PSAT Meta Data Analysis Project

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This study is designed to look at variables explaining:

- Failure rates (percent reporting)
- Percentage of retrieved depth, temperature, and geolocation data
- Retention rates
- Longevity of attachment

Comparisons to be made using data from 662 PSATs deployments worldwide

It is anticipated that:

Patterns will emerge with respect to:

attachment methodologies,

target species,

experimental design.

Allows unprecedented critical appraisal of the overall efficacy of PSAT technology.

Cost Benefit analysis to improve experimental design

Variables in the PSAT Performance Evaluation:

Tag Birthday

Programmed Pop-off date

Age of Tag at Deployment

Sex

% Temperature

% Geolocation

ARGOS longitude

Swivel

Tag Head

Manufacturer

Tag Serial Number

Date Deployed

Species Tagged

Days-at-liberty

% Depth

ARGOS latitude

RD1500

Tether material

Attachment methods

662 PSATs deployed on 18 Species

2000-2004

Bigeye thresher (7)

Bigeye Tuna (4)

Black Marlin (57)

Blue Marlin (34)

Blue Shark (32)

Green Turtle (1)

Loggerhead turtle (8)

Olive Ridley turtle (15)

Short-fin Mako shark (4)

Silky Shark (4)

Striped Marlin (200)

Swordfish (36)

Oceanic White-tip shark (8)

Yellowfin Tuna (17)

Basking shark (1)

Great White (48)

Tarpon (40)

Bluefin tuna (146)

Difficult problem
PSAT failure rates

- Never hear from failed PSATS
- Very few PSATs recovered for inspection
- Exact failure mode(s) unknown

- Shouldn't limit discovery

- Exploration of data reveals much

- Ideas to improve methods

Tag Failure Modes

- **Battery failure – passivation over time (temperature dependent)?**

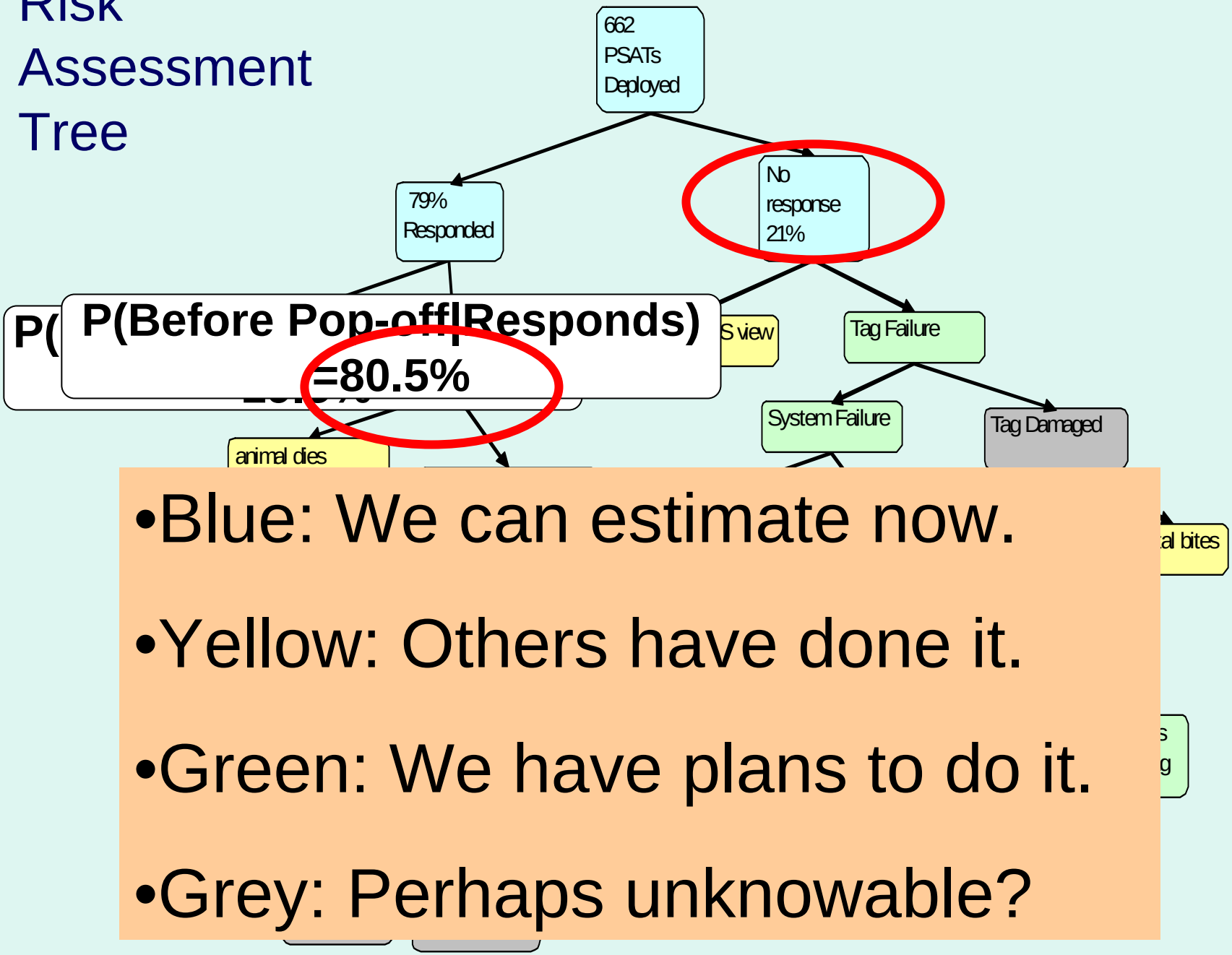
- **Rupture of pressure housings/seals, contraction/expansion, etc. – (extensive vertical movements = low reporting rates of PSATs swordfish & bigeye thresher sharks)?**

