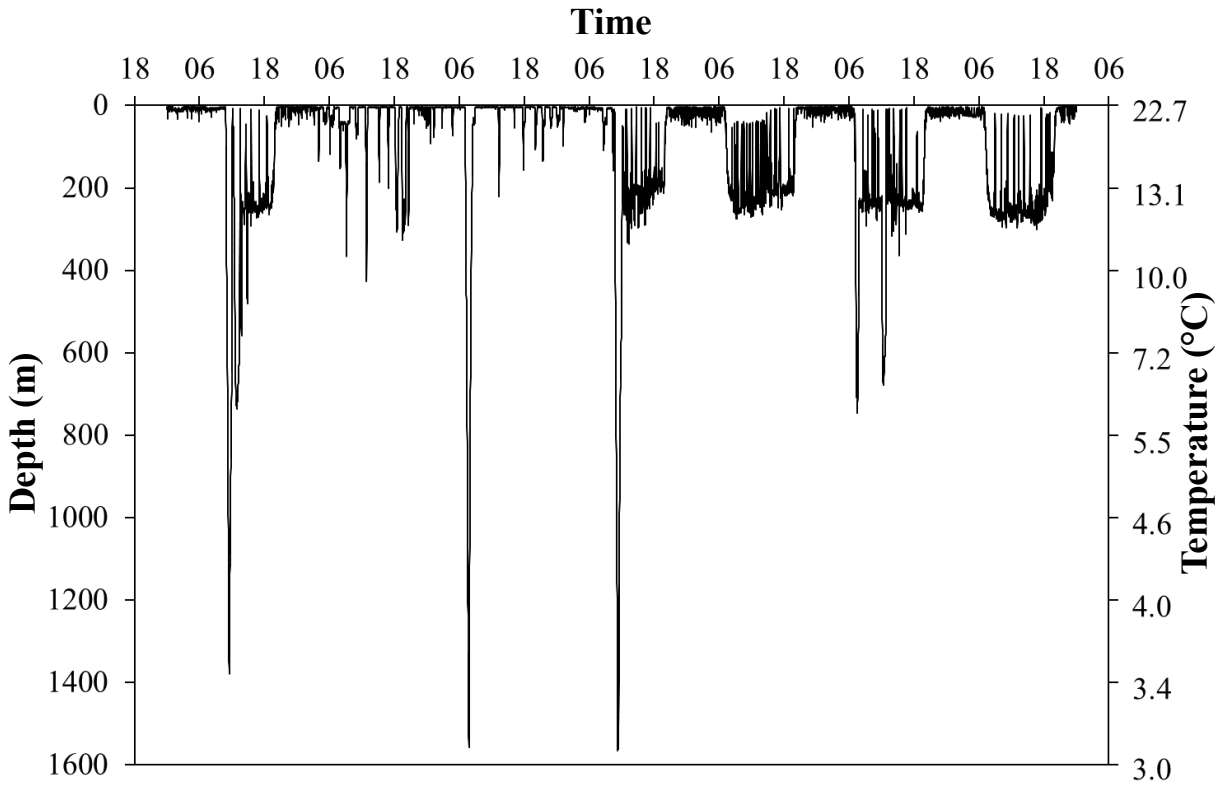
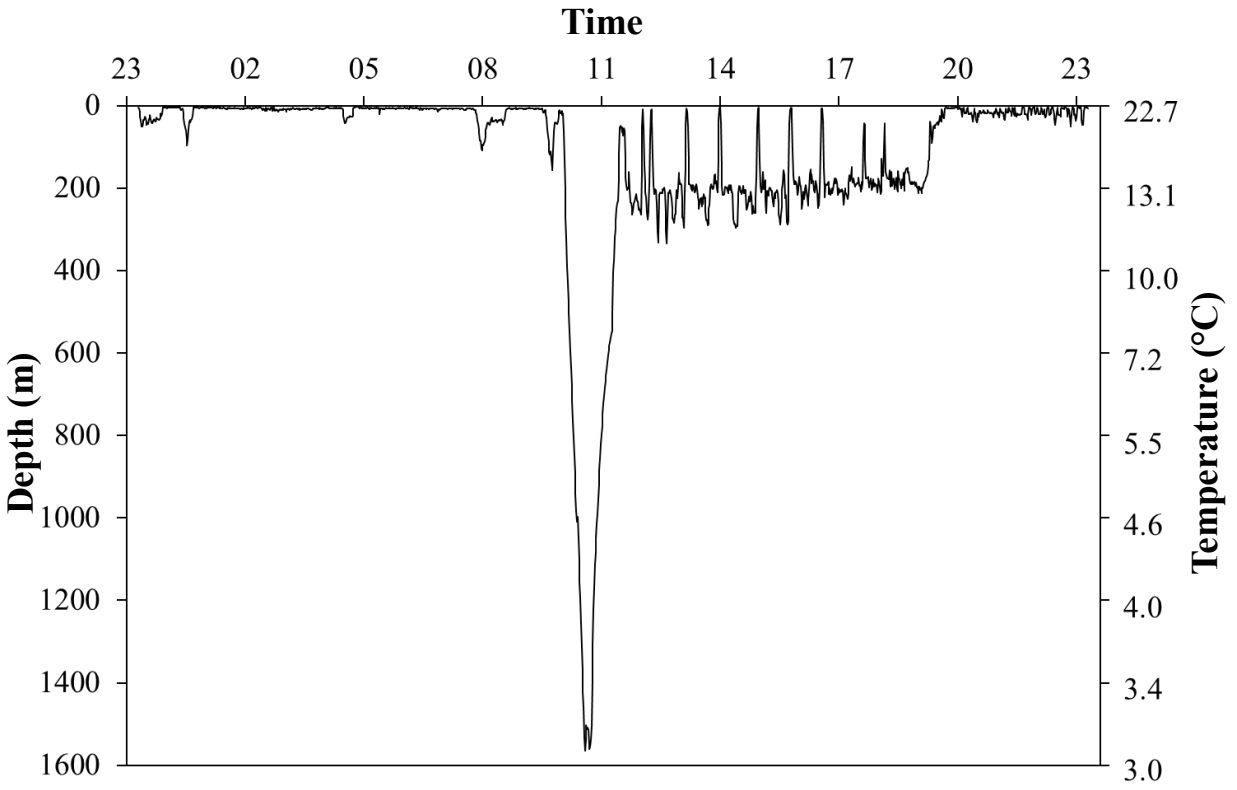
BIGEYE TUNA

- Define 3 distinct behavior type, including associative behavior, by age and size classes
- Evaluate ontogenetic changes in both behavior and habitat
- Bigeye make infrequent dives to great depths exceeding 1000m and, at times, approaching 2000m

BIGEYE TUNA

Bigeye, 77 cm, 1 – Week and 1 – day of with deep diving (>1000 m)





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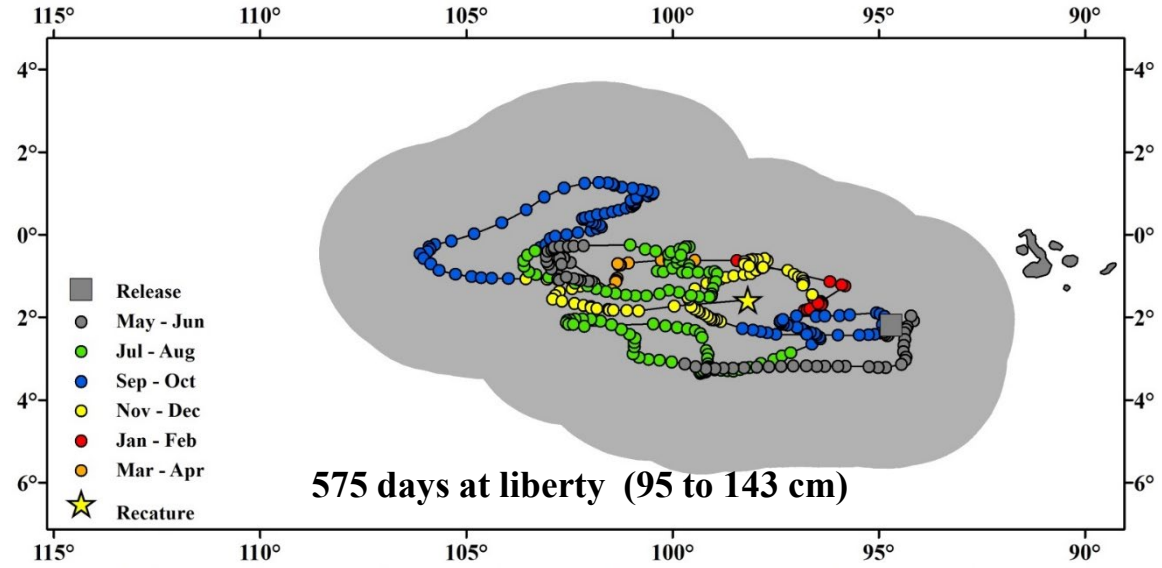
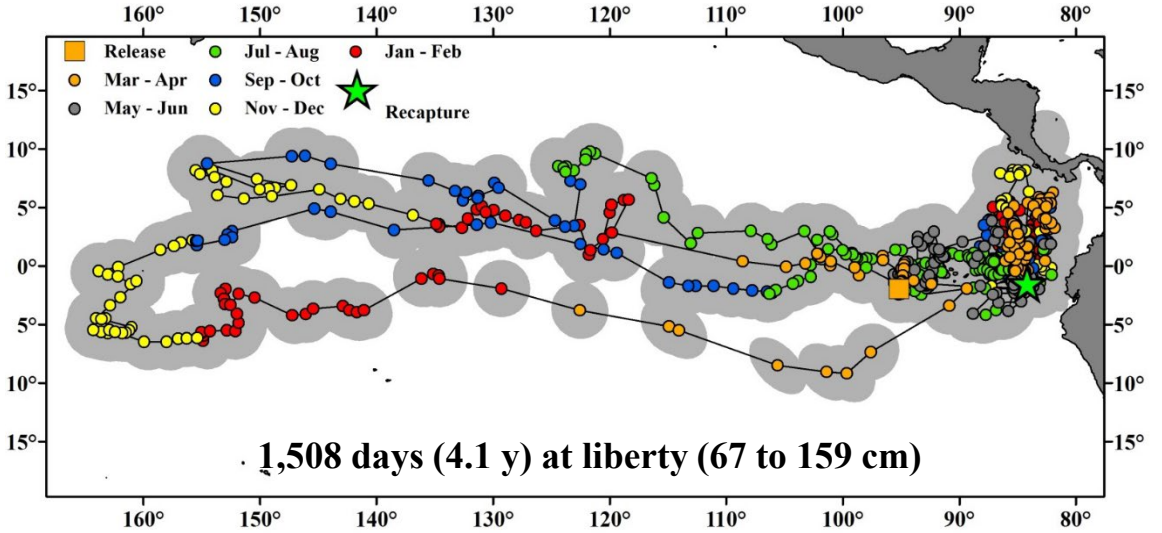
- Position estimates derived from light-levels recorded on the tags, and post processed using the uKFSST model provided most probable movement tracks.

