

**Horizontal Movements of Bigeye Tuna (*Thunnus obesus*) in the Eastern Pacific Ocean, as Determined from Conventional and Archival Tagging Experiments Initiated During 2000-2006**



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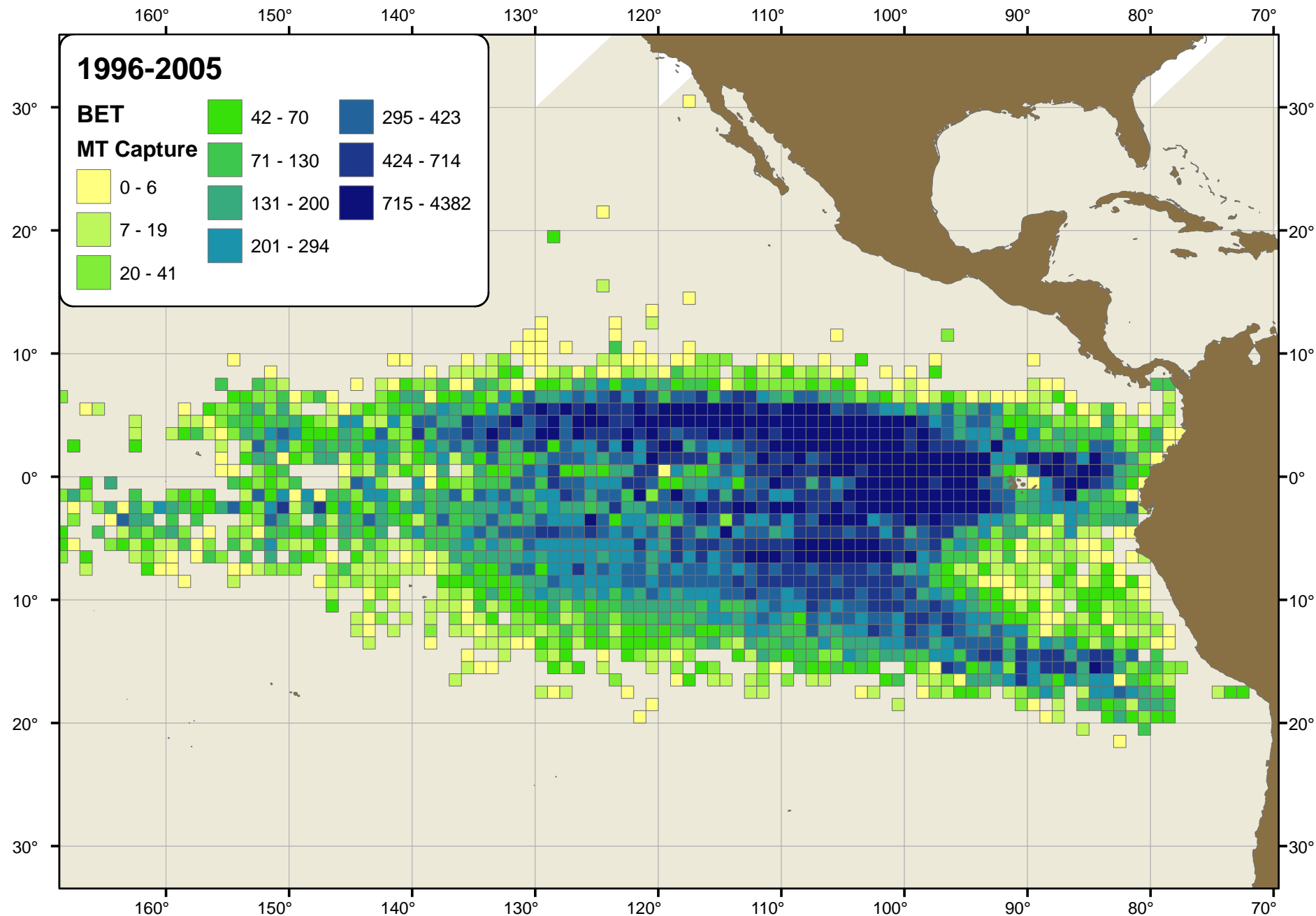
**Inter-American Tropical Tuna Commission**



# **BACKGROUND INFORMATION AND JUSTIFICATION**

- **Development and rapid expansion of the purse-seine fishery on drifting FADs in the EPO in 1994 resulted in a substantial increase in catches of bigeye from about 5 thousand to over 50 thousand tons by 1996**
- **Declining trend in Japanese longline bigeye catch in the EPO from about 100 to less than 50 thousand metric tons by 1996**
- **Concern that the longline fishery for bigeye is being indirectly affected by the purse-seine fishery on FADs**
- **Lack of scientific information on bigeye population structure, movements, mortality, and growth in the EPO**
- **Essential to quantify these and other life history information for inclusion in annual stock assessments for bigeye in the EPO**

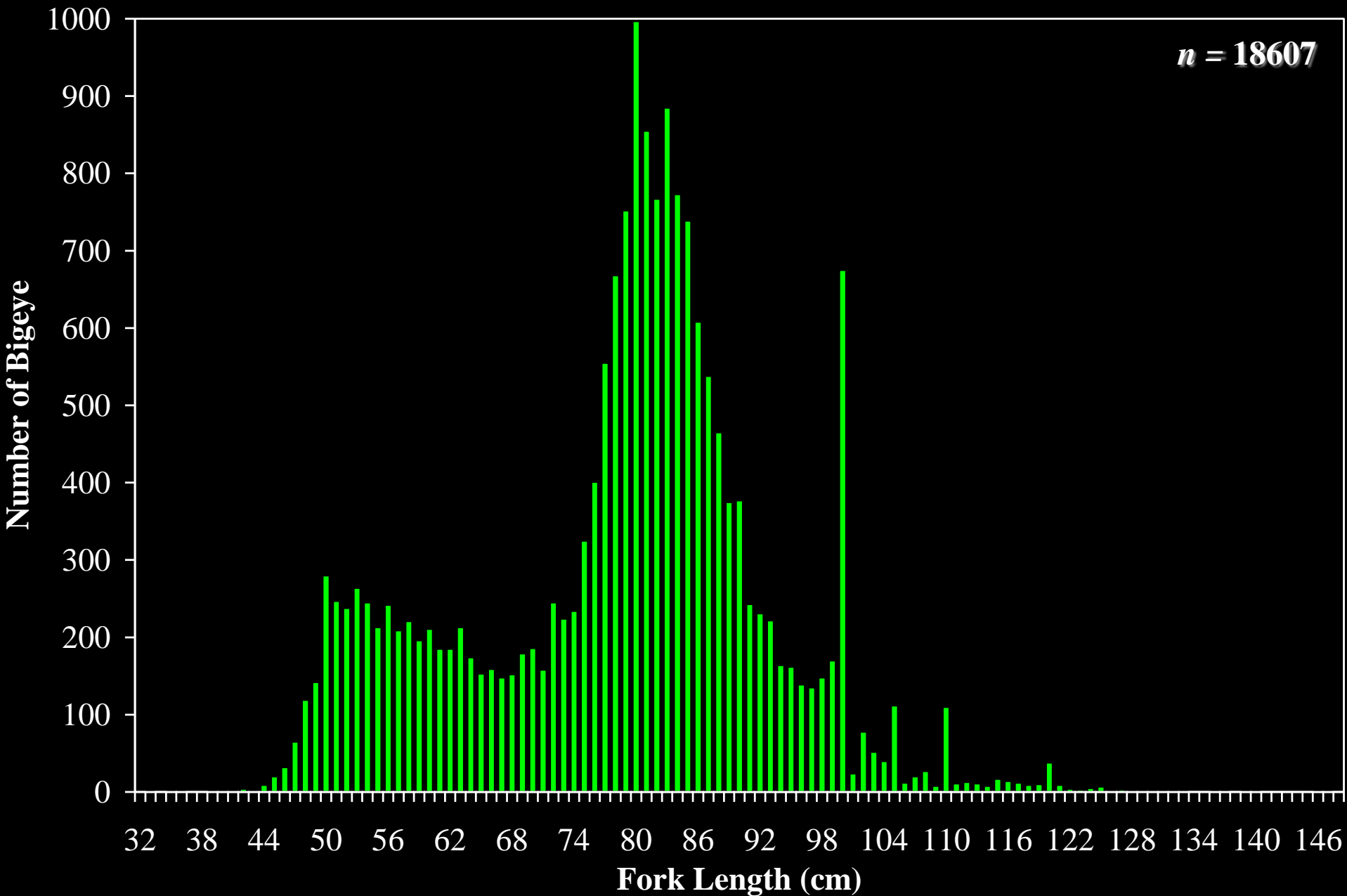
# Purse Seine Catch of Bigeye by 1-Degree Area for 1996-2005



# IATTC Conventional Tag Releases and Returns For EEPO tagging 2000 - 2006

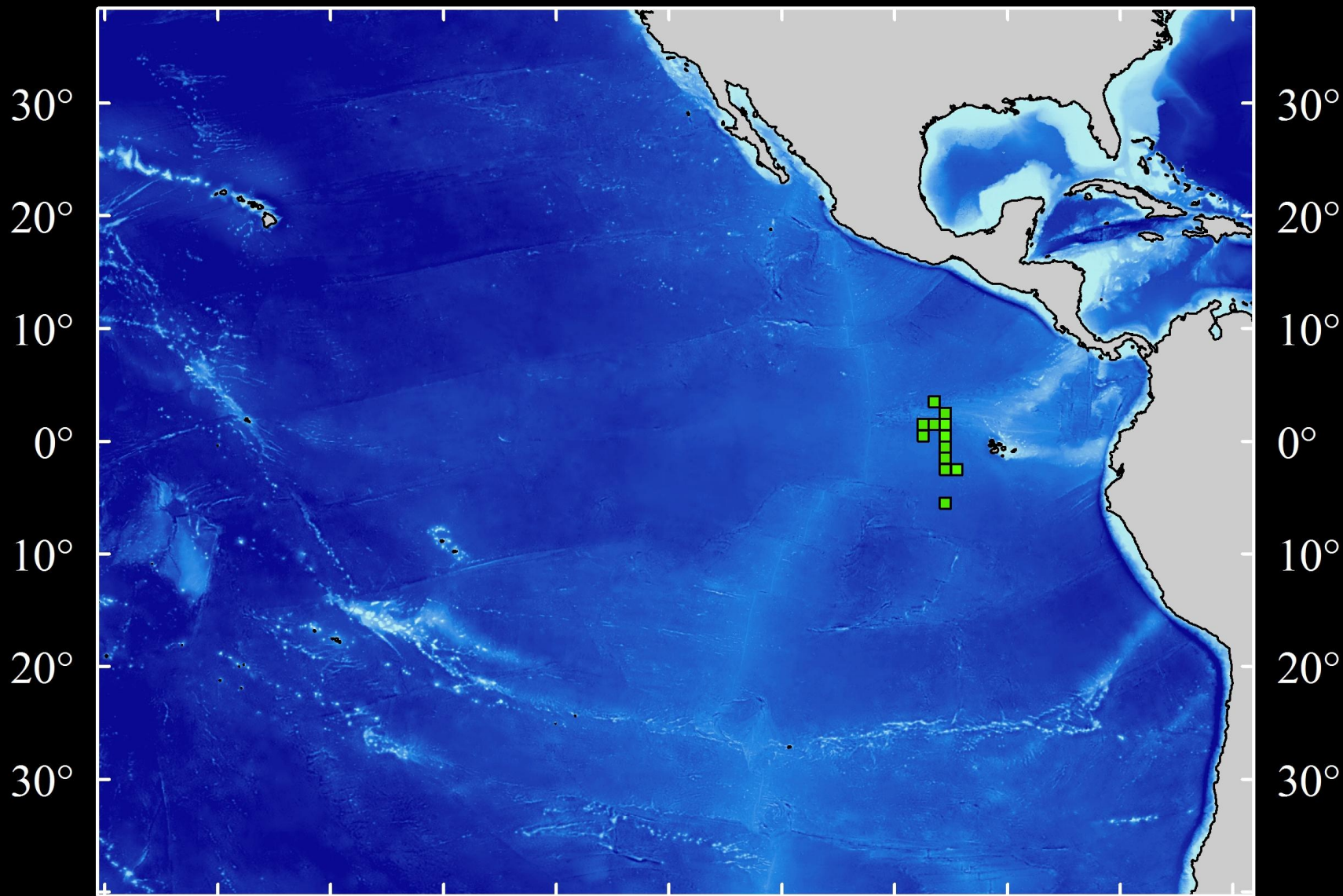
Year	Bigeye Tuna			Skipjack Tuna			Yellowfin Tuna		
	Released	Returned	Percent Returned	Released	Returned	Percent Returned	Released	Returned	Percent Returned
2000	101	22	21.8	1235	262	21.2	73	8	11.0
2002	1418	581	41.0	249	30	12.0	186	29	15.6
2003	8605	4032	46.9	138	22	15.9	863	244	28.3
2004	7089	2800	39.5	878	152	17.3	306	39	12.7
2005	1929	805	41.7	333	32	9.6	265	38	14.3
2006	32	9	28.1	592	65	11.0	541	47	8.7
<b>Total</b>	<b>19174</b>	<b>8249</b>	<b>43.0</b>	<b>3425</b>	<b>563</b>	<b>16.4</b>	<b>2234</b>	<b>405</b>	<b>18.1</b>
	<b>&gt; 30 Days</b>		<b>36.1</b>			<b>9.7</b>			<b>11.2</b>