- **Sharks predation/nuptial bites (sharks attracted to the EMF of PSATs, very few tagged males report back)?**

- **Damage to antennae by predation or fouling organisms?**

- **Malfunction other than battery -Fusible link and/or RD1500?**

Risk Assessment Tree



- Blue: We can estimate now.
- Yellow: Others have done it.
- Green: We have plans to do it.
- Grey: Perhaps unknowable?

Of 662 PSATs attached to sharks, billfish, tunas and turtles, 520 or 79% reported data.

87 or 17% hit their programmed pop-off date

142 or 21% Non-reporting tags is not synonymous with mortality.

18 Species grouped into 4 Depth classes

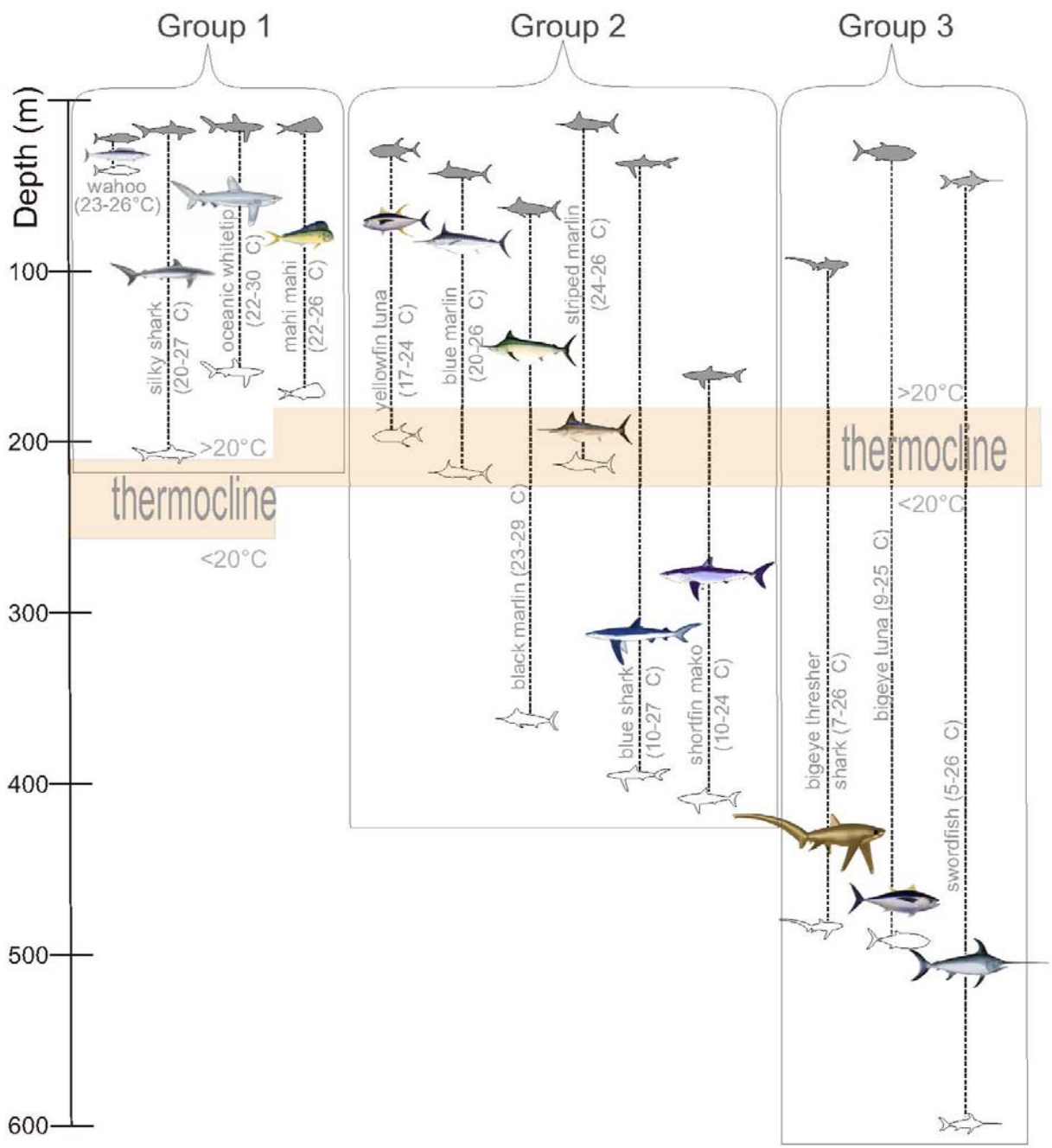
4 Depth classes group 18 species

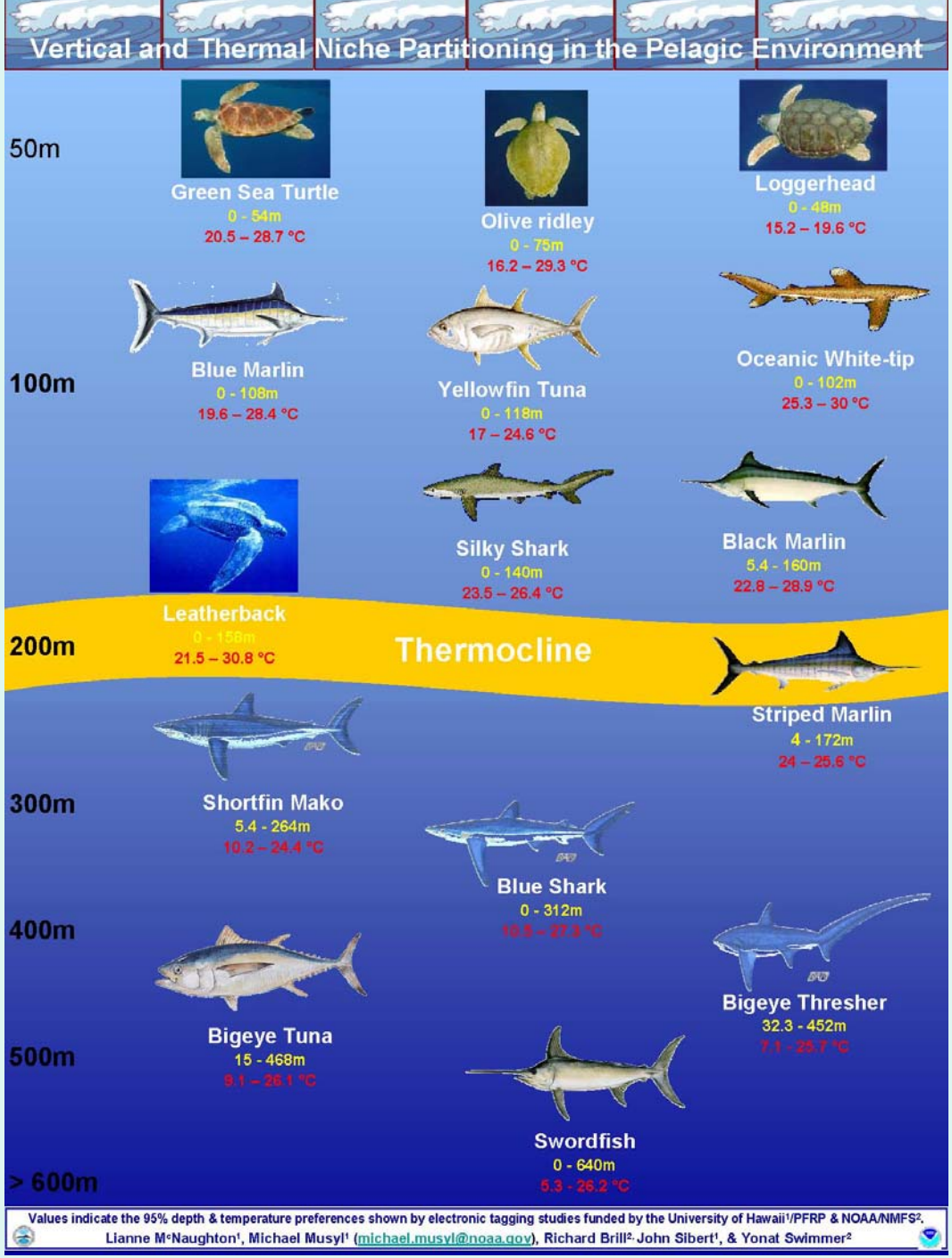
- **0=Littoral**
- **1=Epi-Pelagic**
- **2=Meso Pelagic**
- **3=Bathy-Pelagic**