BIGEYE TUNA

Most probable tracks for two bigeye released with archival tags along the 95°W longitude





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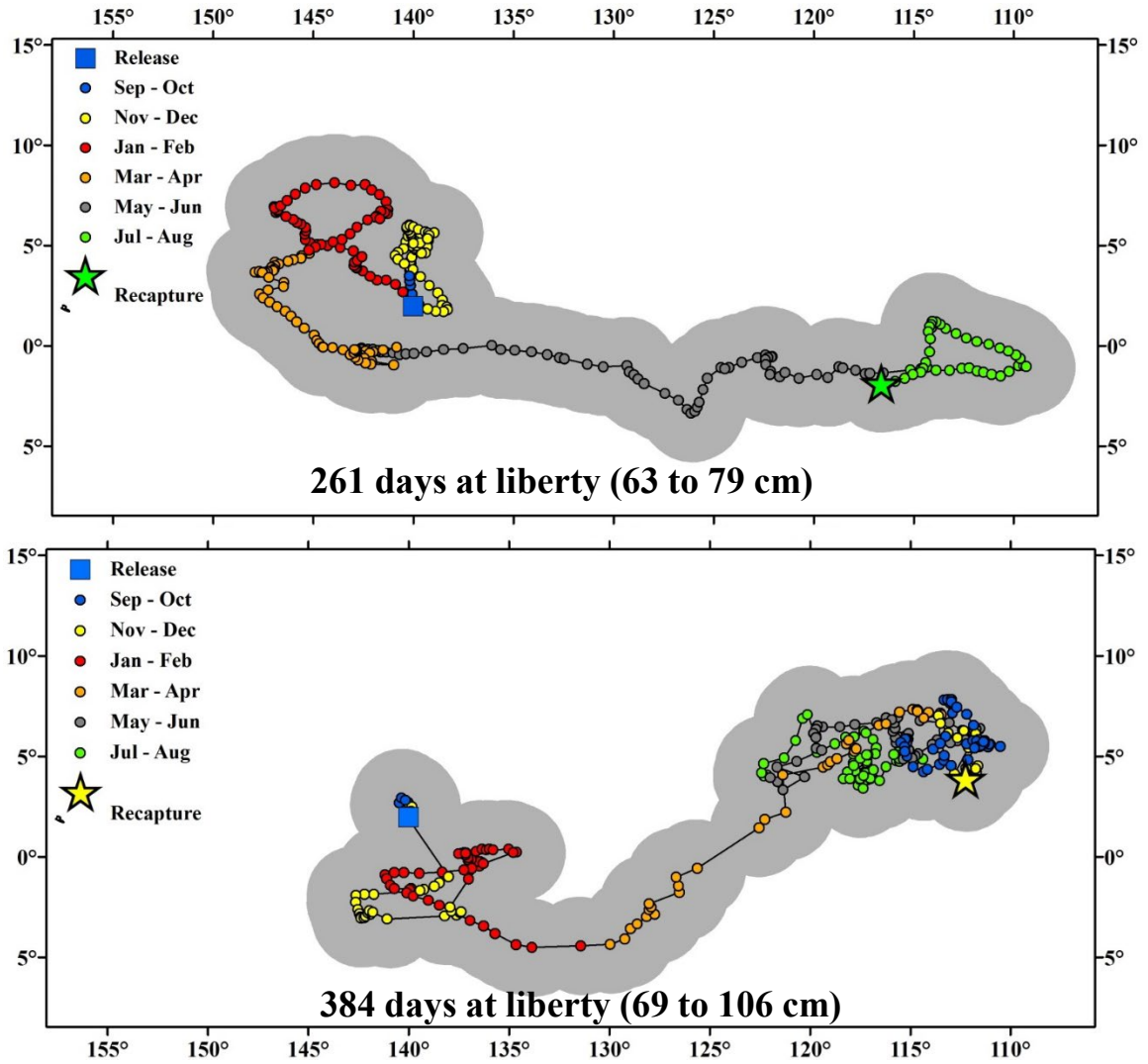
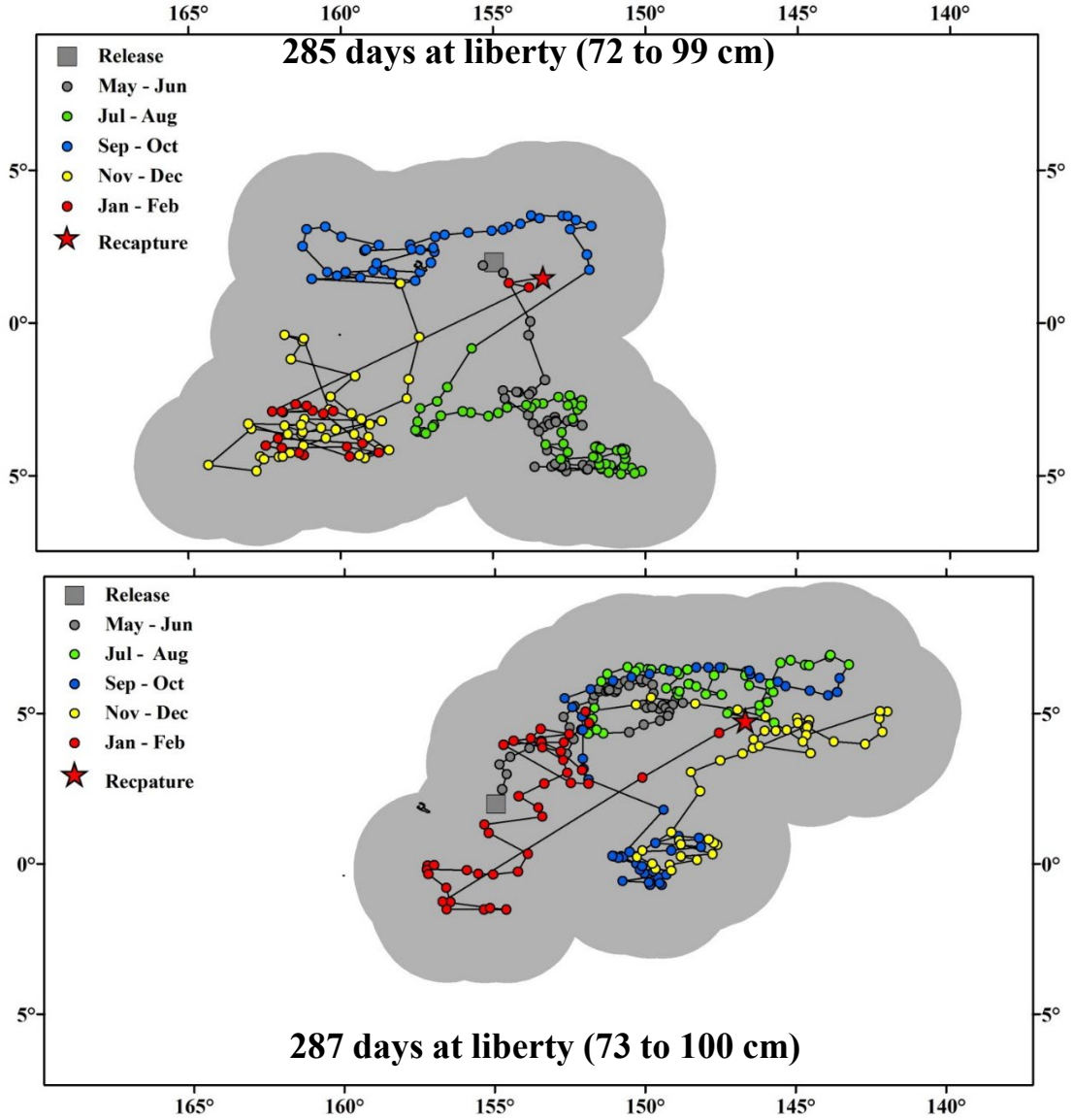
Most probable tracks for two bigeye released with archival tags along the 140°W longitude



BIGEYE TUNA

Most probable tracks for two bigeye released with archival tags along the 155°W longitude



BIGEYE TUNA

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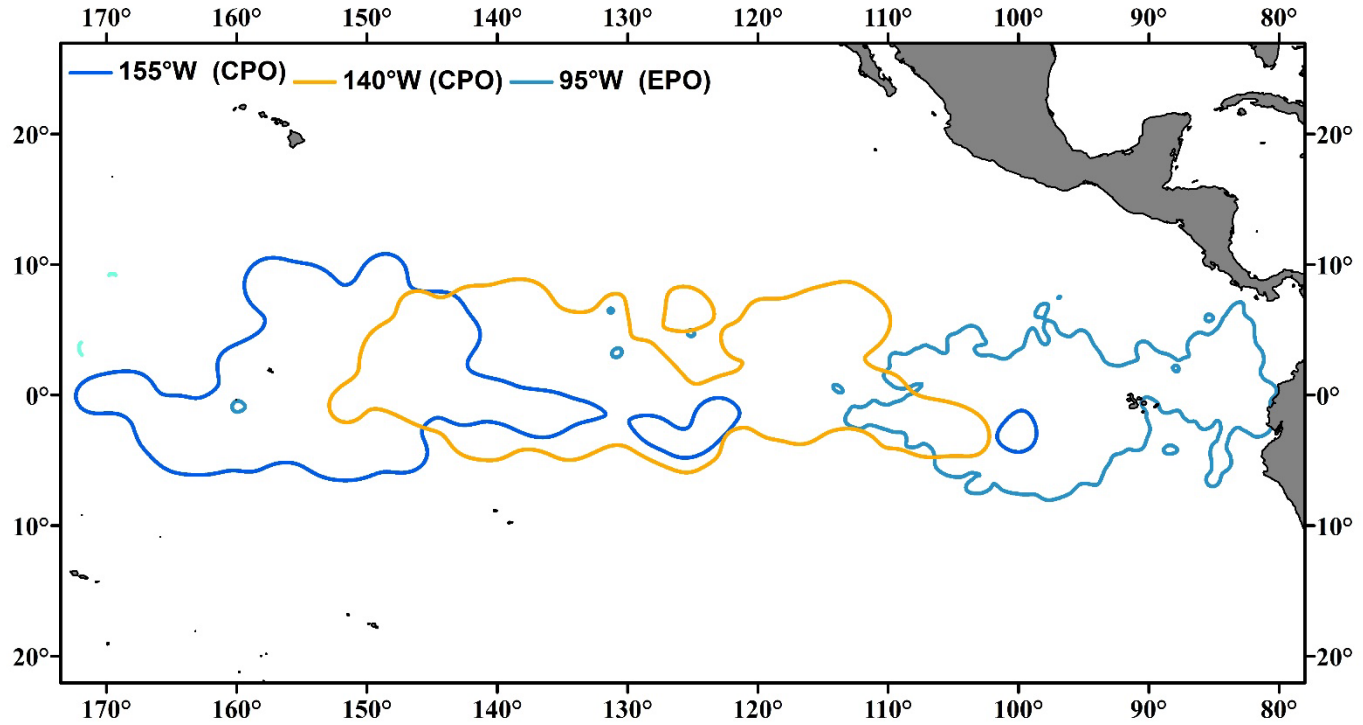
- Derived MPT's for all tags provided data necessary to develop hypotheses about movements and stock structure.