# Length Frequency Distribution for Bigeye Released with Conventional Tags



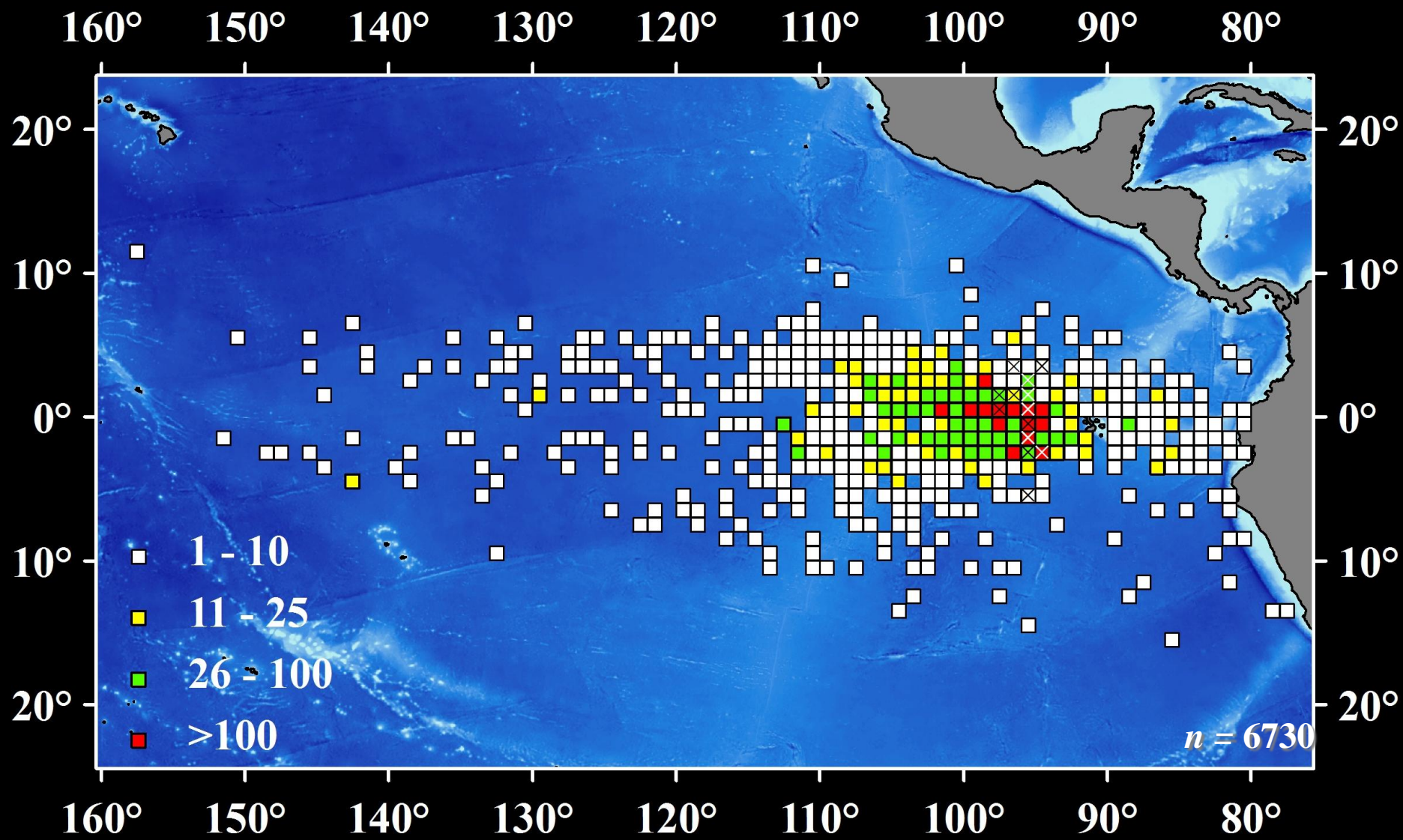
# Bigeye Tag Release Areas 2000 - 2006

170° 160° 150° 140° 130° 120° 110° 100° 90° 80° 70°

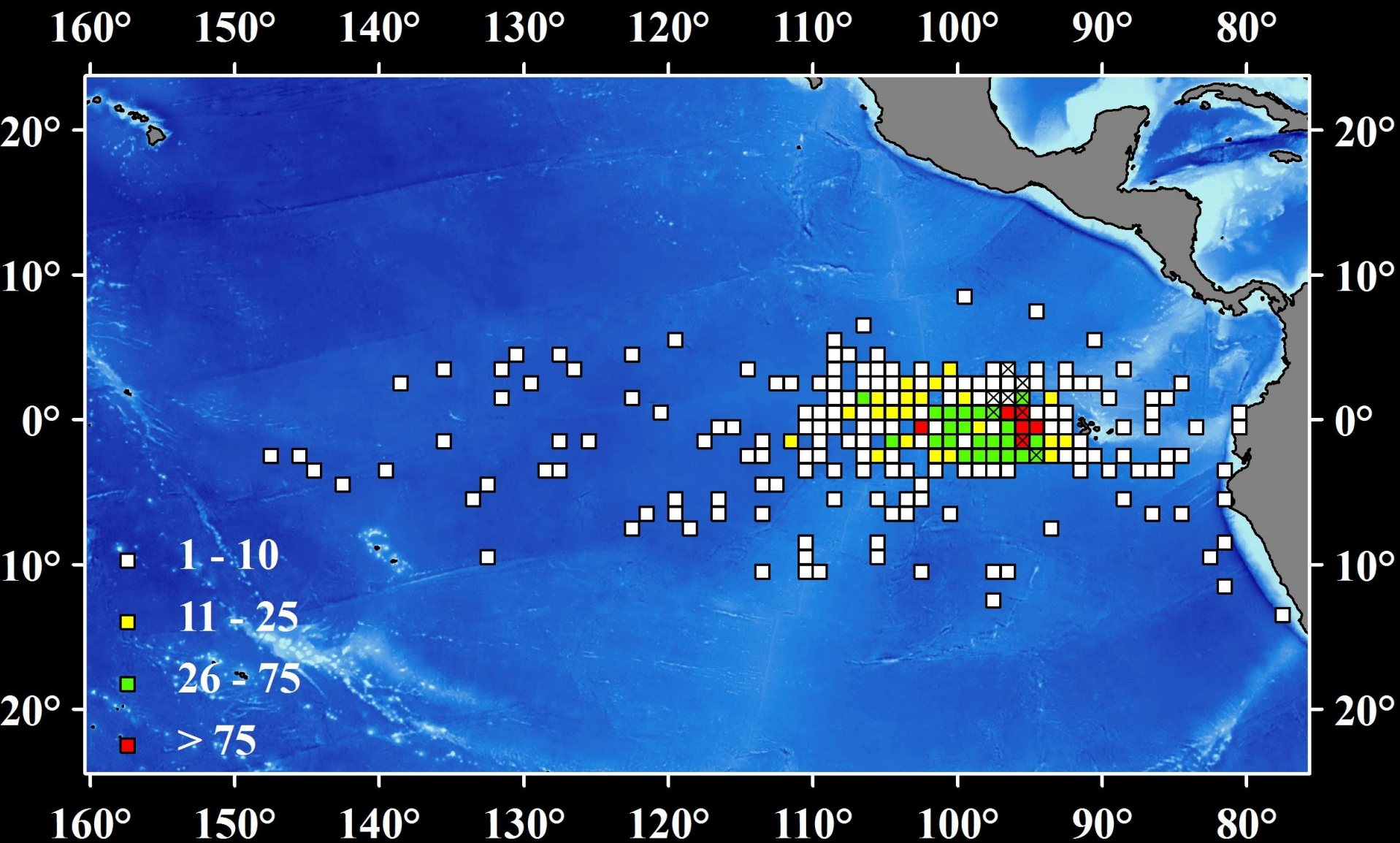


170° 160° 150° 140° 130° 120° 110° 100° 90° 80° 70°

**1-degree Areas of Recapture for Bigeye Released Between 2000 and 2006 at  
Liberty for Greater than 30d, 95% < 1000 nm, Max: 3,830 nm (696d)**

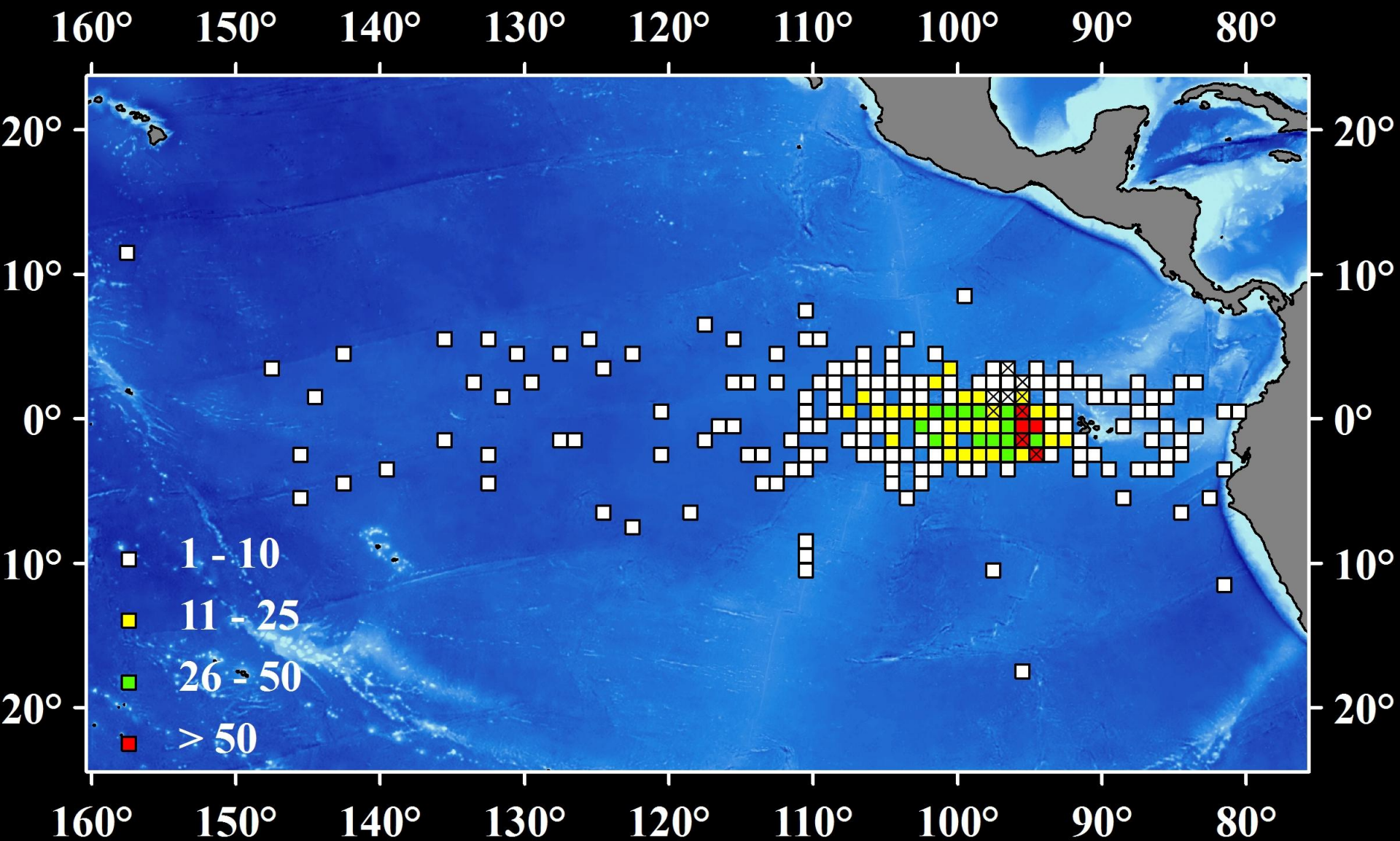


# 1-degree Areas of Recapture for Bigeye Released Between 2000 and 2005 at Liberty for Greater than 180d, Less Than 80 cm