Some species n_s=1 n_s=4; small

To Improve Power:

Use relevant grouping variables


Group 1
Group 2
Group 3
Depth (m)
100
200
300
400
500
600
wahoo (23-26°C)
silky shark (20-27 C)
oceanic whitetip (22-30 C)
mahi mahi (22-26 C)
>20°C
thermocline
<20°C
yellowfin tuna (17-24 C)
blue marlin (20-26 C)
striped marlin (24-26 C)
black marlin (23-29 C)
blue shark (10-27 C)
shortfin mako (10-24 C)
>20°C
thermocline
<20°C
bigeye thresher shark (7-26 C)
bigeye tuna (9-25 C)
swordfish (5-26 C)



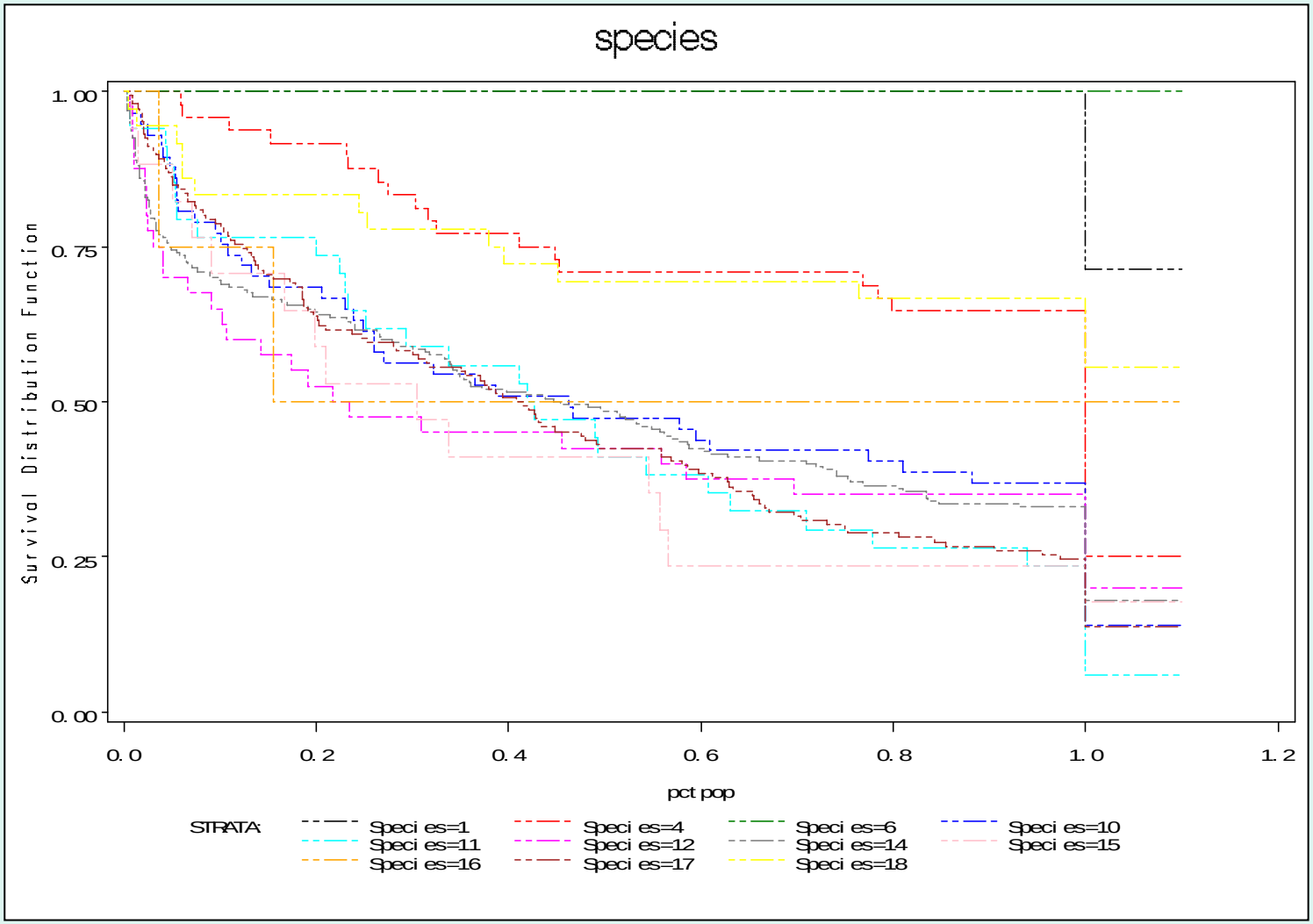
Epi-Pelagic

Meso-Pelagic

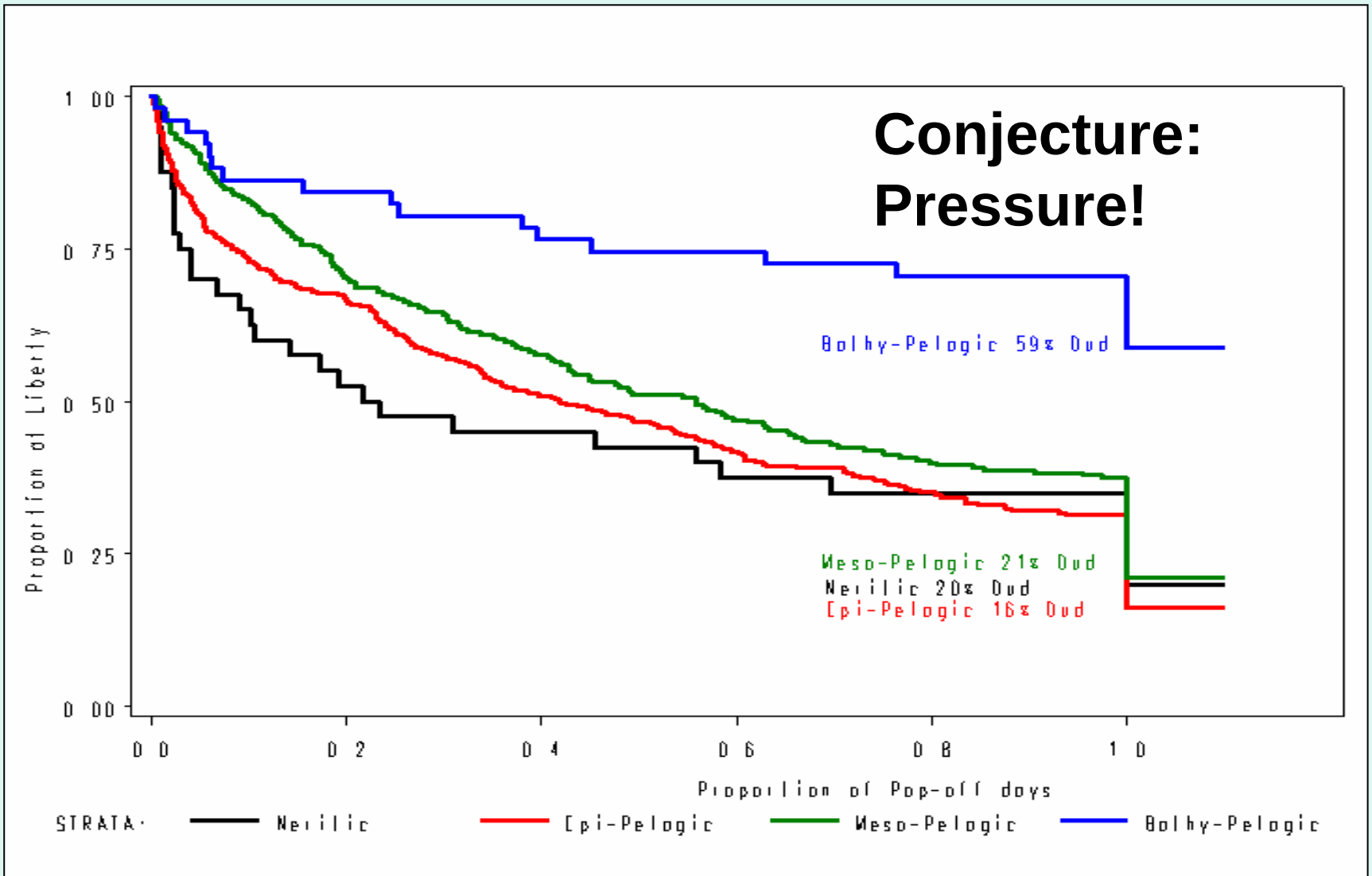
Bathy-Pelagic

Species	Depth Class	Ordinal Code
Tarpon	Littoral	0
Silky shark	Epi-Pelagic	1
Oceanic white-tip shark	Epi-Pelagic	1
Loggerhead turtle	Epi-Pelagic	1
Basking shark	Epi-Pelagic	1
Green turtle	Epi-Pelagic	1
Olive Ridley	Epi-Pelagic	1
Black marlin	Epi-Pelagic	1
Blue marlin	Epi-Pelagic	1
Striped marlin	Epi-Pelagic	1
Great White shark	Meso-Pelagic	2
Blue shark	Meso-Pelagic	2
Yellowfin tuna	Meso-Pelagic	2
Bluefin tuna	Meso-Pelagic	2
Bigeye thresher shark	Bathy-Pelagic	3
Shortfin mako shark	Bathy-Pelagic	3
Bigeye tuna	Bathy-Pelagic	3
Swordfish	Bathy-Pelagic	3