BIGEYE TUNA

95% volume contours calculated from a kernel density function for all archival tag position estimates for three release areas



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- Derived MPT's for all tags provided data necessary to develop hypotheses about movements and stock structure.
- Movement parameters from the uKFSST model can help inform assumptions about mixing rates between stocks in a multi-stock stock assessment models

BIGEYE TUNA

Bigeye movement parameter estimates from the uKFSST model by release area

Area	*n*		σ_x (Degrees)	σ_y (Degrees)	*u* (M/day)	*v* (M/day)	*D* (M^2/day)
95°W	**98**	**Median**	**0.3**	**2.5**	**0.9**	**0.4**	**494.6**
95°W	**98**	**Range**	0.00 - 1.7	0.4 – 10.1	-6.8- 9.5	-5.9 – 11.6	207.4 - 1307.1
140°W	**16**	**Median**	**0.5**	**1.7**	**-4.5**	**-0.7**	**589.9**
140°W	**16**	**Range**	-1.15 – 1.00	0.38 - 10.07	-26.13 - 2.32	-7.24 - 21.39	286.89 - 1392.02
155°W	**15**	**Median**	**0.4**	**1.2**	**0.5**	**-2.8**	**498.6**
155°W	**15**	**Range**	0 - 1.57	0.28 - 2.66	-12.42 - 6.81	-18.45 - 0.19	183.84 - 844.39

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BIGEYE TUNA - CONCLUSIONS

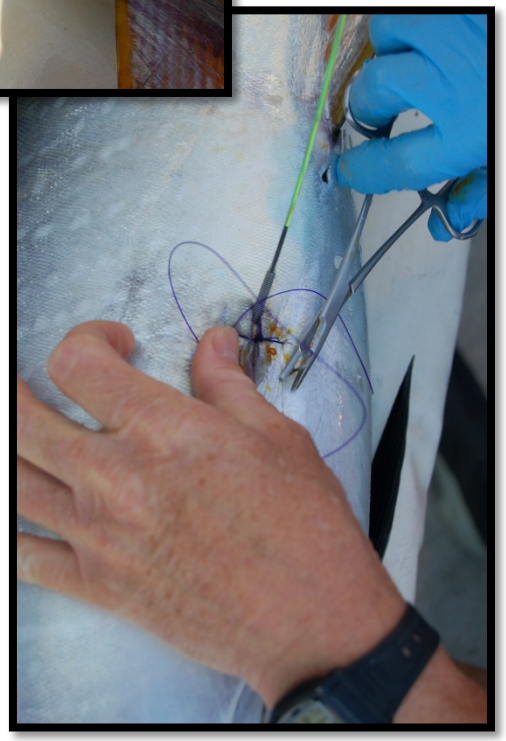
- Analyses of FAD associated behavior has shown smaller (younger) fish spend a higher proportion of days associated with FADs, and the duration of those events are longer
- Conversely, larger (older) bigeye spend a lower proportion of time associated with FADs, and higher proportion of time exhibiting characteristic behavior
- As bigeye get larger, and when exhibiting characteristic behavior, the proportion of time spent at depth increases
- Habitat changes spatially, and subsequently the average daytime depths get deeper as the fish move west, this pattern exist across all size classes tagged
- Considerable variation in movement patterns exists among individuals and among release longitudes. The movement patterns for the releases along the 155°W illustrate fairly strong regional fidelity to release location, but those for the releases along the 140°W illustrate less regional fidelity and some extensive eastward movements. In comparison, releases at 95°W, the predominant movement patterns indicate strong regional fidelity to release location, with restricted westward movements.

YELLOWFIN TUNA TAGGING - THE VESSELS

Royal Star, Shogun, Her Grace, Ao Shibi Go, and Gutsy Lady 4

YELLOWFIN TUNA – TAGGING MRTHODS

YELLOWFIN TUNA TAGGING PROGRAM AT THE REVILLAGIGDO ISLANDS, MEXICO



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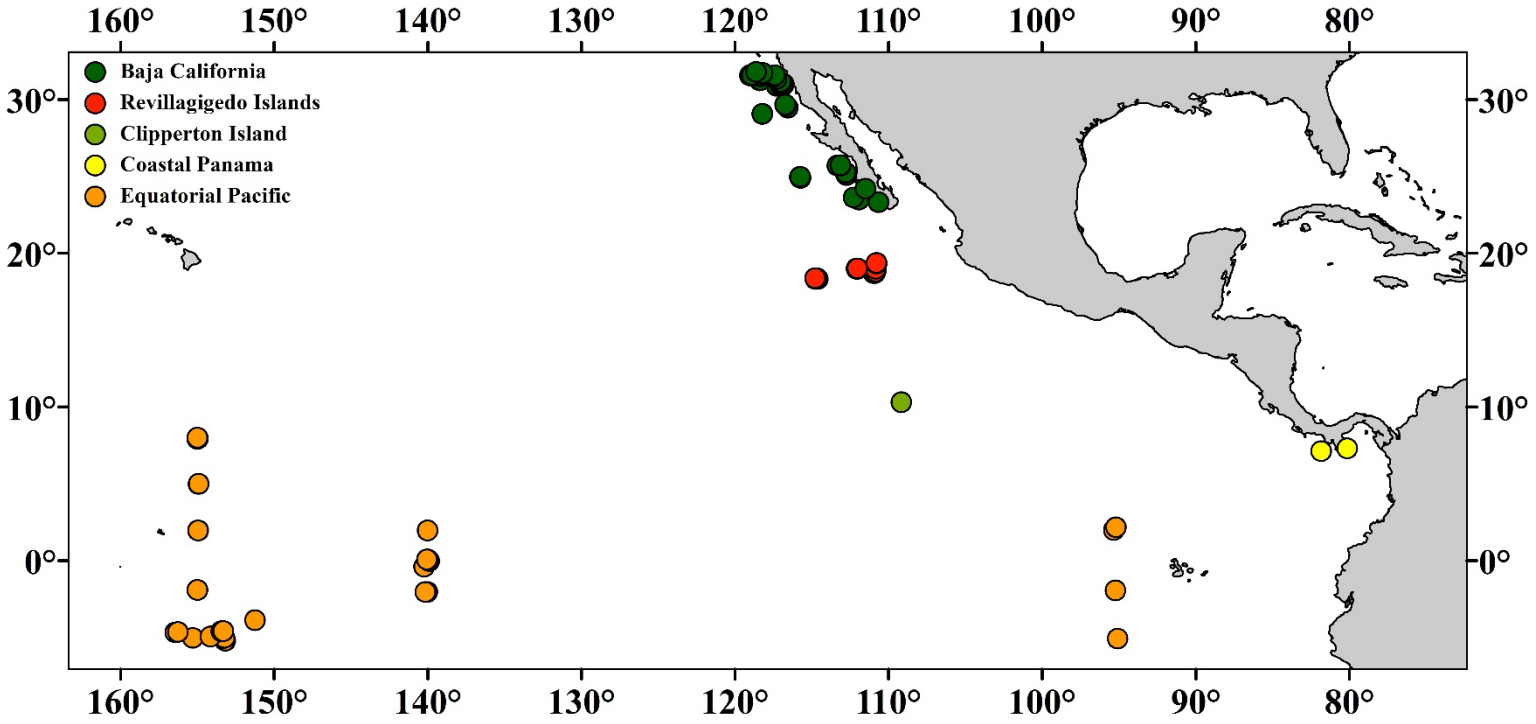
YELLOWFIN TUNA

YELLOWFIN TUNA ARCHIVAL TAGGING

Area	Released	Returns	% Returned
Baja California (TOPP)	500	260	52.0
Revillagigedo Islands	335	99	29.6
Clipperton	167	32	19.2
Coastal Panama	110	23	20.9
Equatorial Pacific Ocean	234	21	9.0
Total	1346	435	32.3

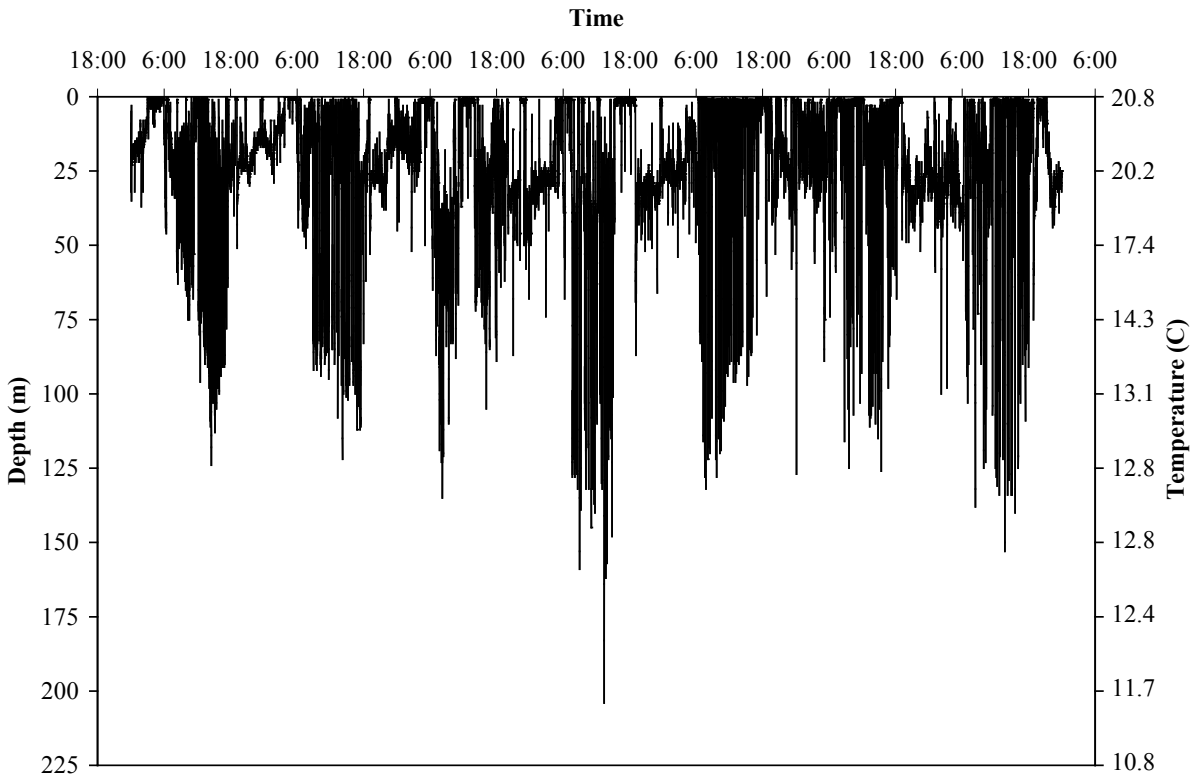


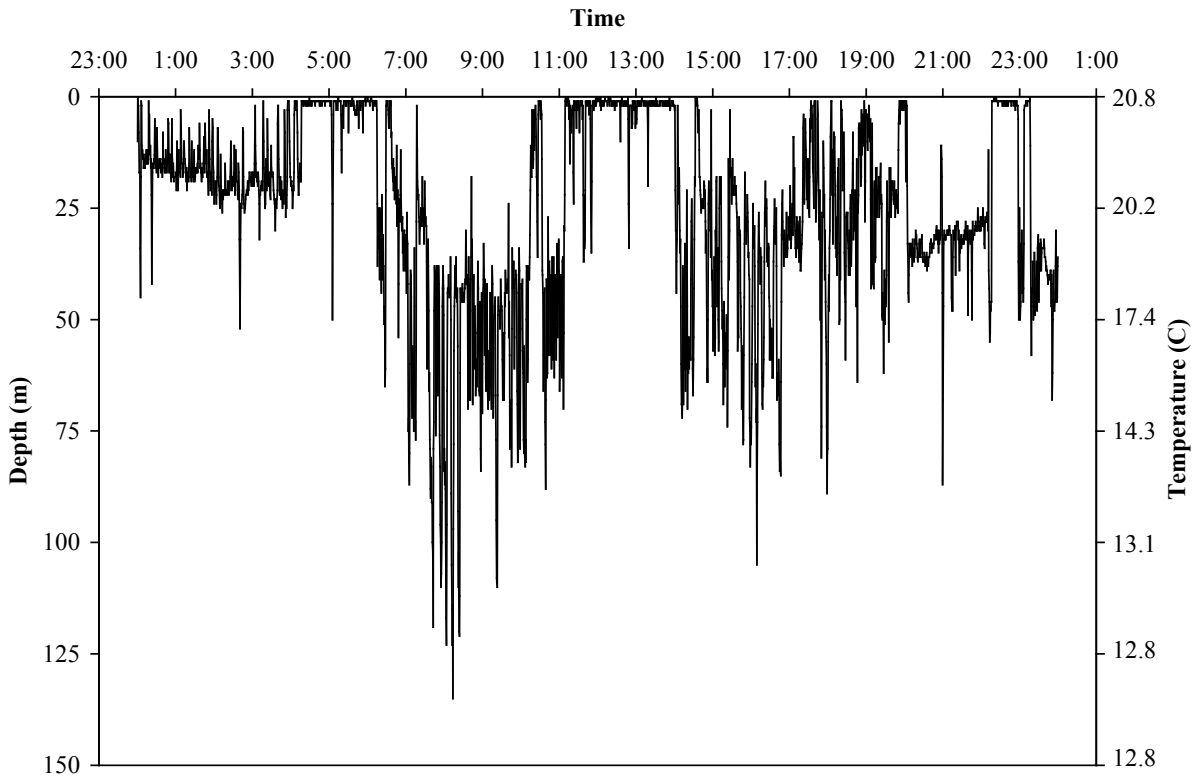
YELLOWFIN TUNA

- Define 2 distinct behavior types, Type-1 and Type-2 (repetitive bounce diving), by size and age class