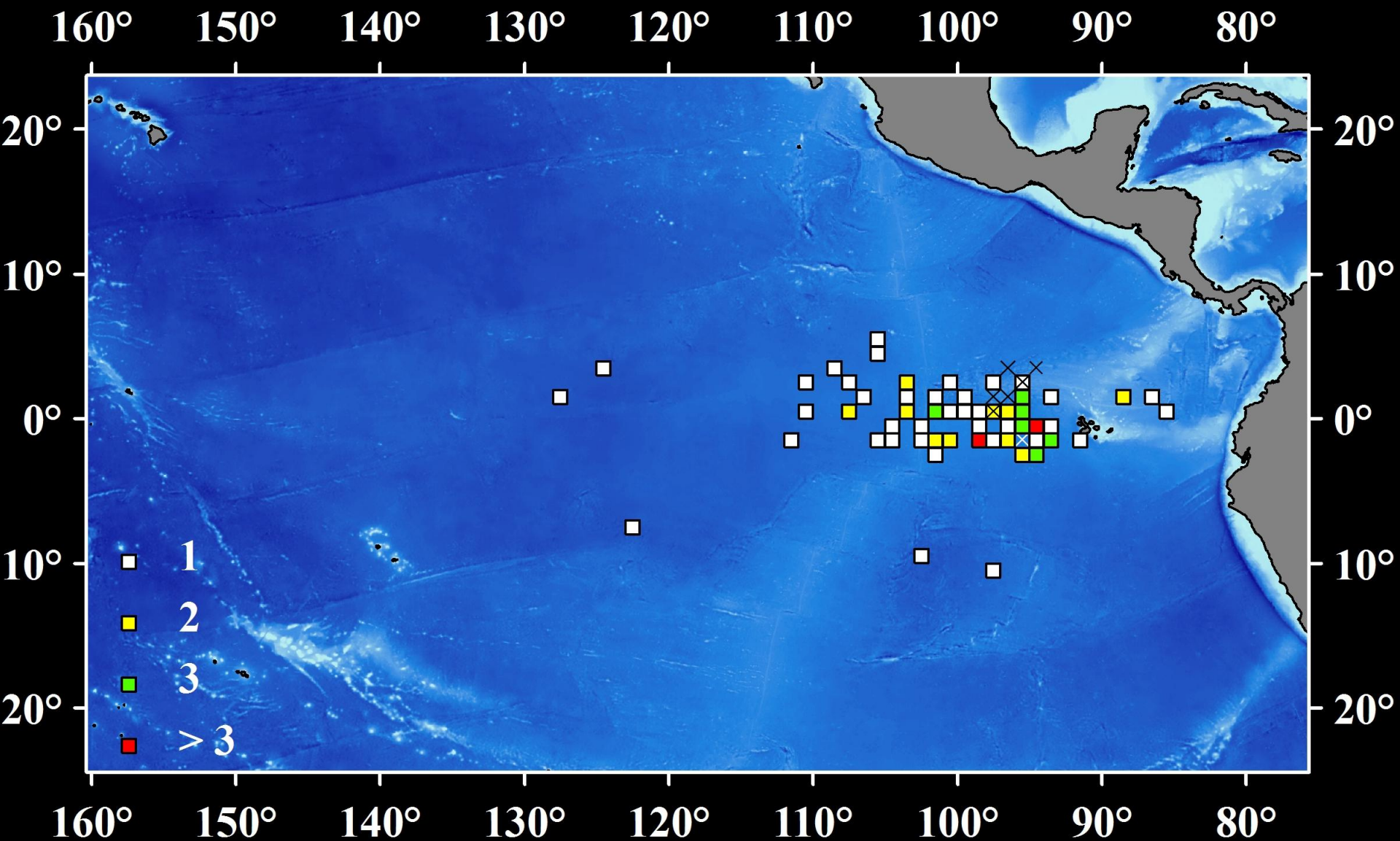




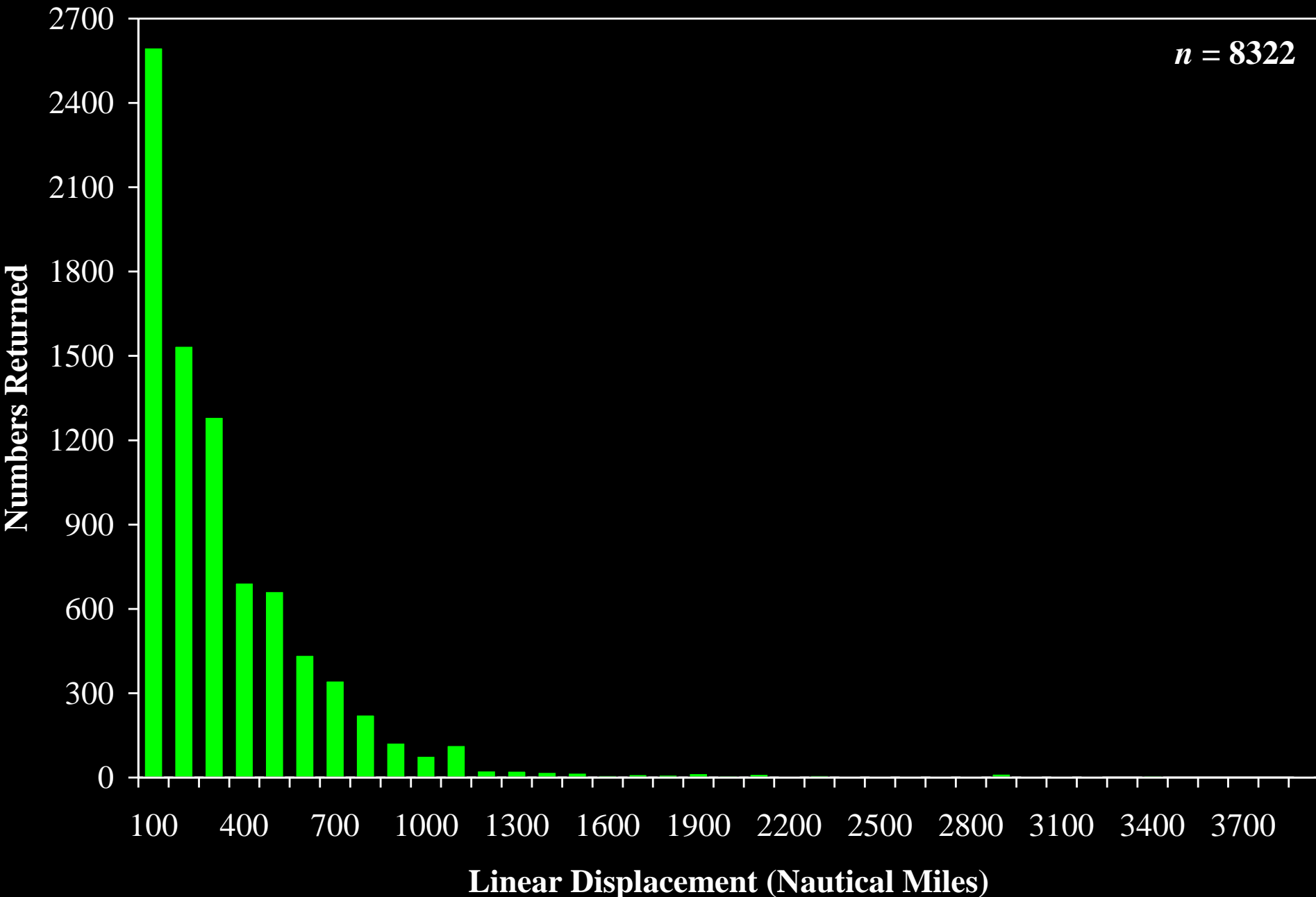
# 1-degree Areas of Recapture for Bigeye Released Between 2000 and 2005 at Liberty for Greater than 180d, 80 to 100 cm



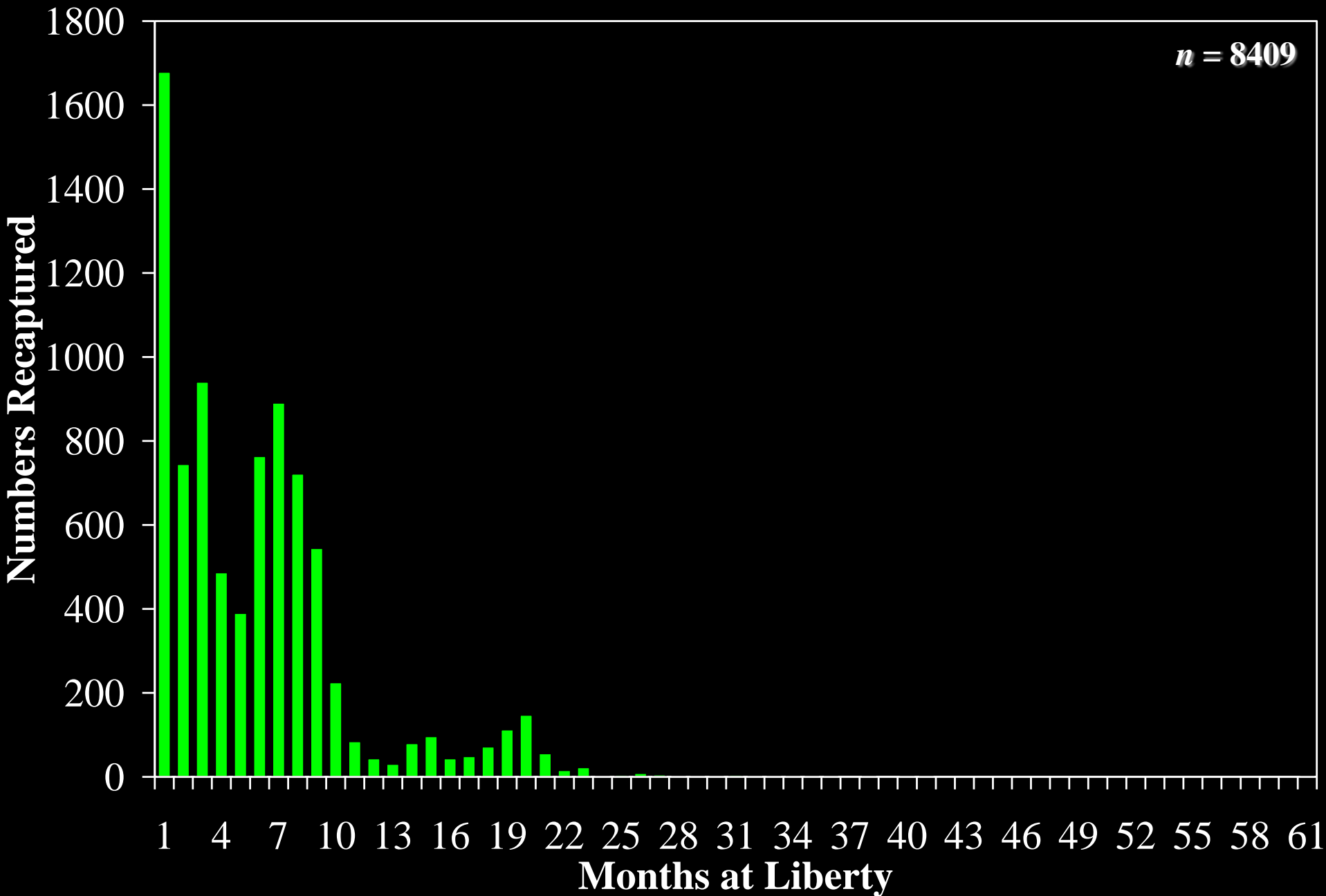
# 1-degree Areas of Recapture for Bigeye Released Between 2000 and 2005 at Liberty for Greater than 180d, Greater than 100 cm