18 Species
Proportion at Liberty

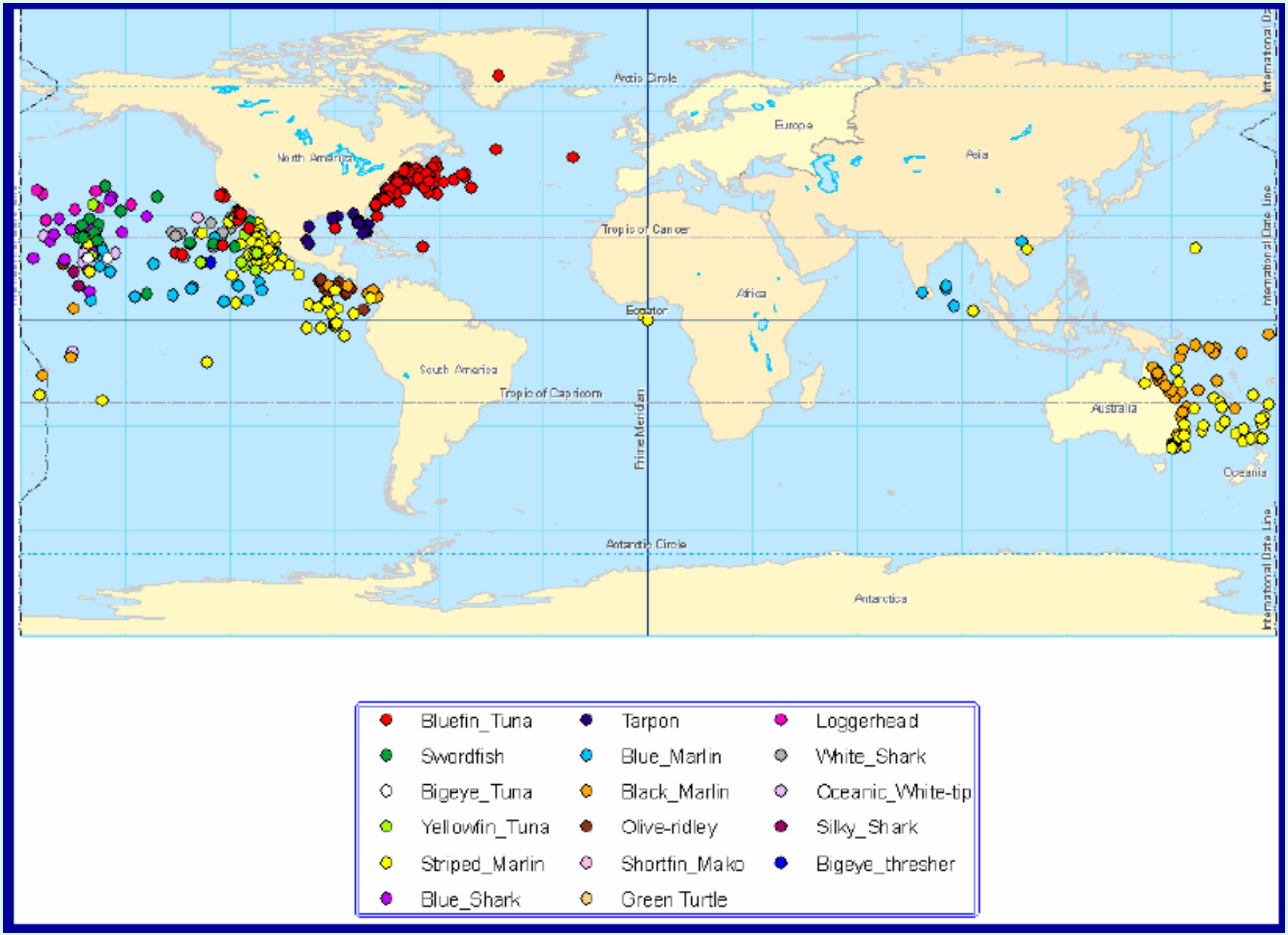


4 Depth Classes
Proportion at Liberty

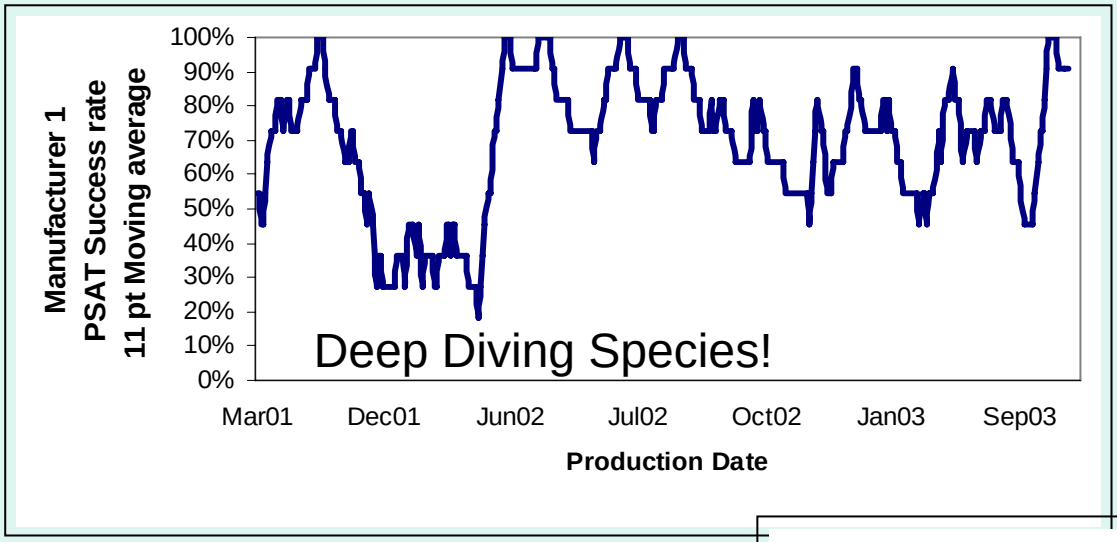


Geographic Location

- Retention model has Latitude at pop off
- Tagger teams operate in different regions.
- Thus tagger team is also a REGION variable.