YELLOWFIN TUNA

Type-1 diving behavior for seven days, March 6 - 12, 2009 and 1-day, March 8, 2009 for an estimated 81 cm yellowfin tuna at an estimated location is 24.5°N 113.3°W.





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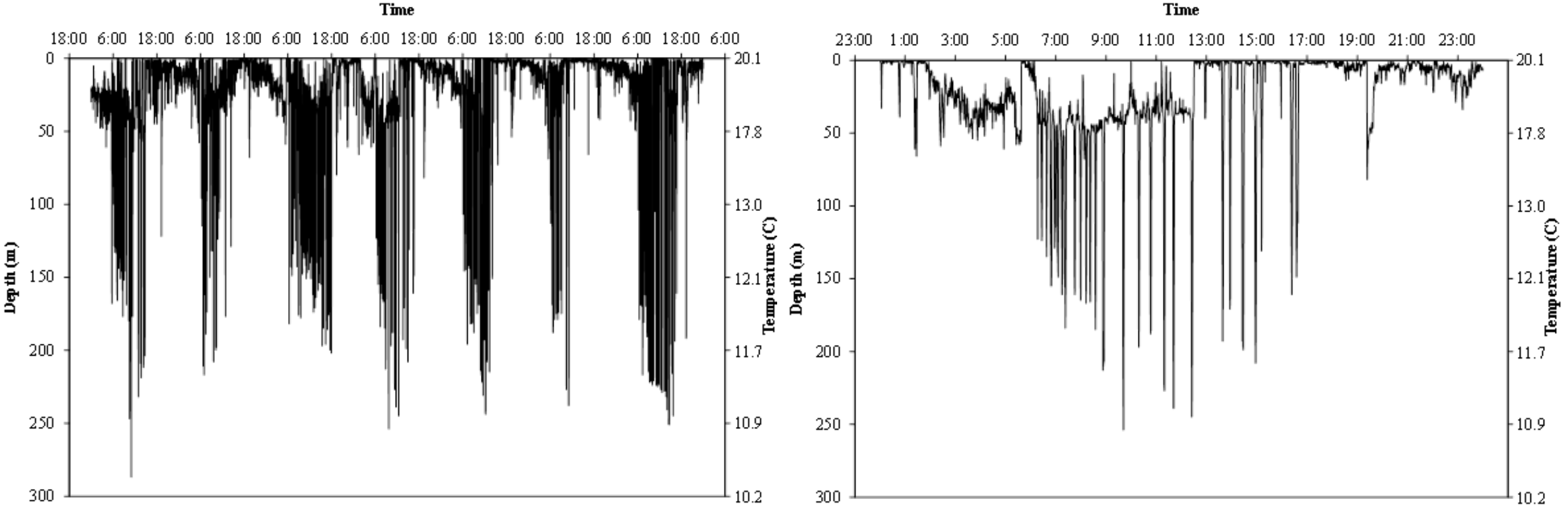
YELLOWFIN TUNA

Repetitive bounce diving behavior. (A) Seven days, April 15 - 21, 2009. (B) One day, April 17, 2009. Estimated location is 23.5°N 112.0°W. Estimated length is 85 cm



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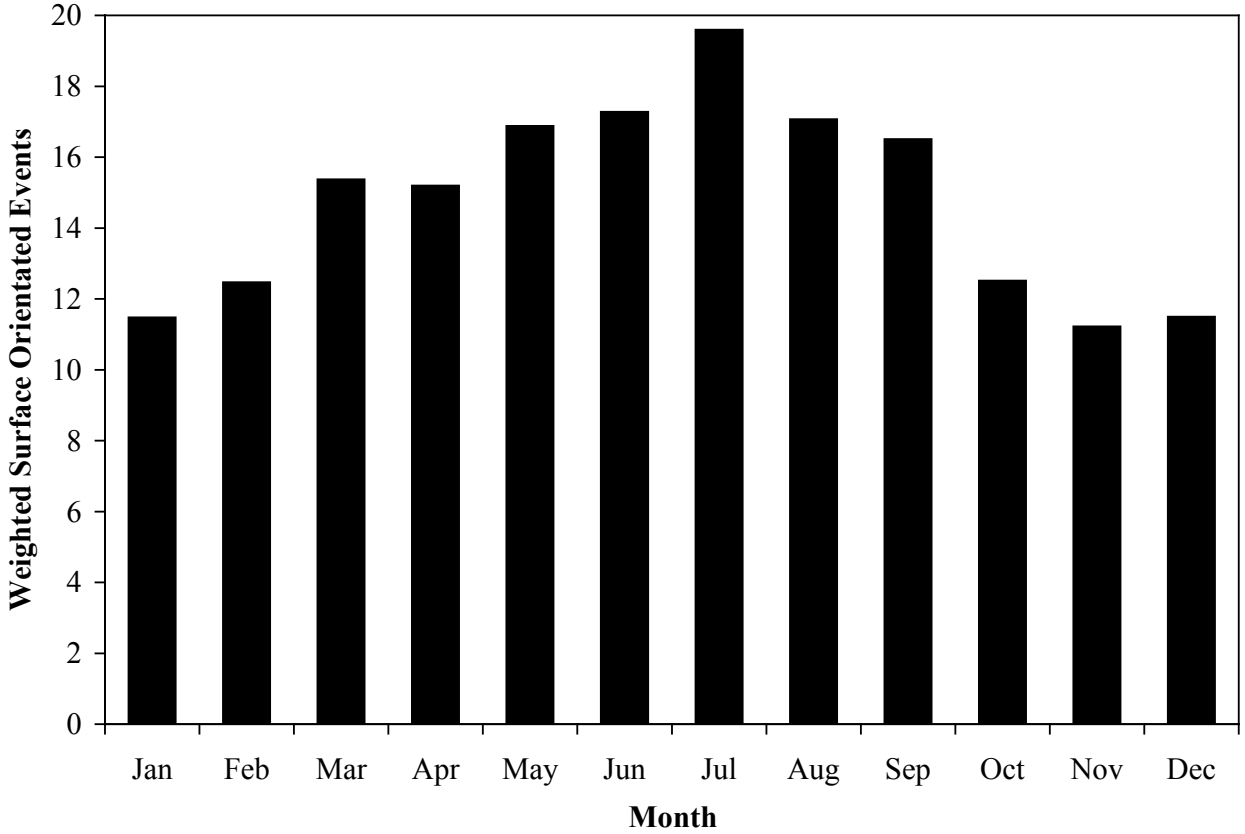
YELLOWFIN TUNA

- Define 2 distinct behavior types, Type-1 and Type-2 (repetitive bounce diving), by size and age class
- Describe surface-orientated events, where fish were within 10m of the surface for more than 10 minutes to evaluate potential detection and ultimately vulnerability to purse-seine fishing

YELLOWFIN TUNA

Summary of 413,173 surface-oriented events per day by month, weighted by the number of days per month for which events occurred



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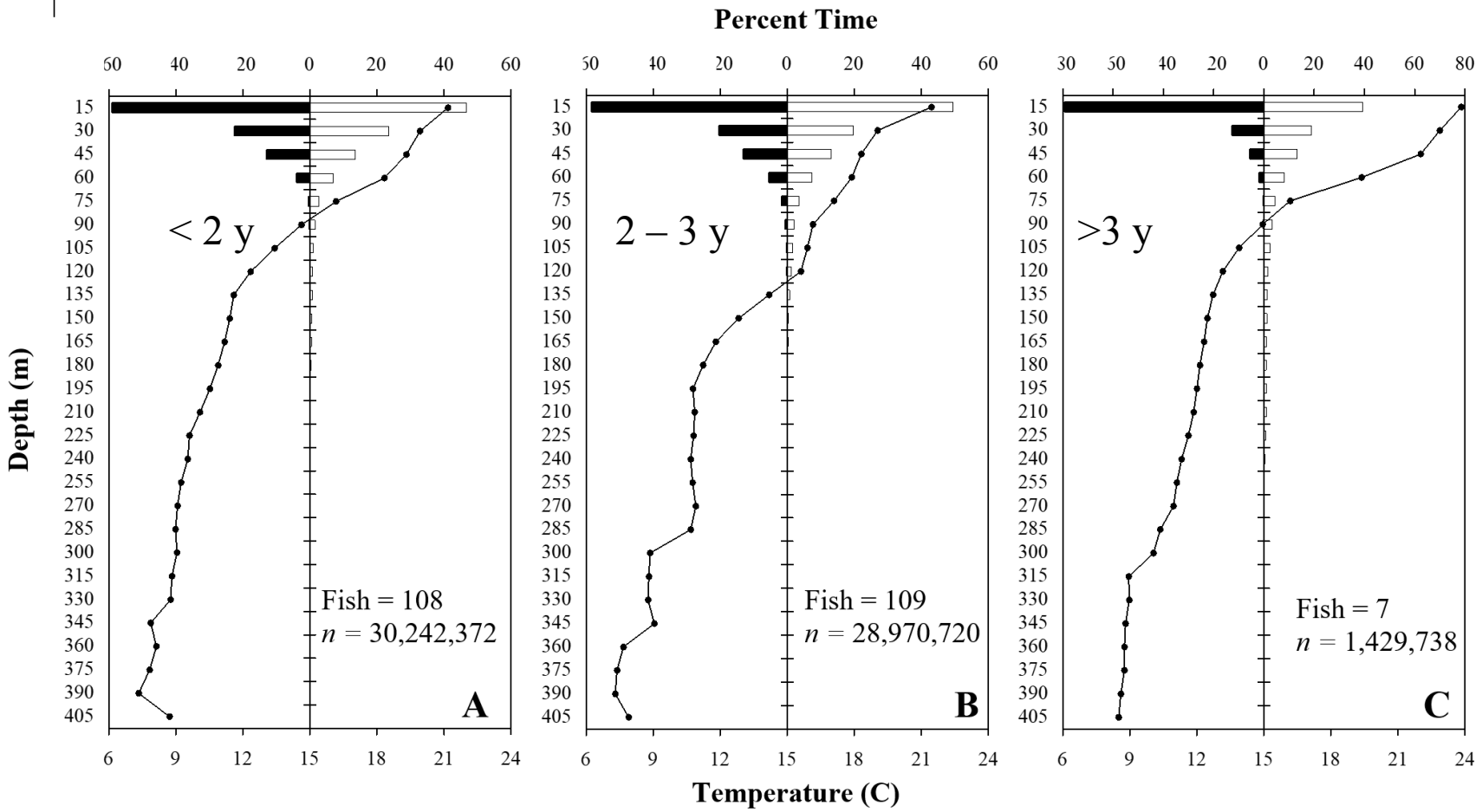
YELLOWFIN TUNA