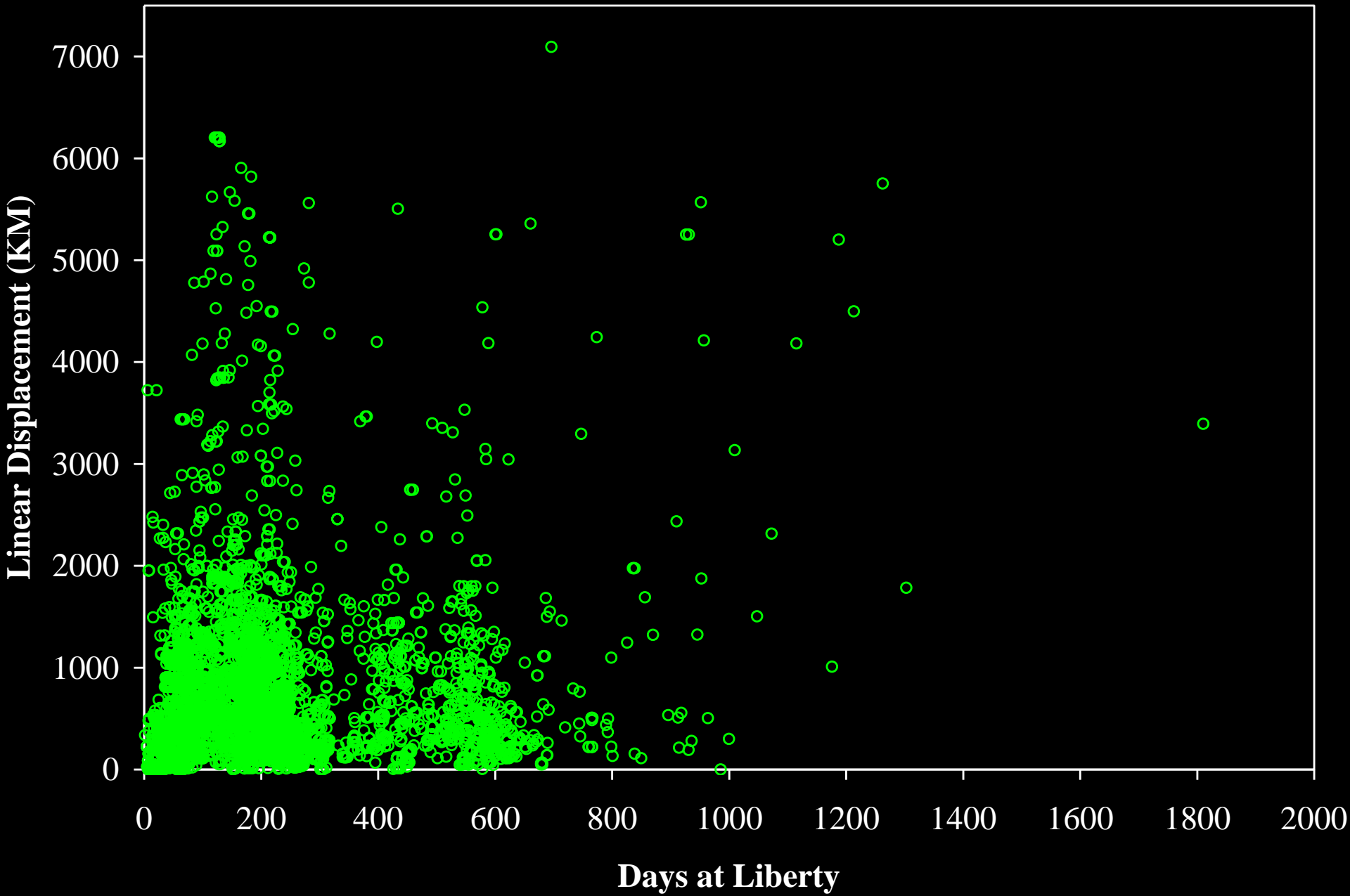
# Bigeye Linear Displacements



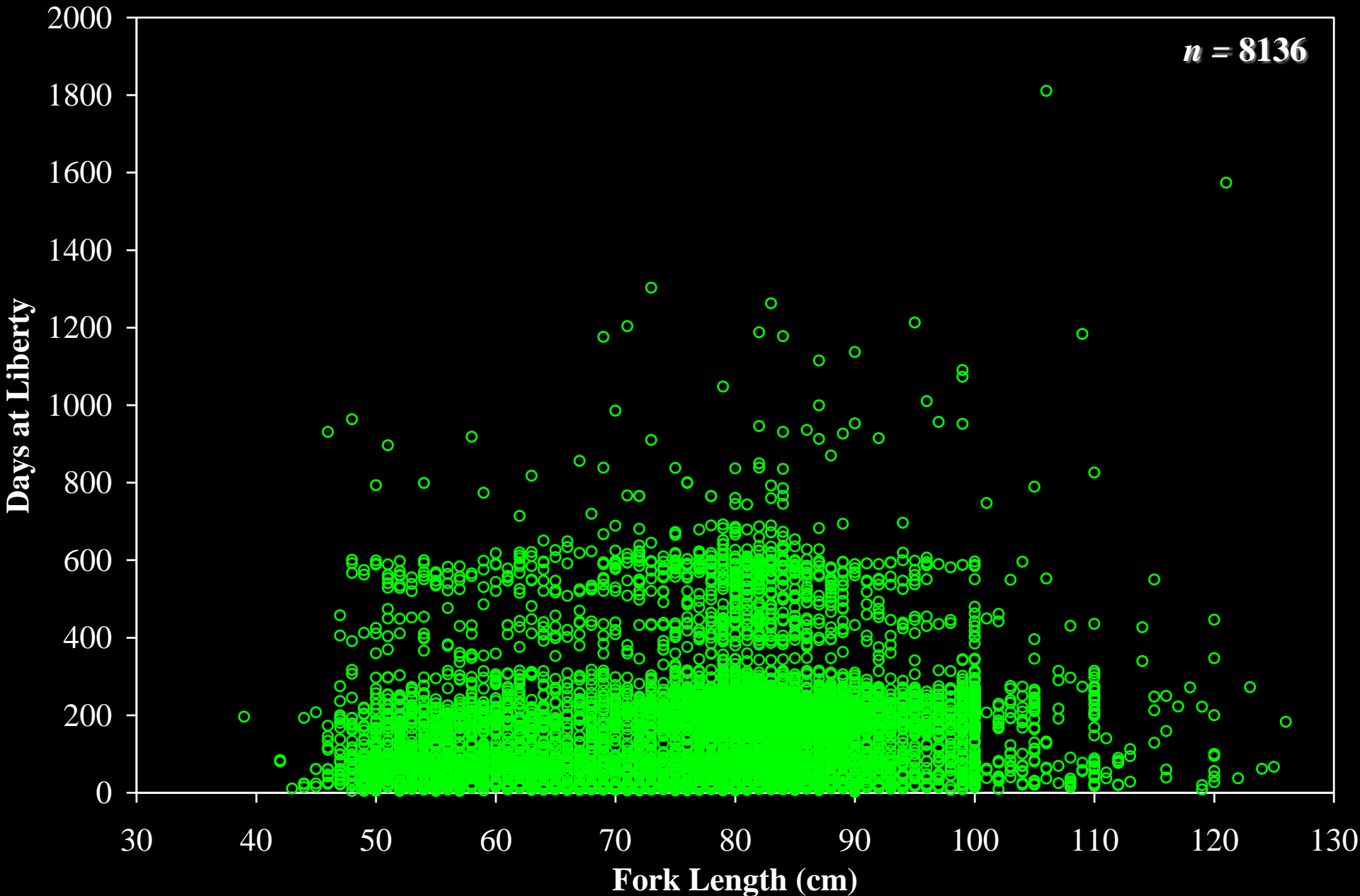
# Tag Recaptures by Months at Liberty



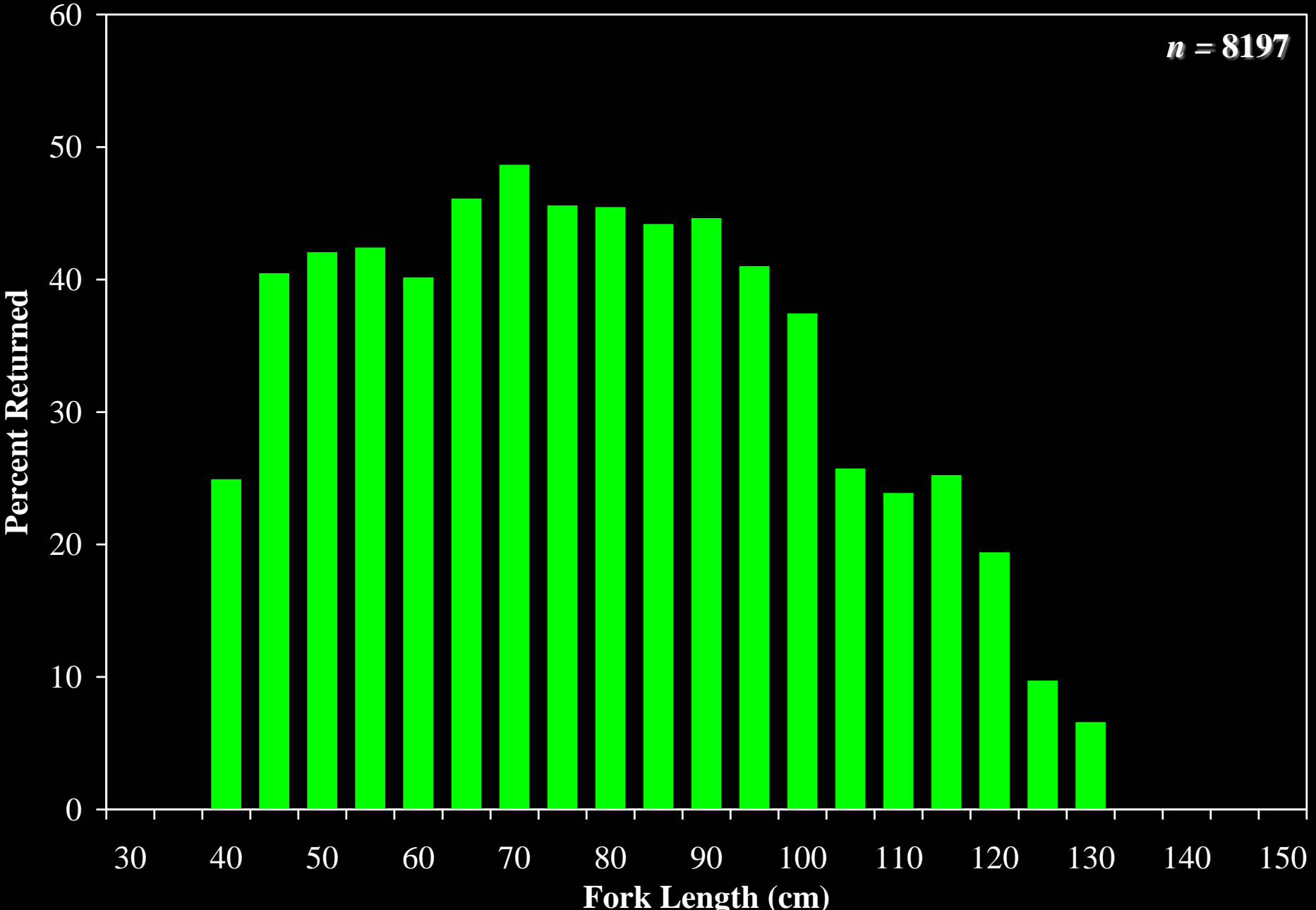
# Linear Displacement for Time at Liberty of 8,319 Bigeye Recaptures