Vertical habitat utilization by day and night, by age class



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YELLOWFIN TUNA

Daily classification of behavior types for 126 yellowfin tuna, by age groups

Age	Type-1 diving			Type-2 diving			Surface oriented		
	% days	events	$\bar{x}$ duration	% days	events	$\bar{x}$ duration	events	$\bar{x}$ events/day	$\bar{x}$ duration
1.25	89.8	23	8.8	10.2	20	1.6	199	6.5	23.5
1.50	79.7	304	6.4	20.3	297	1.9	12,924	5.0	22.5
1.75	81.5	633	7.2	18.5	614	1.9	55,110	6.9	23.0
2.00	86.0	815	10.1	14.0	788	1.8	106,856	8.3	24.6
2.25	87.8	263	12.3	12.2	237	1.6	100,159	7.7	23.9
2.50	82.3	250	13.2	17.7	227	2.5	57,722	8.1	24.2
2.75	87.7	119	13.7	12.3	109	1.9	32,525	9.9	25.4
3.00	81.6	64	8.6	18.4	59	1.7	18,929	8.5	25.4
3.25	86.8	22	15.4	13.2	20	2.0	6,580	6.1	25.1
3.50	61.3	28	8.6	38.7	27	4.7	5,721	7.1	27.7
3.75	67.9	24	3.7	32.1	25	2.9	3,270	6.5	23.4
4.00	53.9	28	4.7	46.1	27	3.0	2,566	4.6	24.8
4.25	38.6	24	2.8	61.4	24	4.8	2,330	5.3	25.2
4.50	56.0	27	3.9	44.0	28	2.9	3,283	9.3	31.6
4.75	68.7	38	2.8	31.3	37	1.4	2,580	6.4	29.1
5.00	39.1	16	5.2	60.9	16	6.4	2,482	5.3	21.6
Pooled	82.9	2555	9.3	17.1	2678	2.0	151,110	7.6	24.2

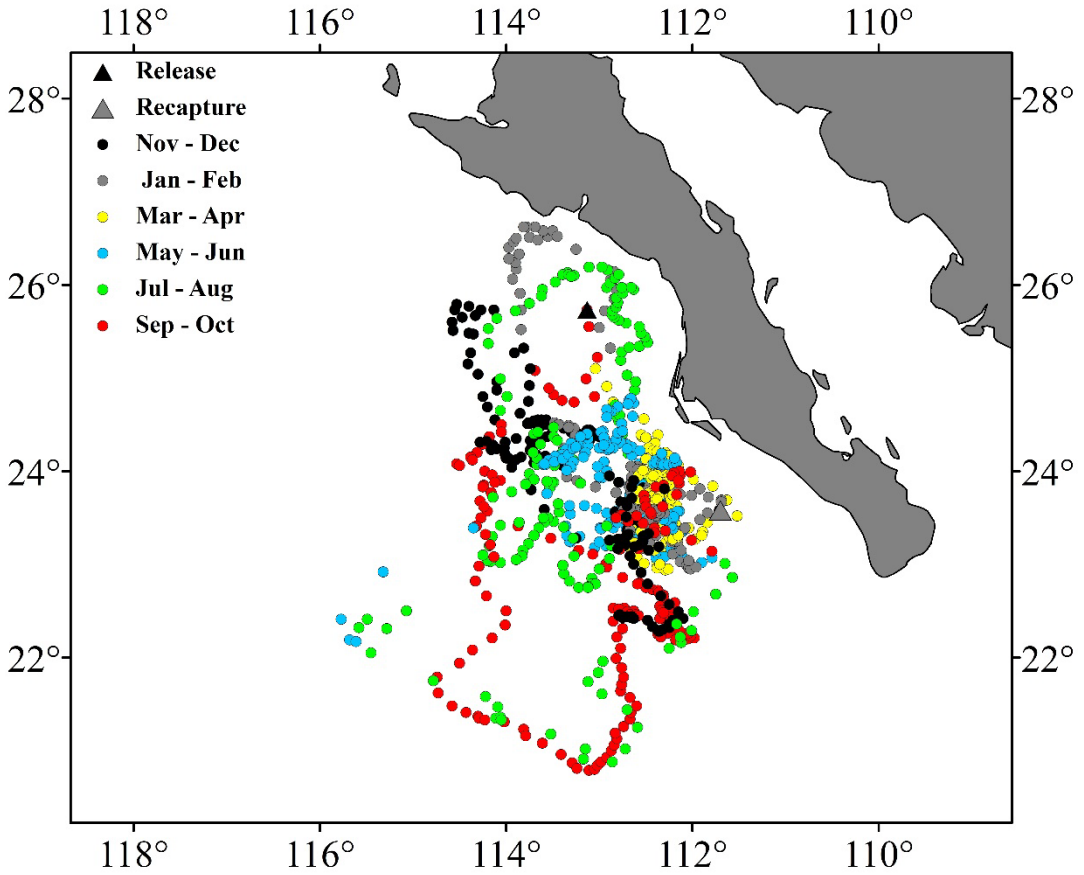
Schaefer, K.M., Fuller, D.W., and Block, B.A., 2011. Movements, behavior, and habitat utilization of yellowfin tuna (*Thunnus albacares*) in the Pacific Ocean off Baja California, Mexico, determined from archival tag data analyses, including unscented Kalman filtering. Fish. Res. 112:22-37.

YELLOWFIN TUNA

- Define 2 distinct behavior types, Type-1 and Type-2 (repetitive bounce diving), by size and age class
- Describe surface-orientated events, where fish were within 10m of the surface for more than 10 minutes to evaluate potential detection and ultimately vulnerability to purse-seine fishing
- Evaluate ontogenetic changes in both behavior and habitat
- Position estimates derived from light-levels recorded on the tags, and post processed using the uKFSST model provided most probable movement tracks.

YELLOWFIN TUNA

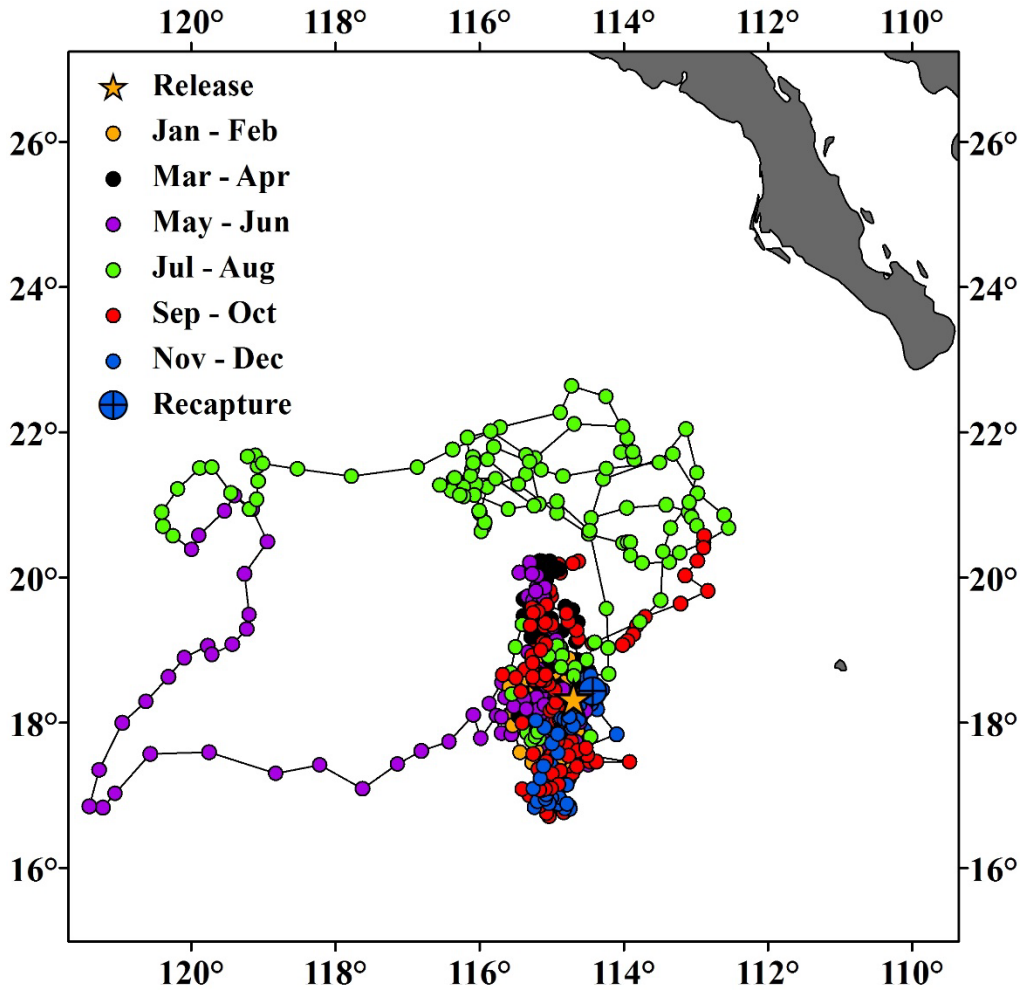
Most probable track for a yellowfin released off southern Baja California, at liberty for 1160d, estimated from the uKFSST model



Schaefer, K.M., Fuller, D.W., and Block, B.A., 2011. Movements, behavior, and habitat utilization of yellowfin tuna (*Thunnus albacares*) in the Pacific Ocean off Baja California, Mexico, determined from archival tag data analyses, including unscented Kalman filtering. Fish. Res. 112:22-37.

YELLOWFIN TUNA

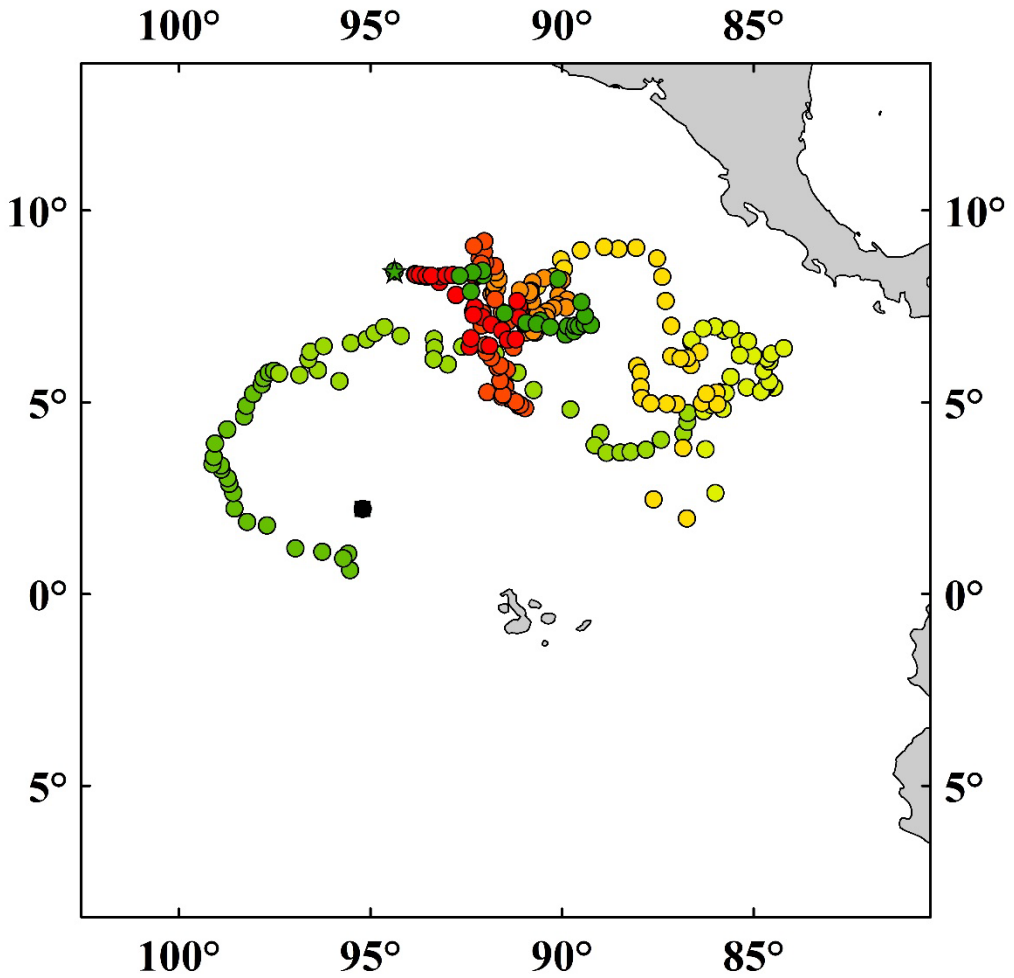
Most probable track for a yellowfin released at Clarion Island, at liberty for 635d, estimated from the uKFSST model



Schaefer, K.M., D.W. Fuller, and G. Aldana. 2014. Movements, behavior, and habitat utilization of yellowfin tuna (*Thunnus albacares*) in waters surrounding the Revillagigedo Islands Archipelago Biosphere Reserve, Mexico. Fish. Ocean. 23(1):65-82.

YELLOWFIN TUNA

Most probable track for a yellowfin released in the equatorial eastern Pacific, at liberty for 311d, estimated from the uKFSST model



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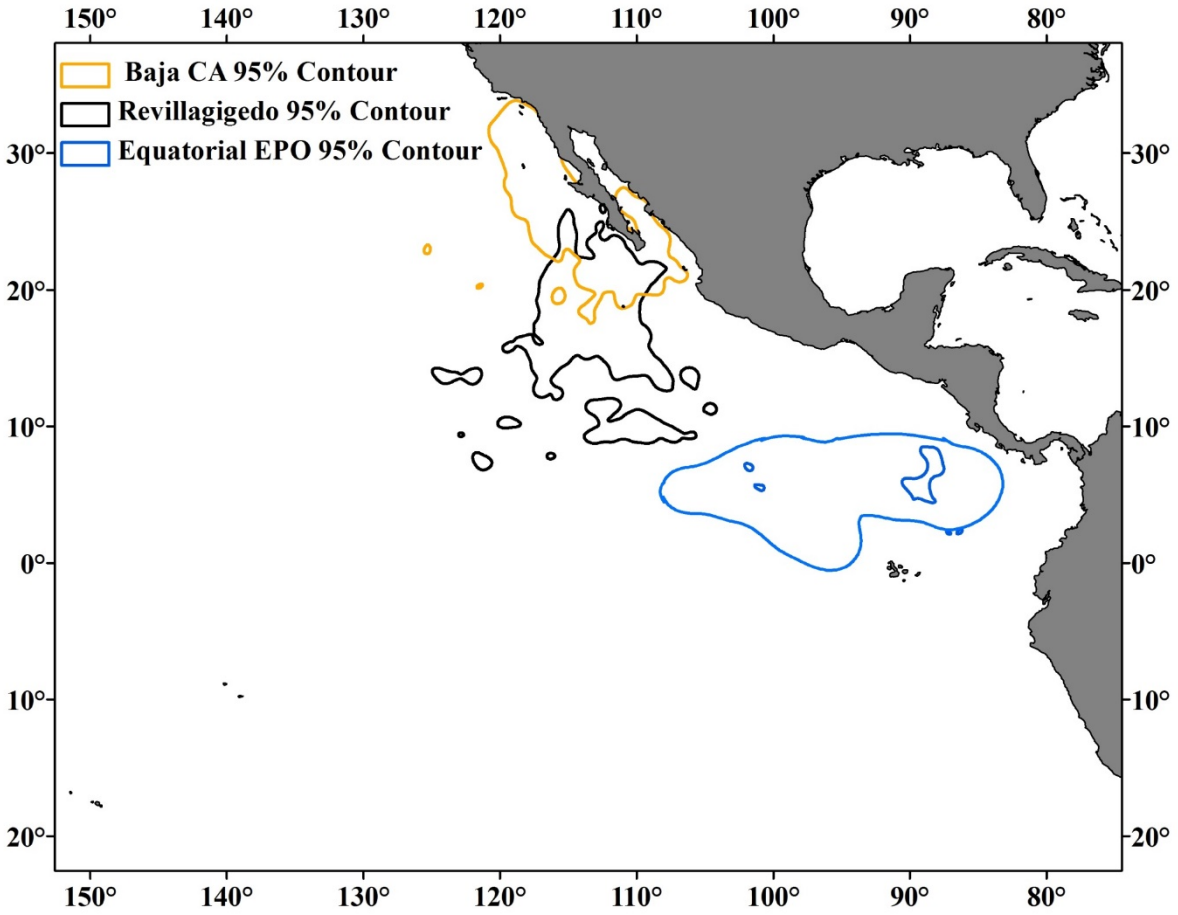
- Derived MPT's for all tags provided data necessary to develop hypotheses about movements, mixing rates and stock structure

YELLOWFIN TUNA

95% volume contours calculated from a kernel density function for all archival tag position estimates for three release areas



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- Derived MPT's for all tags provided data necessary to develop hypotheses about movements, mixing rates and stock structure.
- Movement parameters from the uKFSST model can help inform assumptions about mixing rates between stocks in a multi-stock stock assessment models

YELLOWFIN TUNA

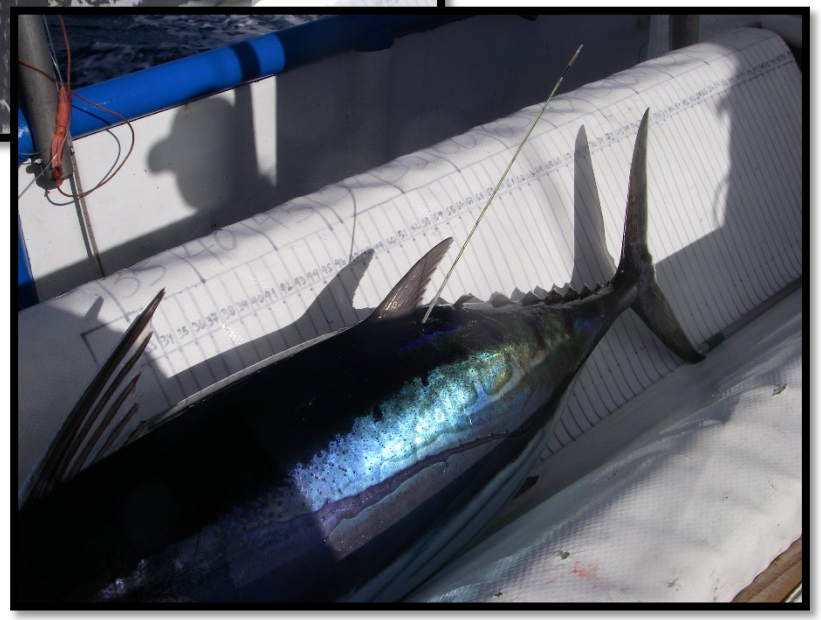
Bigeye movement parameter estimates from the uKFSST model by release area

Area		σ_x (Degrees)	σ_y (Degrees)	*u* (nm/day)	*v* (nm/day)	*D* (nm^2/day)
Northern Baja	**Median**	0.46	1.67	0.16	-0.50	135.09
	Range	0.30 – 0.60	1.44 – 2.12	-0.38 – 0.59	-1.84 – 0.42	84.37 – 267.77
Southern Baja	**Median**	0.43	2.79	0.05	0.06	117.80
	Range	0.36 – 0.53	1.53 – 4.56	-0.14 – 0.22	-0.35 – 0.98	62.45 – 219.76
Revillagigedo Islands	**Median**	0.43	2.79	0.05	0.06	117.80
	Range	0.36 – 0.53	1.53 – 4.56	-0.14 – 0.22	-0.35 – 0.98	62.45 – 219.76
Panama	**Median**	0.97	3.04	0.56	0.54	92.06
	Range	0.79 – 1.31	1.46 – 5.36	-0.06 – 1.02	0.21 – 0.96	67.62 – 114.83
Equatorial EPO	**Median**	0.52	2.57	2.75	4.17	584.08
	Range	0.19 – 0.79	0.83 – 4.09	-4.79 – 7.78	0.66 – 10.42	411.76 – 858.10

YELLOWFIN TUNA - CONCLUSIONS

- Higher proportions of Type-2, repetitive bounce diving, behavior was exhibited for larger fish and those away from the coast or islands
- Larger fish and those released in offshore areas had a higher proportion of time spent at greater depths and lower temperatures during the day
- There are spatial, temporal, and size/age differences in the behavior of yellowfin and thus unequal vulnerability to capture by purse-seine vessels throughout the EPO
- Surface oriented behavior, during the day, appears to be a reasonable approximation for the potential detection and vulnerability to capture by purse-seine vessels