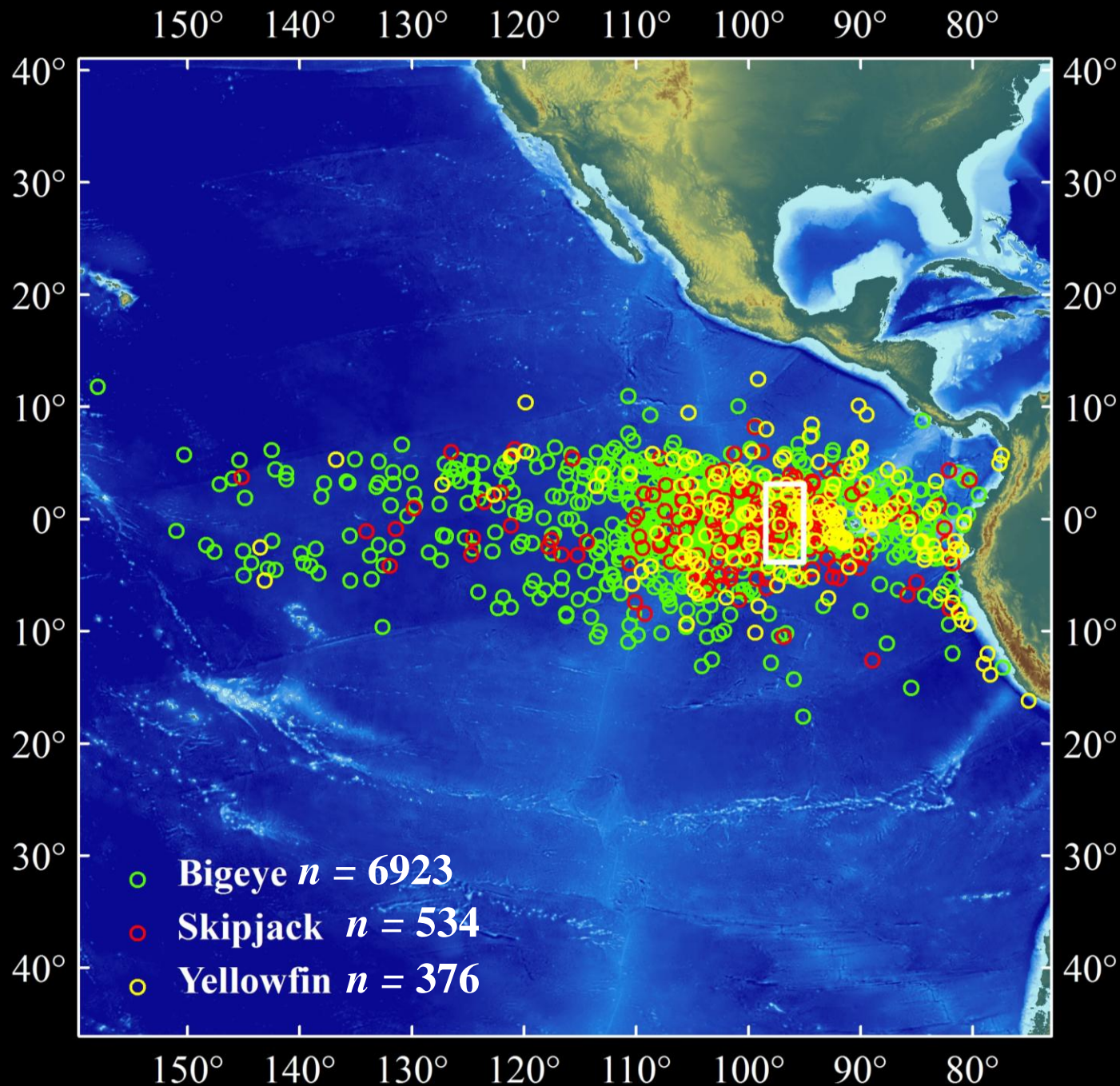
# Length in Centimeters at Release and Time at Liberty for Recaptured Bigeye



# Percent of Bigeye Recaptured and Returned Within each Length Class at Release



# Tuna Recaptures (>30 d) From Releases 2000 to 2006 in the Equatorial EPO

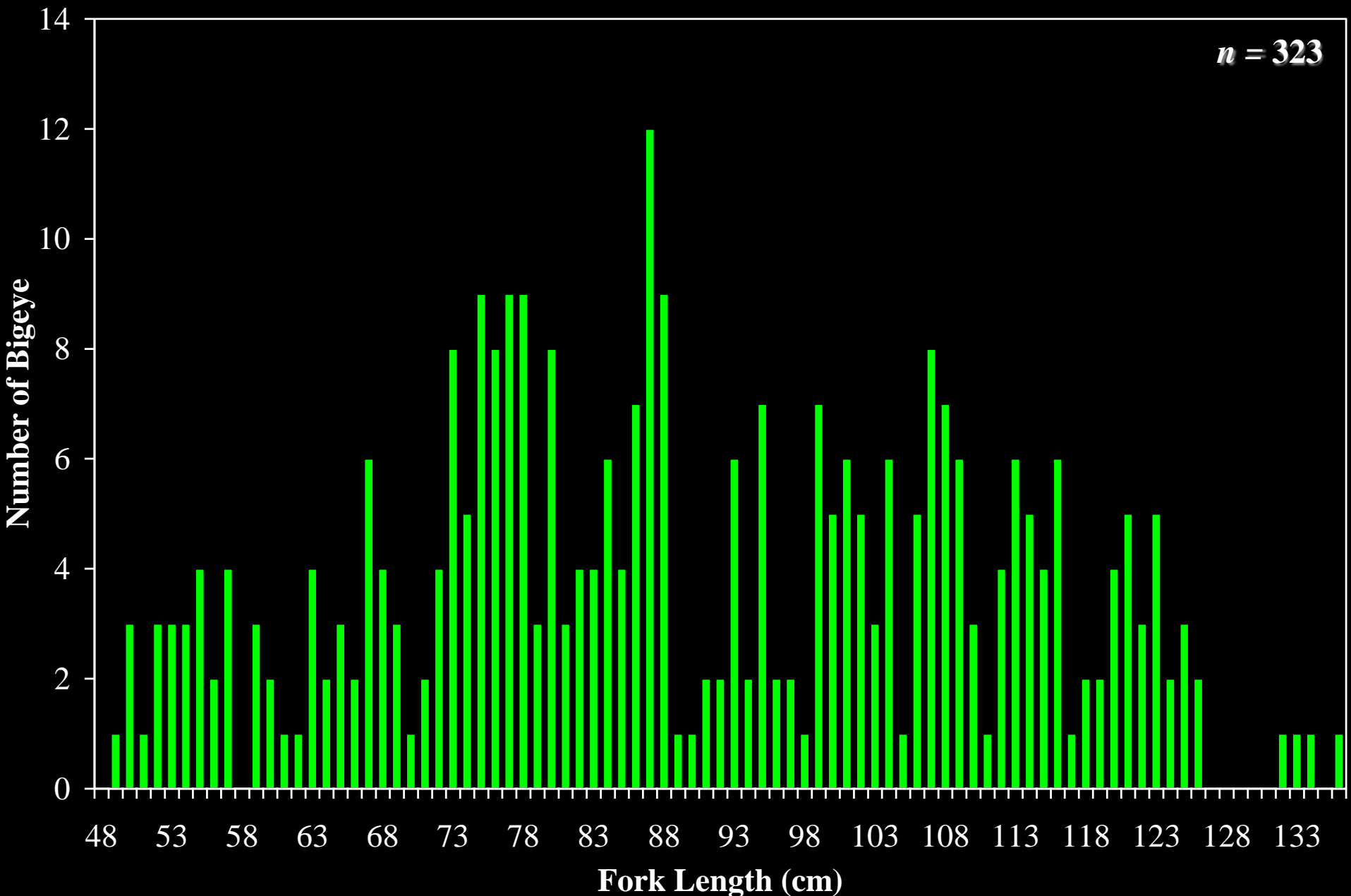




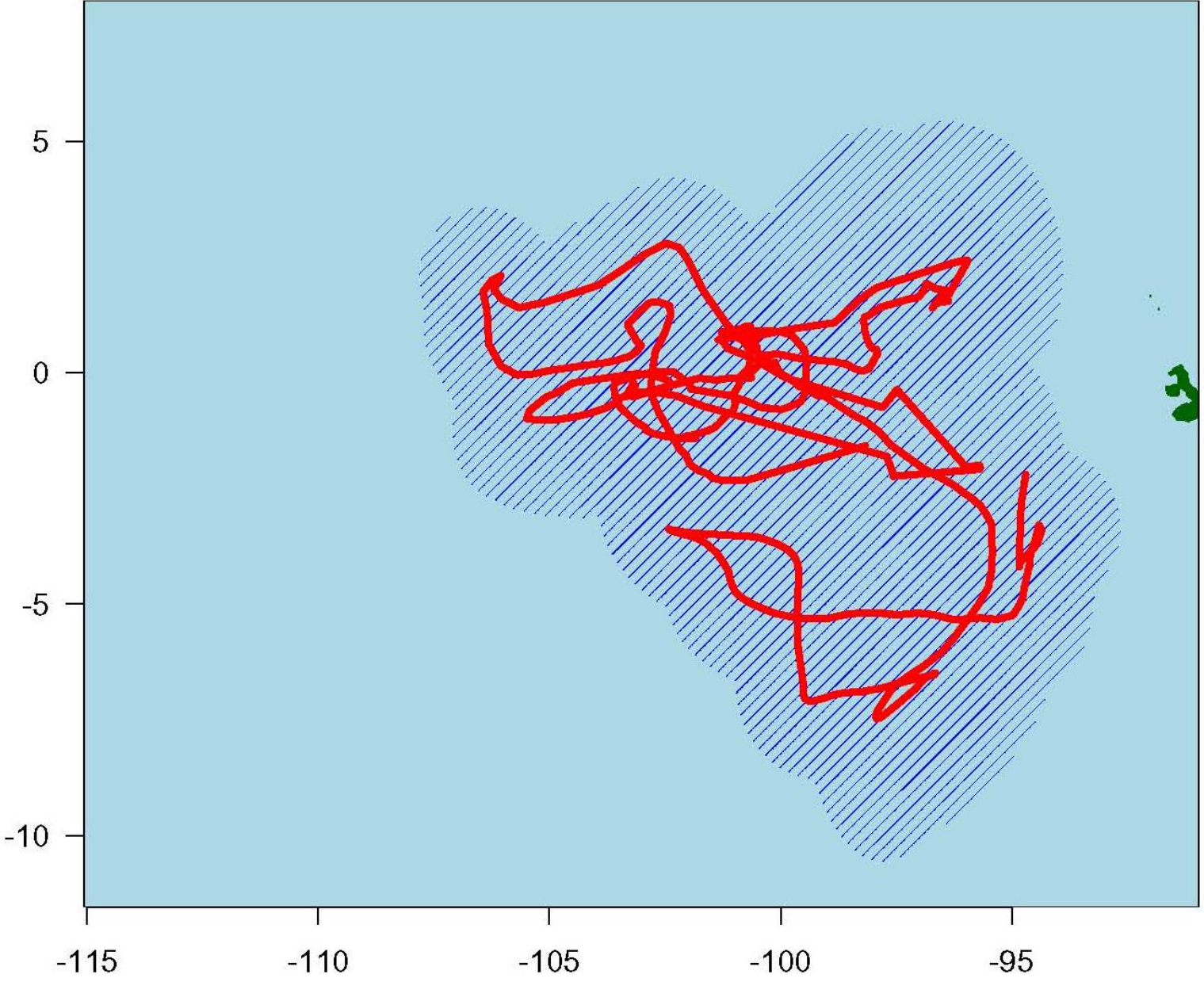
# IATTC Archival Tag Releases and Returns For EEPO tagging 2000 - 2005

Year	Released	Returned					Total (Percent returned)
		< 30 d	30 -89 d	90 - 179 d	180 - 365 d	> 365 d	
2000	96	5	14	4	5	8	36 (37.5)
2002	26	1	2	4	1	0	8 (30.8)
2003	90	38	2	6	6	3	55 (61.1)
2004	58	3	4	8	12	5	32 (55.2)
2005	53	0	10	8	14	1	33 (62.3)
<b>Total</b>	<b>323</b>	<b>47</b>	<b>32</b>	<b>30</b>	<b>38</b>	<b>15</b>	<b>163 (50.5)</b>