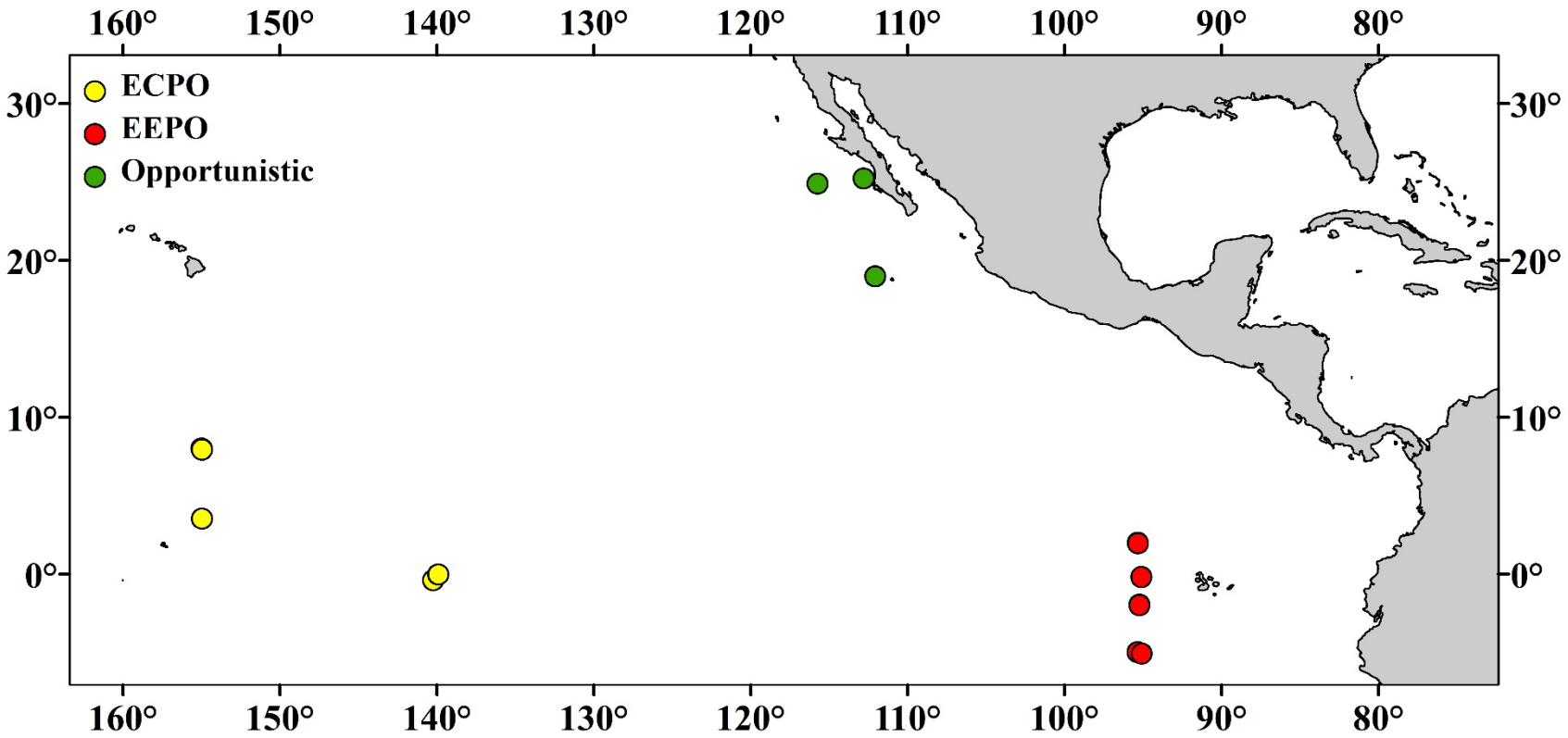
SKIPJACK - TAGGING METHODS



SKIPJACK TUNA

SKIPJACK TUNA ARCHIVAL TAGGING

Area	Released	Returned	% Returned
Equatorial EPO	133	7	5.3
Equatorial CPO	30	0	0.0
Opportunistic tagging	23	0	0.0

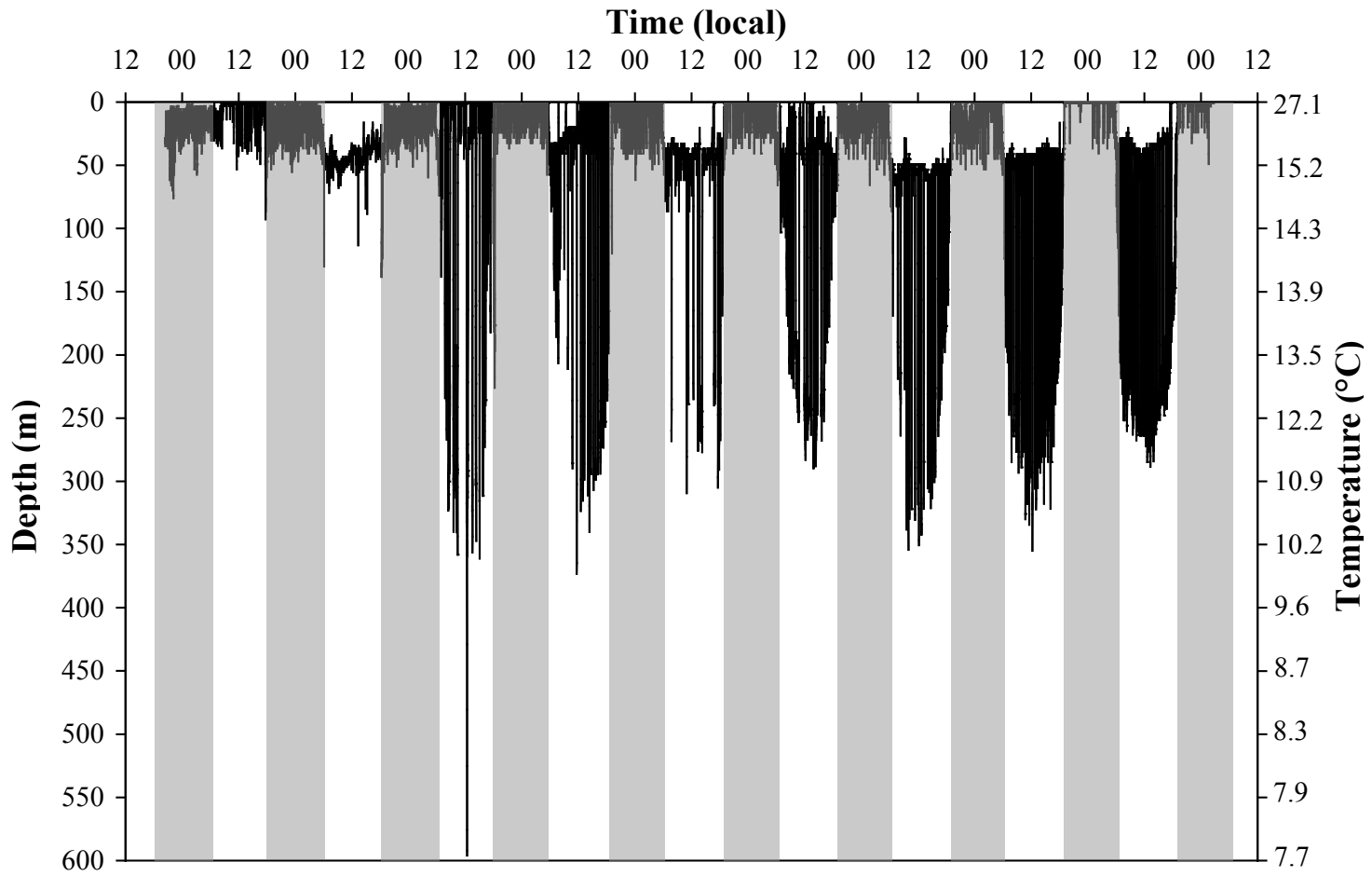


SKIPJACK TUNA

- Based on acoustic tracking studies it was possible to define associated behavior (Schaefer and Fuller, 2005)
- Using this information, it was possible to classify behavior as either unassociated or associated with a floating object
- When not associated Skipjack commonly exhibited repetitive bounce diving behavior

SKIPJACK TUNA

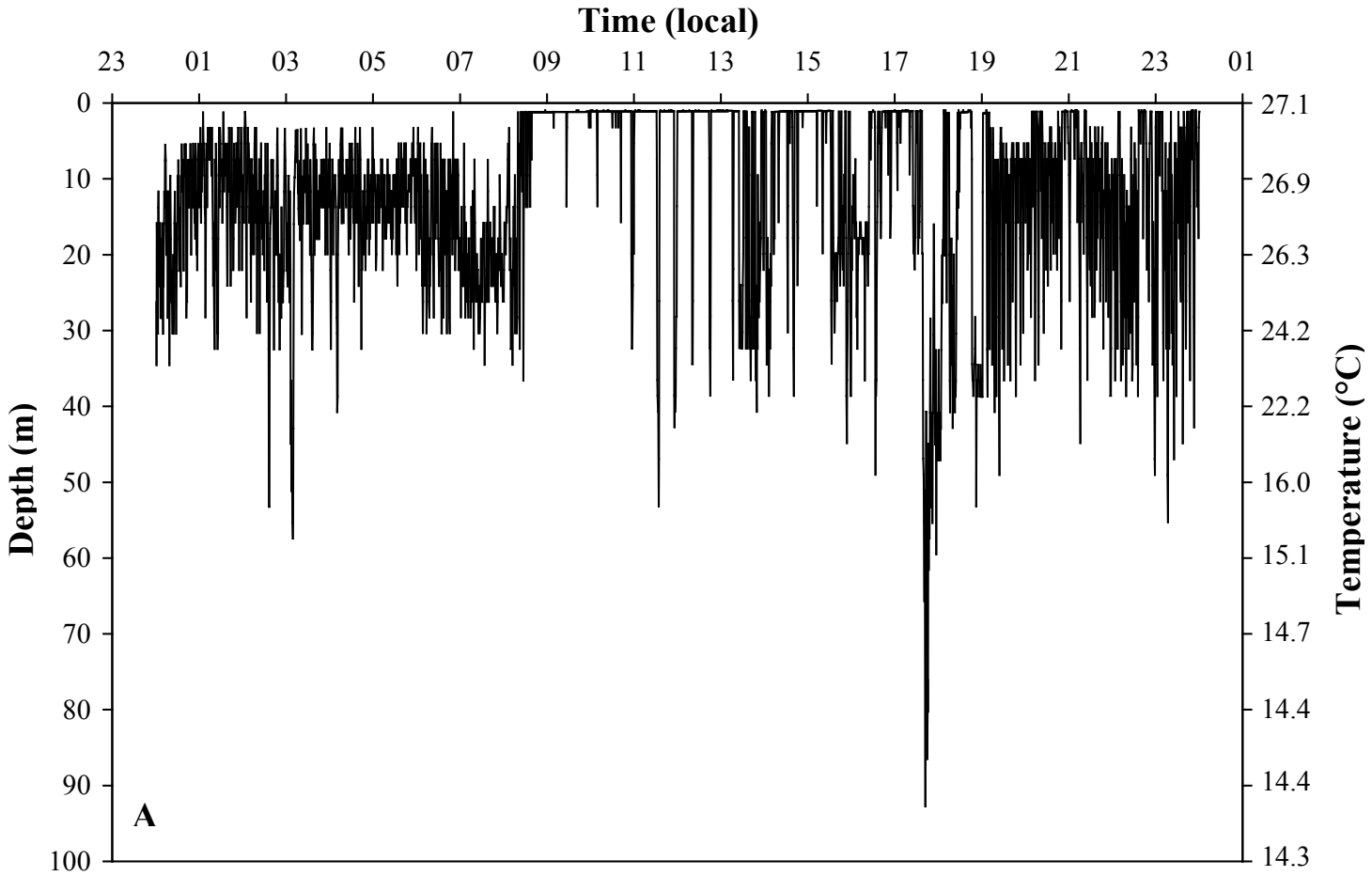
One week (April 10-20, 2004) of Skipjack behavior showing both associated and unassociated behavior



Schaefer, K.M., and D.W. Fuller. 2007. Vertical movement patterns of skipjack tuna (Katsuwonus pelamis) in the eastern equatorial Pacific Ocean, as revealed with archival tags. Fishery Bulletin, 105(3): 379-389.

SKIPJACK TUNA

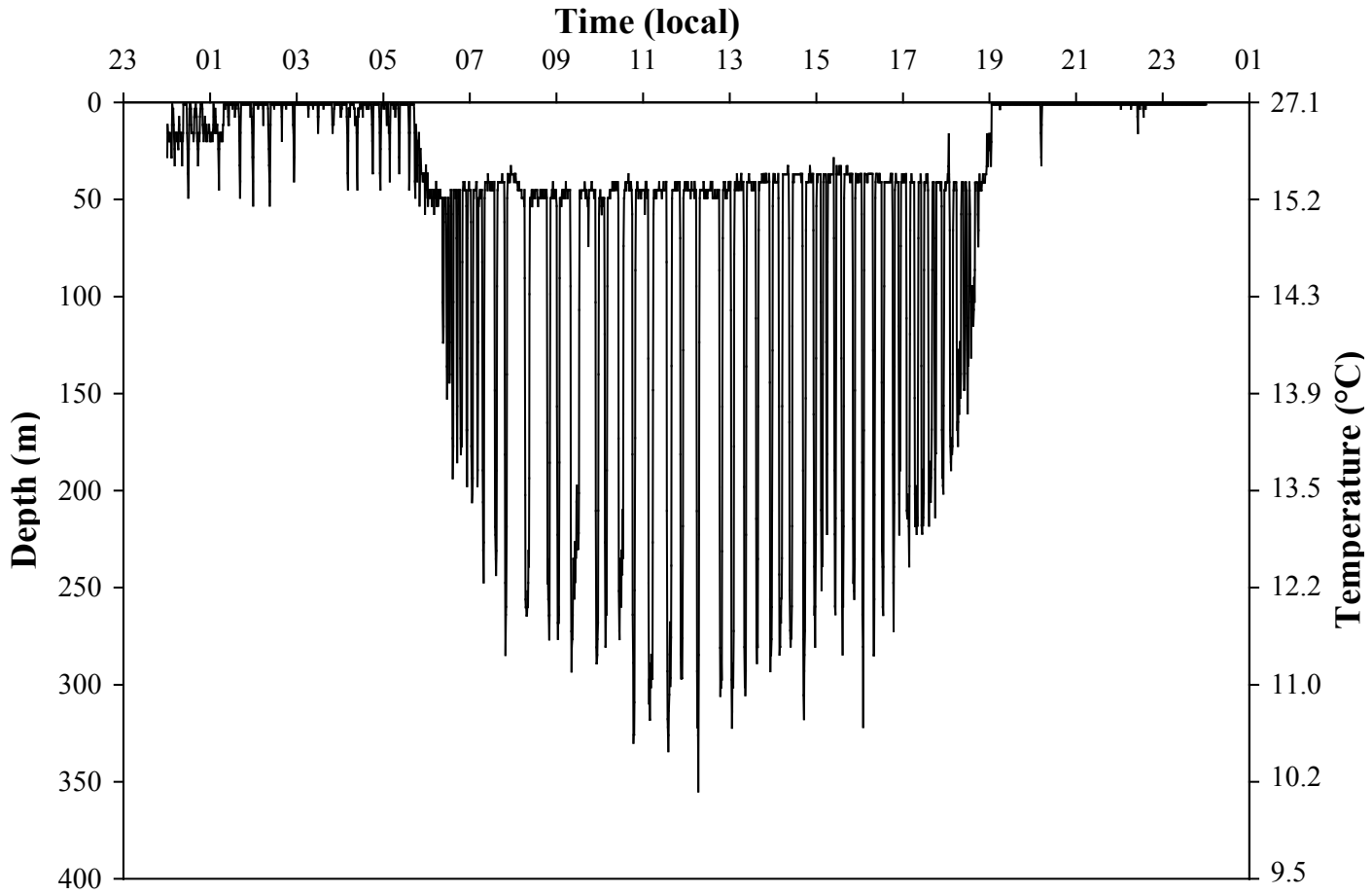
Skipjack tuna exhibiting associated behavior on April 11, 2004



Schaefer, K.M., and D.W. Fuller. 2007. Vertical movement patterns of skipjack tuna (Katsuwonus pelamis) in the eastern equatorial Pacific Ocean, as revealed with archival tags. Fishery Bulletin, 105(3): 379-389.

SKIPJACK TUNA

Skipjack tuna exhibiting repetitive bounce diving behavior on April 18, 2004



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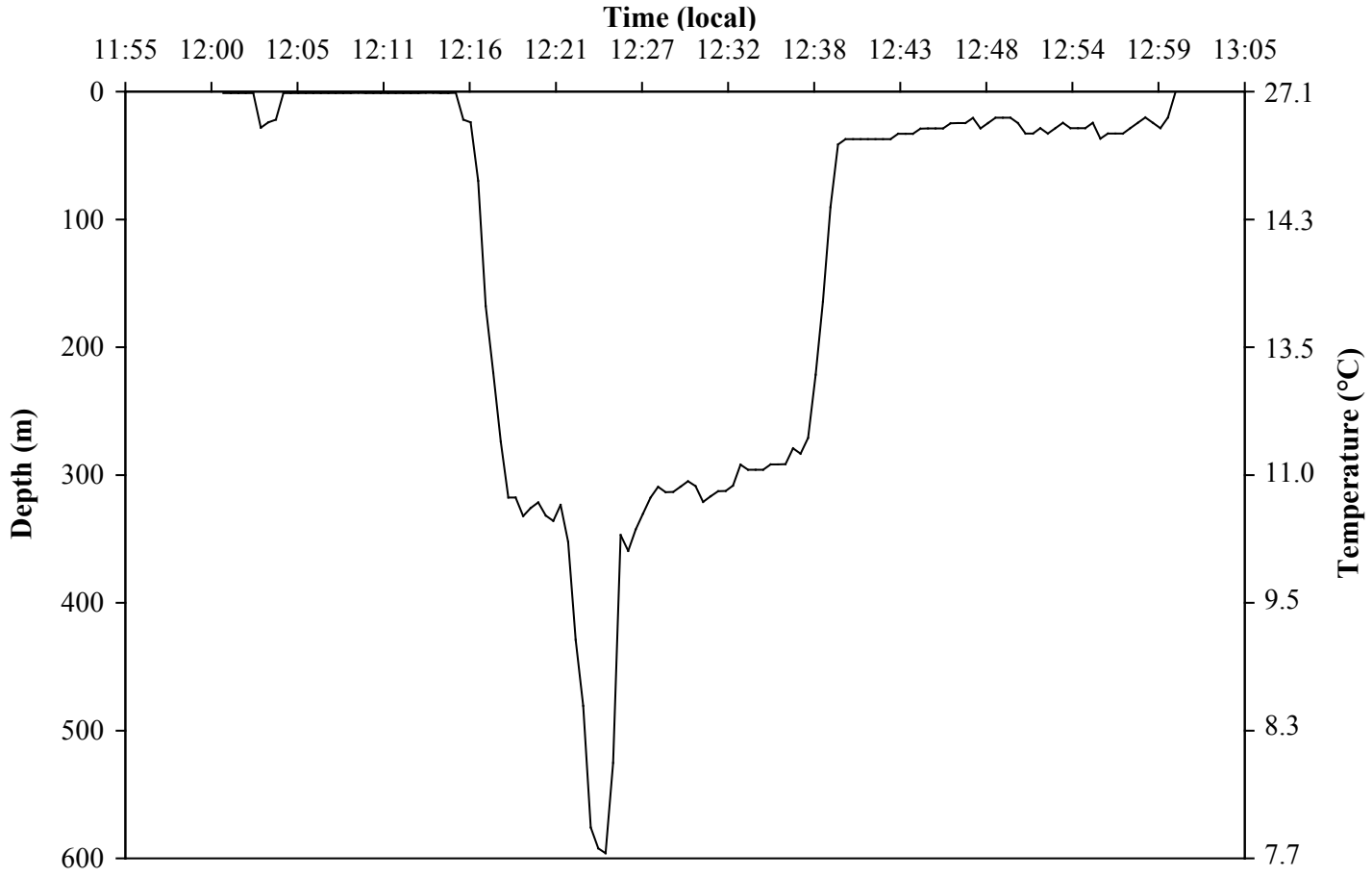
- Skipjack are able to make deep dives, in excess of 500m

SKIPJACK TUNA

Skipjack tuna exhibiting deep diving behavior



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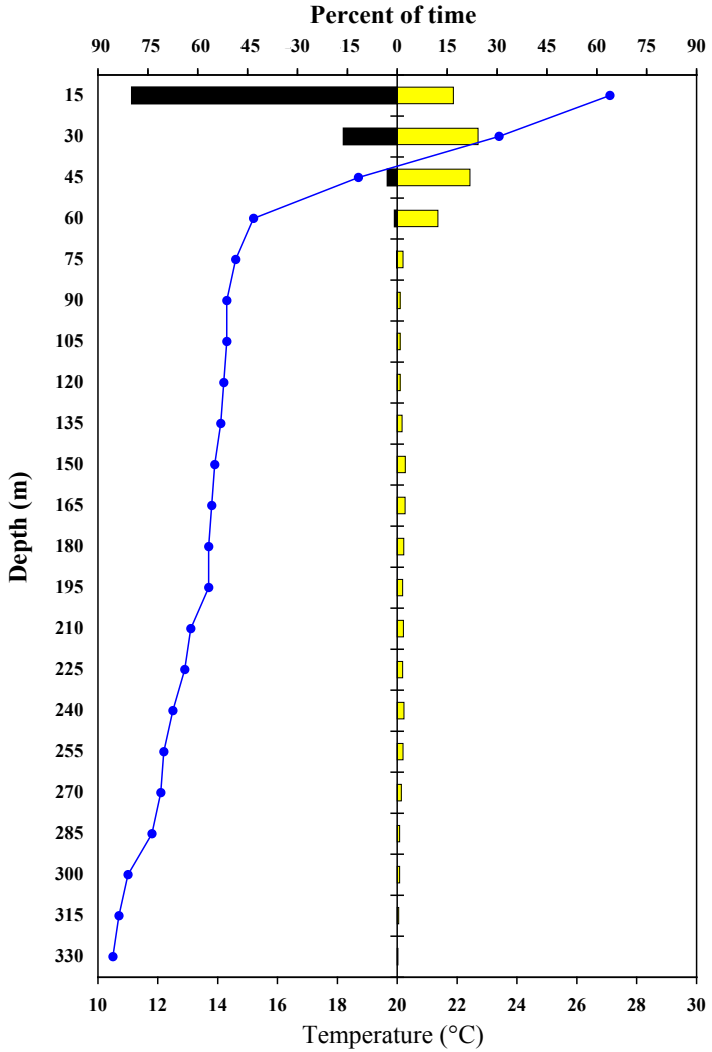
- Skipjack are able to make deep dives, in excess of 500m
- Skipjack habitat was defined for all unassociated days

SKIPJACK TUNA

Skipjack tuna habitat by day and night



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SKIPJACK TUNA- CONCLUSIONS

- Archival tag recovery rates for skipjack tuna are highly variable and getting reasonable numbers of archival tags returned has proved challenging
- Skipjack tuna exhibited distinct associated behavior, remaining primarily in the mixed layer
- Skipjack tuna exhibited distinct unassociated repetitive bounce diving between 50 and 300 m during the day
- The deepest dive recorded was 596 m (7.7°C)
- Vertical habitat utilization distributions indicate 98.6 % of time above the thermocline during the night and 37.7% of time below the thermocline during the day

ARCHIVAL TAGGING SUMMARY

- Archival tagging studies require substantial financial support for consecutive years in order to obtain a reasonable understanding of stock structure, movements, behavior, and habitat utilizations, by size and age, within large areas such as the eastern Pacific Ocean
- Archival tags can provide rich data sets which can be used in numerous applications for fisheries research and management, many of which have not yet been fully explored or discovered
- Processing large volumes of archival tag data requires substantial computer resources and time, even with various programs now available for data analyses

Questions