# Length Frequency Distribution for Bigeye Released with Archival Tags

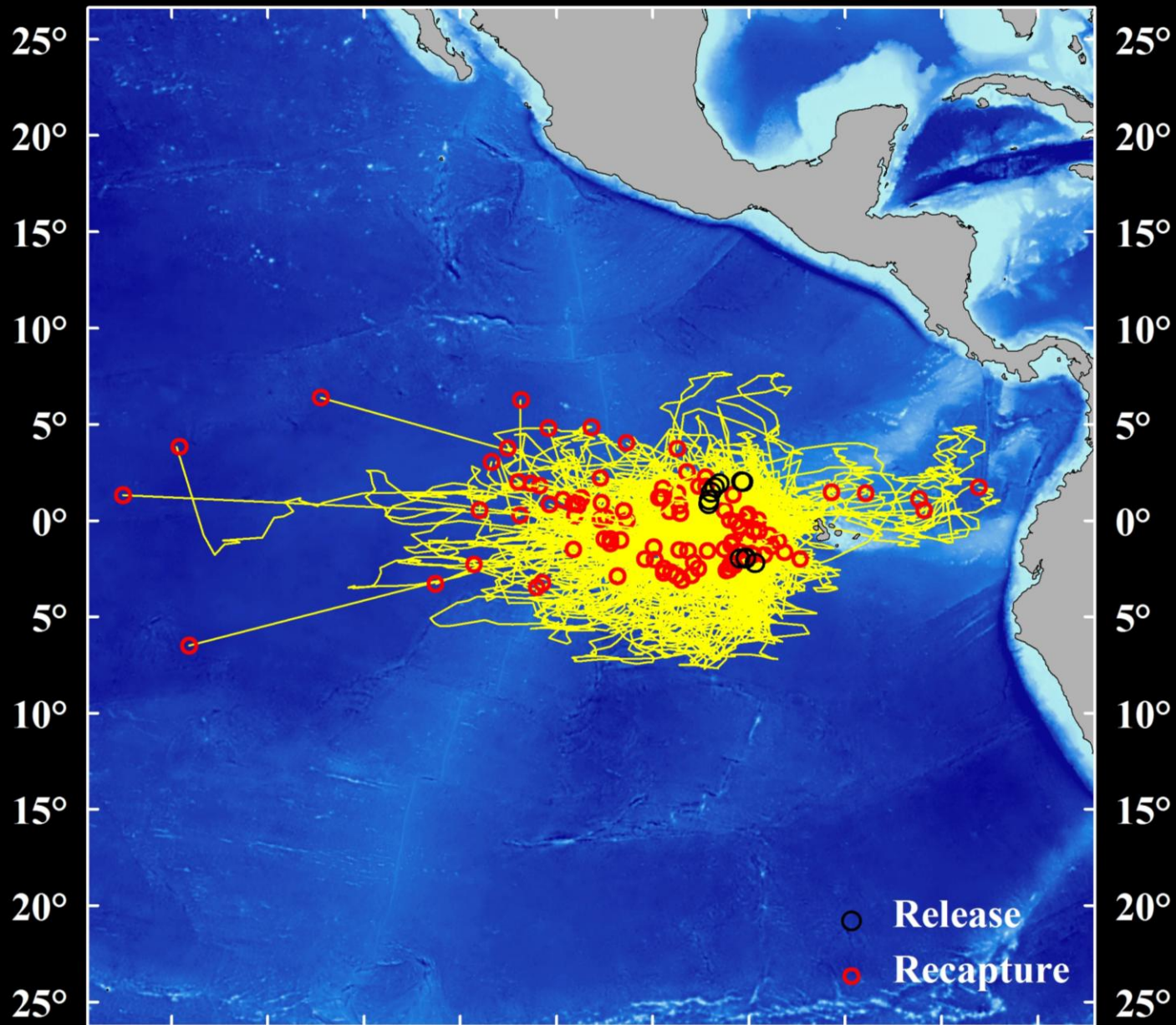


**Movement Path and Confidence Region for a Bigeye at Liberty for 575 day (95 – 143 cm)**



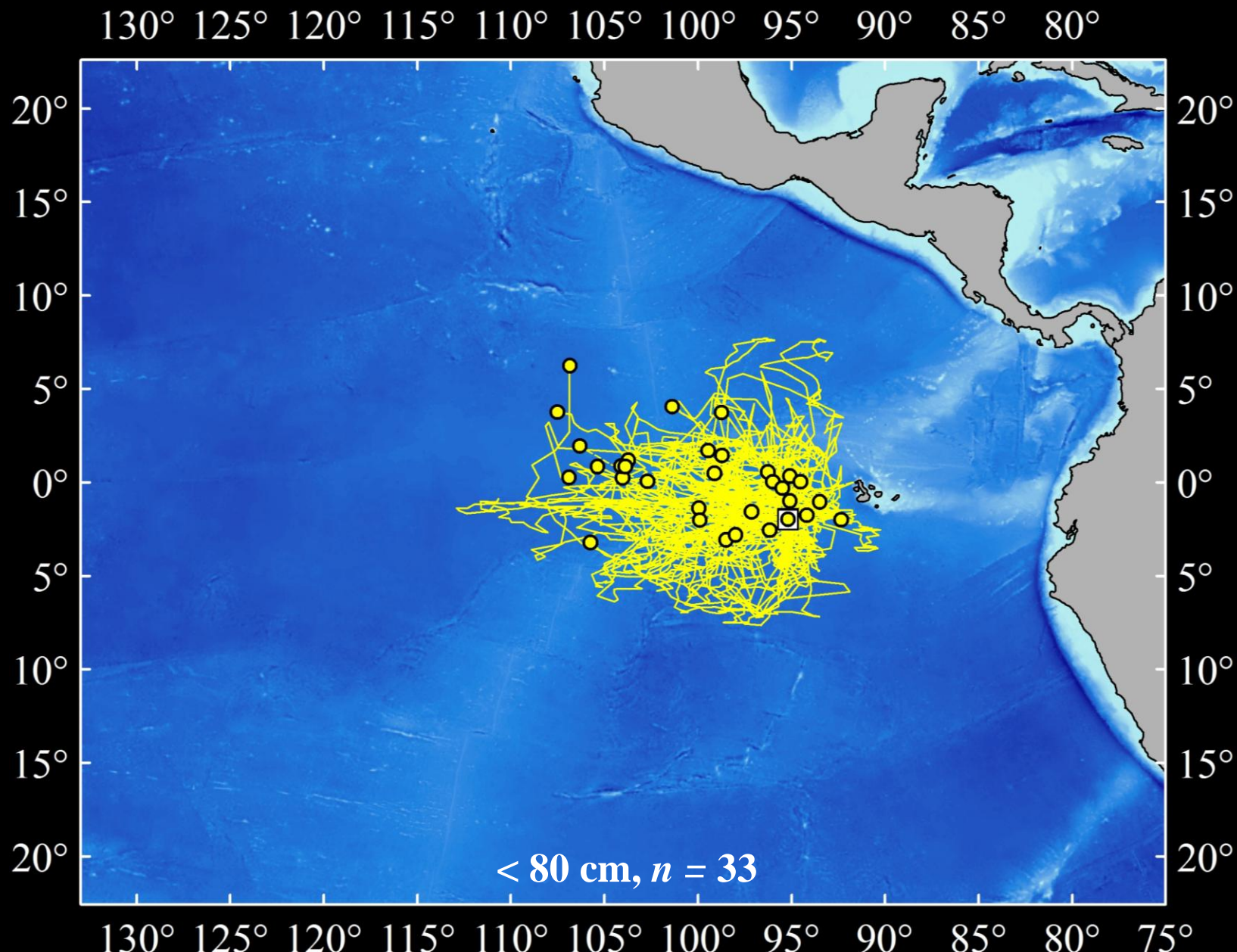
# Bigeye Movement Paths >30 d, 2000 - 2005 Releases ( $n = 98$ )

125° 120° 115° 110° 105° 100° 95° 90° 85° 80°

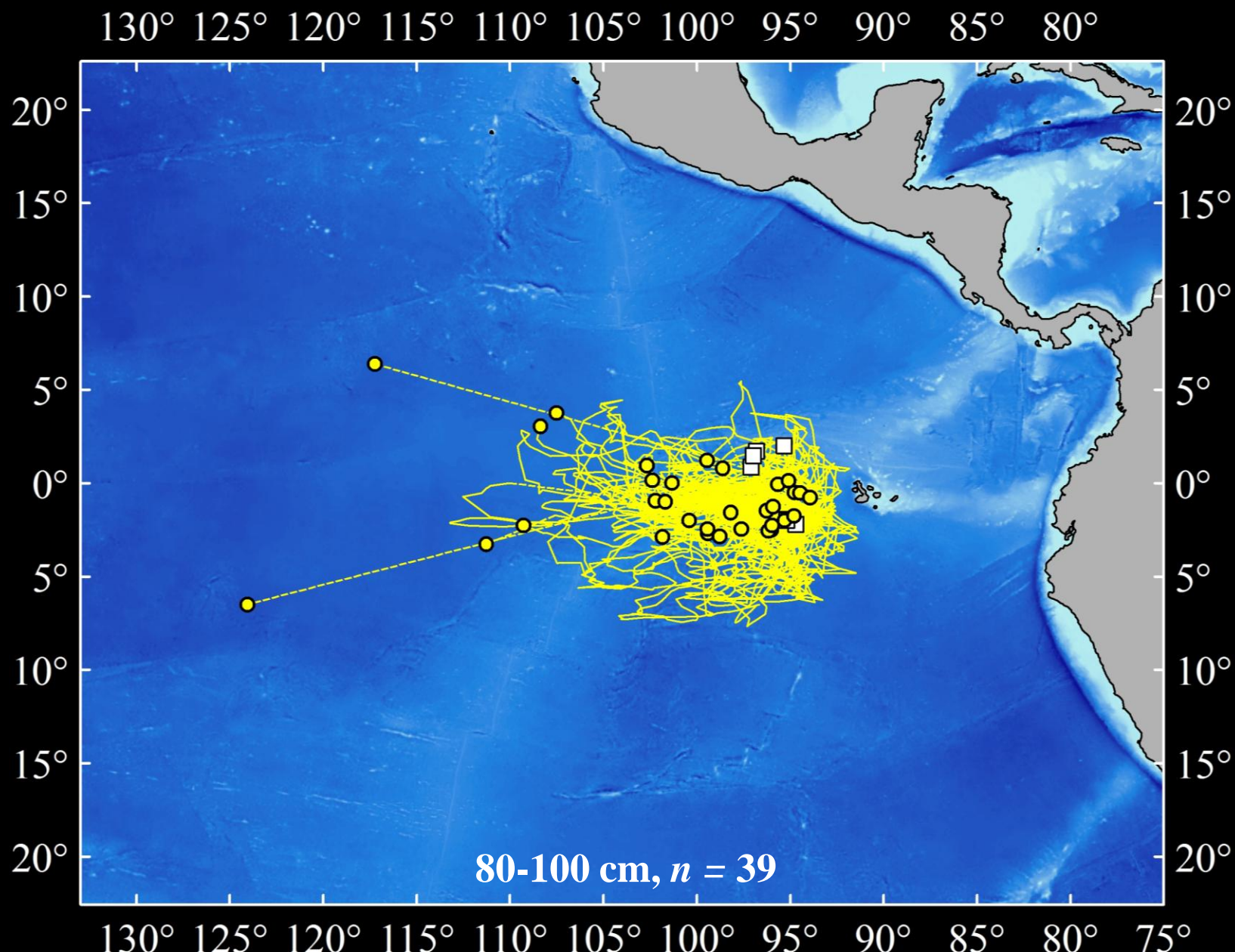


125° 120° 115° 110° 105° 100° 95° 90° 85° 80°

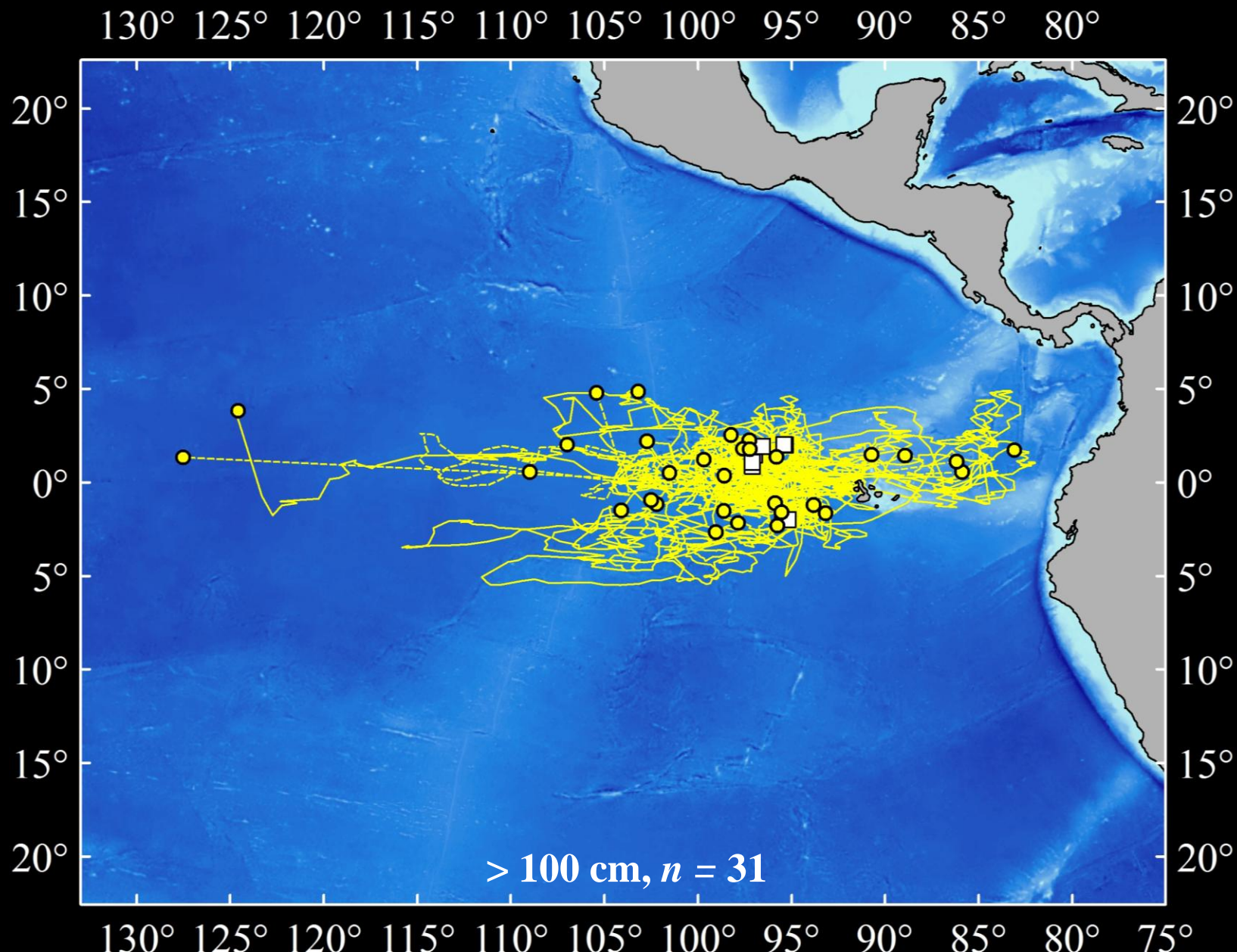
# Compiled Movement Paths from uKF Corrected Position Estimates for 33 Bigeye (<80 cm) at Liberty for More Than 30 Days



# Compiled Movement Paths from uKF Corrected Position Estimates for 39 Bigeye (80-100 cm) at Liberty for More Than 30 Days

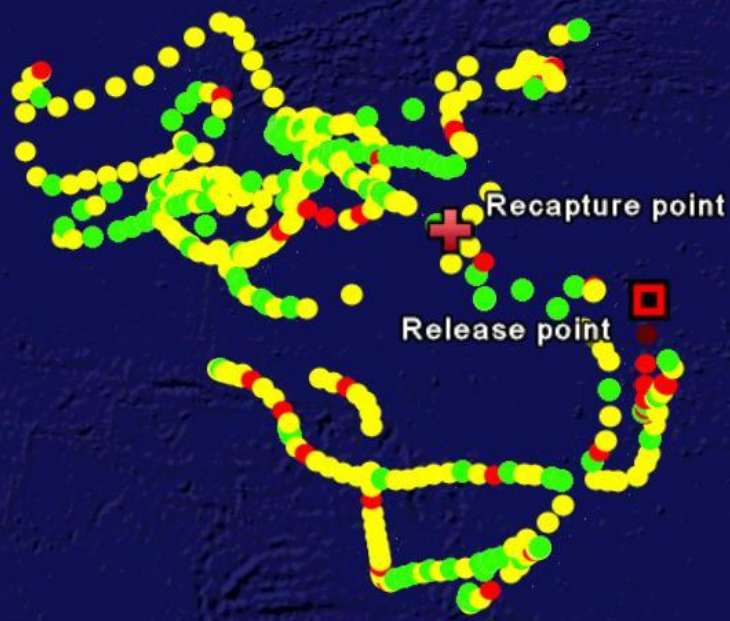


# Compiled Movement Paths from uKF Corrected Position Estimates for 31 Bigeye (>100 cm) at Liberty for More Than 30 Days



# Behavior Classification at Each uKFSST Position Estimate for a Bigeye Released in 2004

Bigeye 95 - 143 cm, 575 d  
● Classical (43.5%)  
● Associative (5.7%)  
● Other (50.8%)

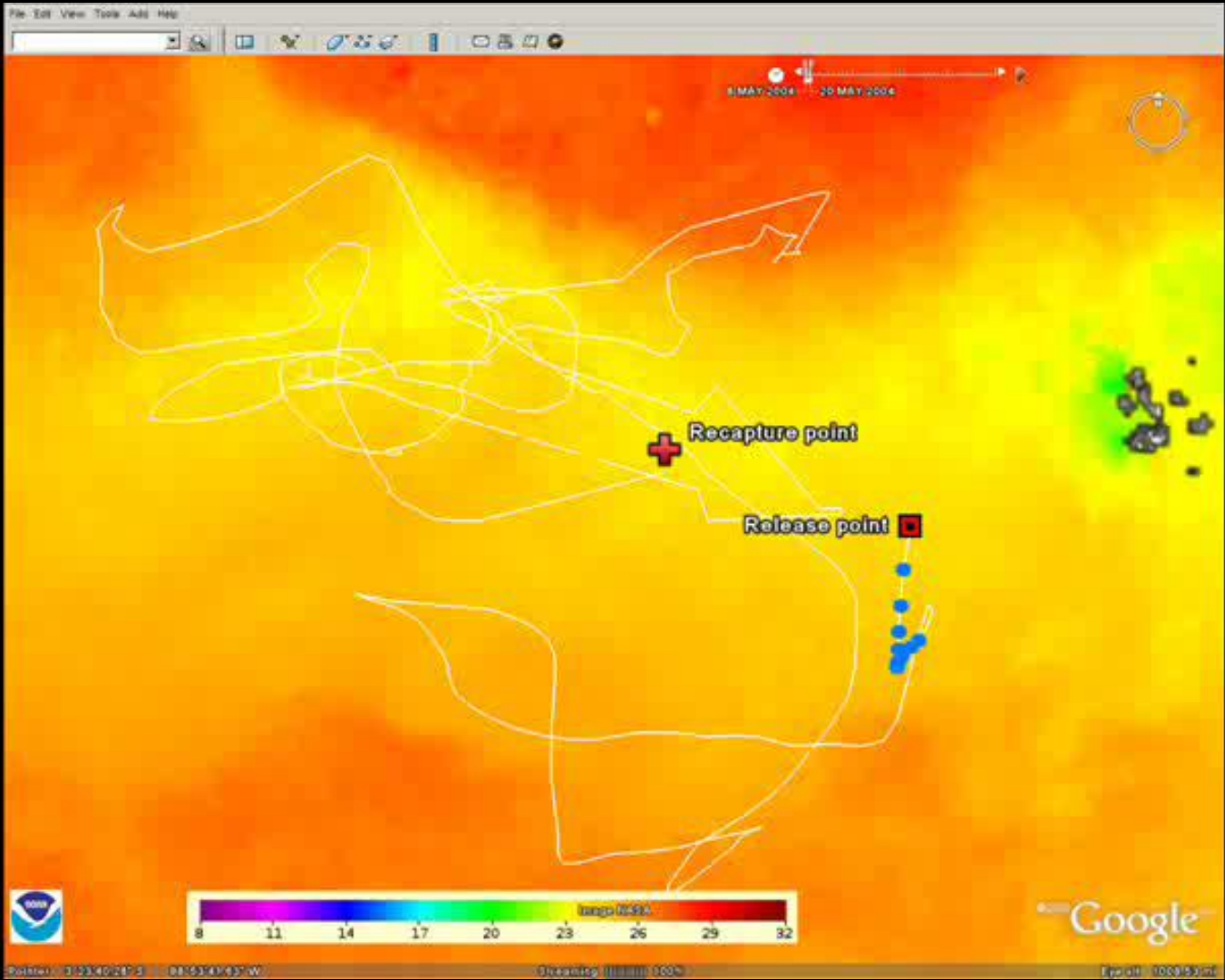


9 MAY 2004 6 DEC 2005

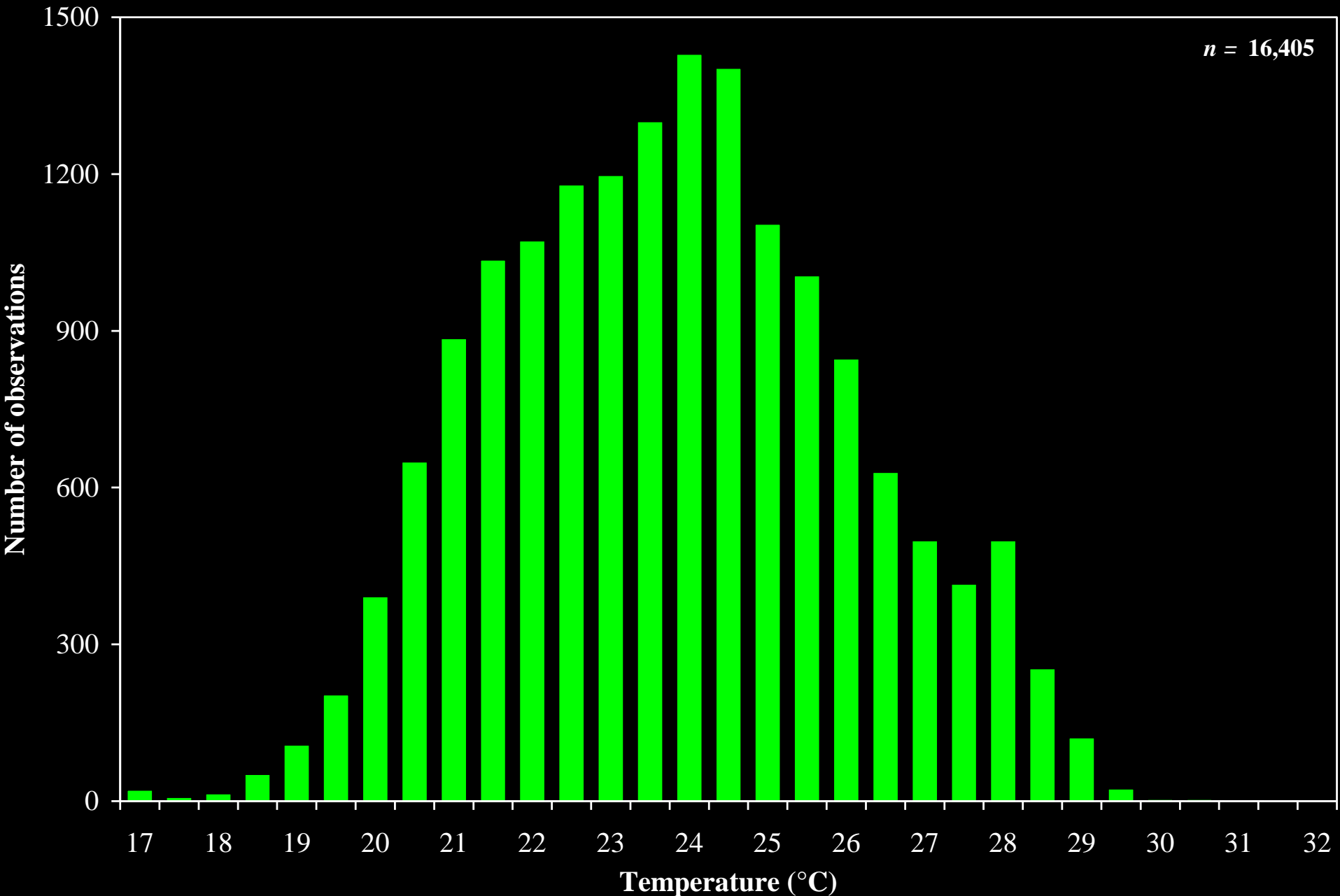
Image NASA  
Image © 2008 TerraMetrics

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# Daily SST Observations from 98 Archival Tags



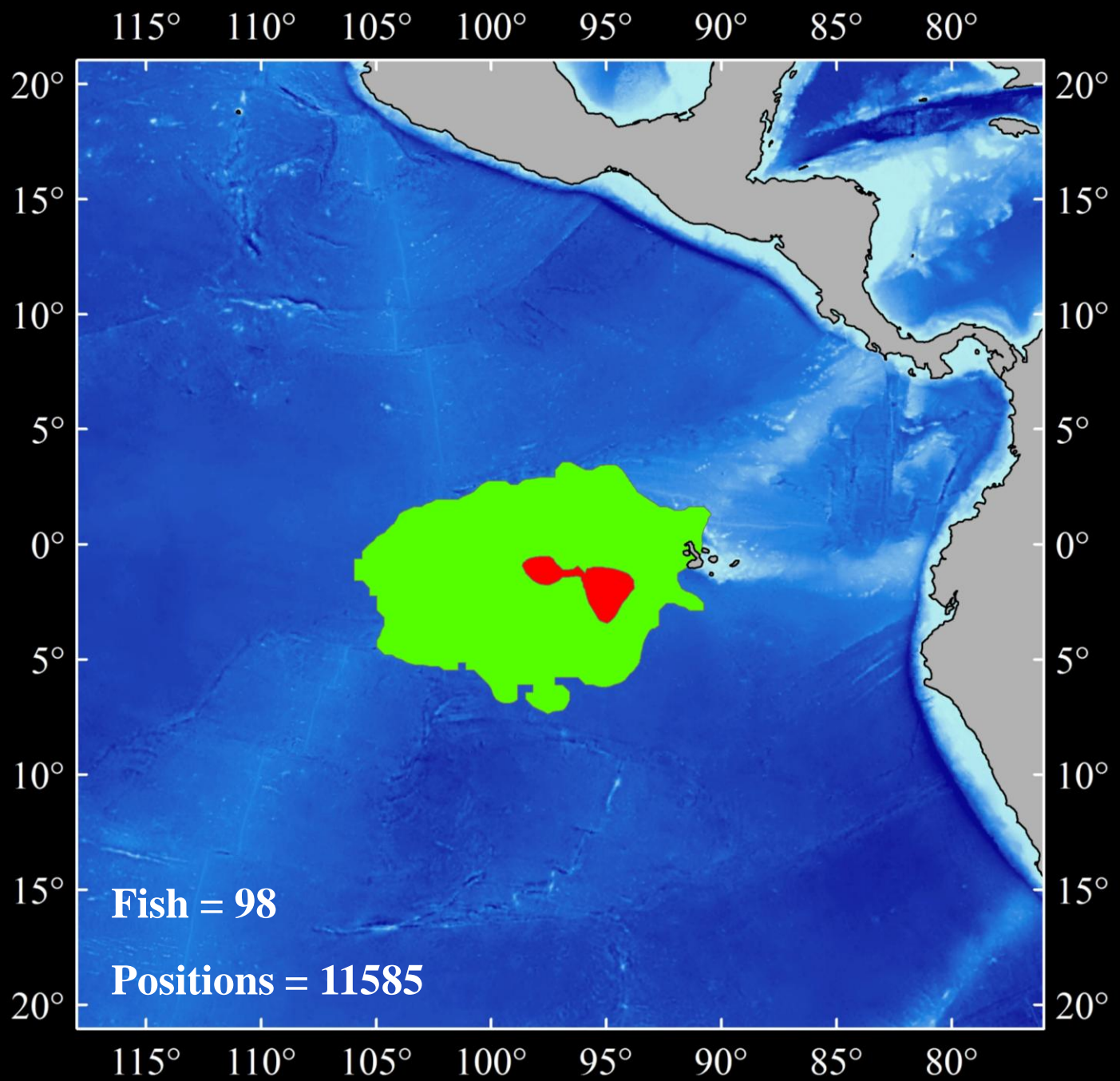
# Parameter Estimates from the Unscented Kalman Filter Model by Year of Release and for all Tags

Year		$\sigma_x$ (Degrees)	$\sigma_y$ (Degrees)	$u$ (nm/day)	$v$ (nm/day)	$D$ (nm <sup>2</sup> /day)
2000	Median	0.19	2.54	-0.15	-0.81	398.15
2000	Range	0.00001 - 0.43	0.77 - 7.04	-6.82 - 4.96	-15.27 - 5.09	193.81 - 1157.40
2003	Median	0.40	2.45	2.63	0.69	465.69
2003	Range	0.00001 - 1.14	0.55 - 7.43	-0.35 - 6.91	-5.81 - 11.64	158.00 - 1036.15
2004	Median	0.36	2.07	1.35	0.34	410.39
2004	Range	0.00002 - 1.71	0.20 - 4.94	-3.94 - 10.44	-3.69 - 8.43	38.33 - 1307.10
2005	Median	0.26	2.50	2.26	2.02	685.10
2005	Range	0.00001 - 1.20	0.45 - 19.67	-2.68 - 13.97	-12.43 - 8.06	180.92 - 1253.96
<b>Totals</b>	<b>Median</b>	<b>0.27</b>	<b>2.34</b>	<b>1.25</b>	<b>0.35</b>	<b>464.59</b>
<b>Totals</b>	<b>Range</b>	<b>0.00001 - 1.71</b>	<b>0.20 - 19.67</b>	<b>-6.82 - 13.97</b>	<b>-15.27 - 11.64</b>	<b>38.34 - 1307.10</b>

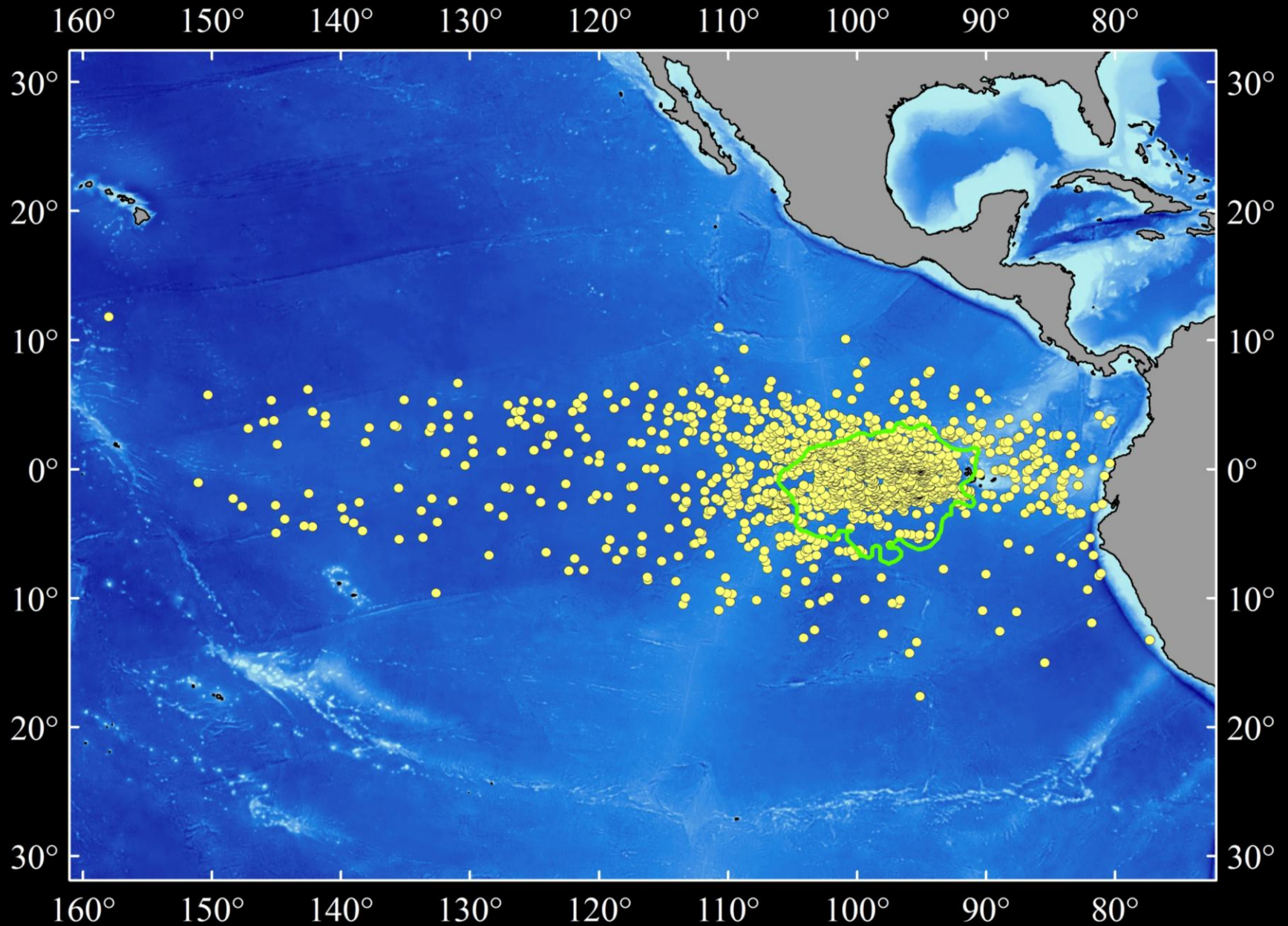
# Spatial statistics for 98 bigeye tuna at liberty for more than 30 days From Positions Corrected with the Unscented Kalman Filter Model

Tag no.	<i>n</i>	%	Distance (km)	speed (km/d)	Linearity	MSD (km 10 <sup>4</sup> )	MSD/Month	95% UD (km <sup>2</sup> )	50% UD (km <sup>2</sup> )
2000 Mean	116	83.8	6,153.8	39.5	0.15	14.9	3.0	535,705.6	85,070.4
2003 Mean	149	72.5	7,854.3	37.6	0.15	19.3	3.3	661,354.1	95,693.4
2004 Mean	126	70.6	6,058.8	32.9	0.13	12.4	2.4	504,333.4	65,826.1
2005 Mean	96	76.4	6,592.1	50.4	0.18	16.2	4.8	742,015.7	120,043.9
<b>Total</b>	<b>118</b>	<b>76.3</b>	<b>6,554.2</b>	<b>40.7</b>	<b>0.15</b>	<b>15.4</b>	<b>3.4</b>	<b>610,549.6</b>	<b>92,353.2</b>

# Bigeye 95% and 50% Utilization Distributions April 2000 – March 2006



# Conventional and Archival Tag Recapture Positions and the 95% Utilization Distribution from the uKF Corrected Position Estimates for all Archival Tags



# SUMMARY

- **Analyses of both conventional and archival tag data provide invaluable information about movements, stock structure, and exploitation**
- **Processing the archival tag geolocation data using uKFsst appears to provide promising results including most probable movement paths and parameters, such as dispersion rates**
- **Vertical movement and behavior need to be integrated with the horizontal movement, and analyzed along with environmental data, for understanding movement dynamics critical to stock assessments and management**
- **Results from these experiments indicate restricted movements and regional fidelity of bigeye tagged and released in the eastern equatorial Pacific Ocean**

# Acknowledgements

- Japan Fisheries Agency
- Taiwan Fisheries Administration
- Lotek Wireless
- Wildlife Computers
- F/V *Her Grace* and Crew