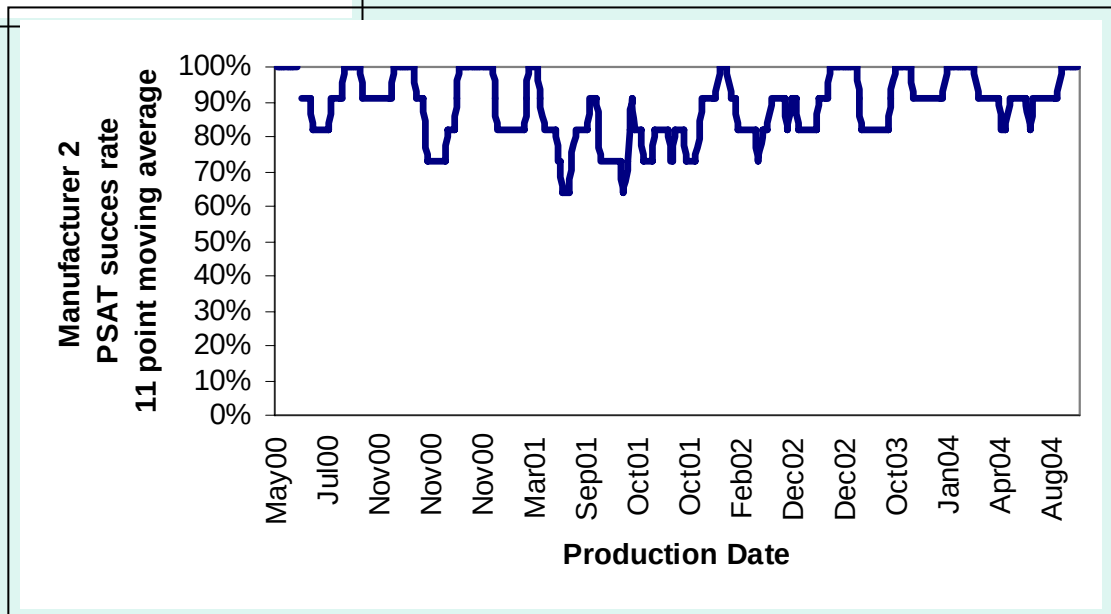

Arctic Circle
Europe
Asia
North America
Tropic of Cancer
Africa
Equator
South America
Tropic of Capricorn
Prime Meridian
Australia
Oceania
Antarctic Circle
Antarctica
International Date Line
Bluefin_Tuna
Swordfish
Bigeye_Tuna
Yellowfin_Tuna
Striped_Marlin
Blue_Shark
Tarpon
Blue_Marlin
Black_Marlin
Olive-ridley
Shortfin_Mako
Green Turtle
Loggerhead
White_Shark
Oceanic_White-tip
Silky_Shark
Bigeye_thresher

PSAT Response by tag production date

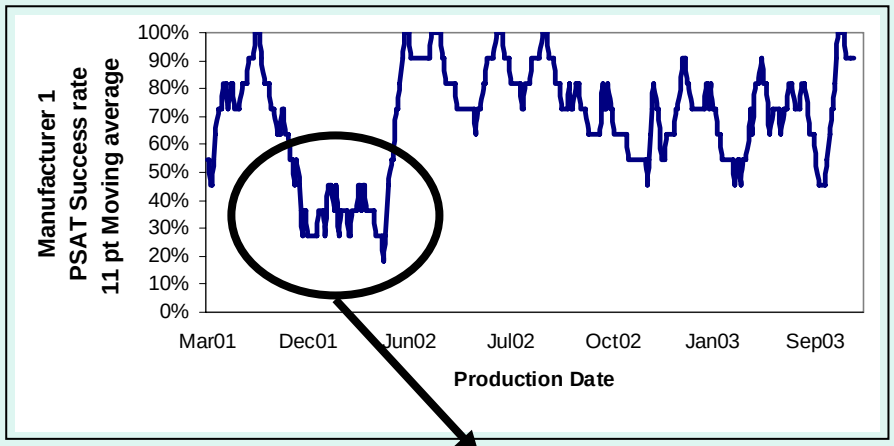


Data set ends in 2004.

Trend towards improvement?



Spurious ‘Bad Batch’???



Dec 2001 to March 2002

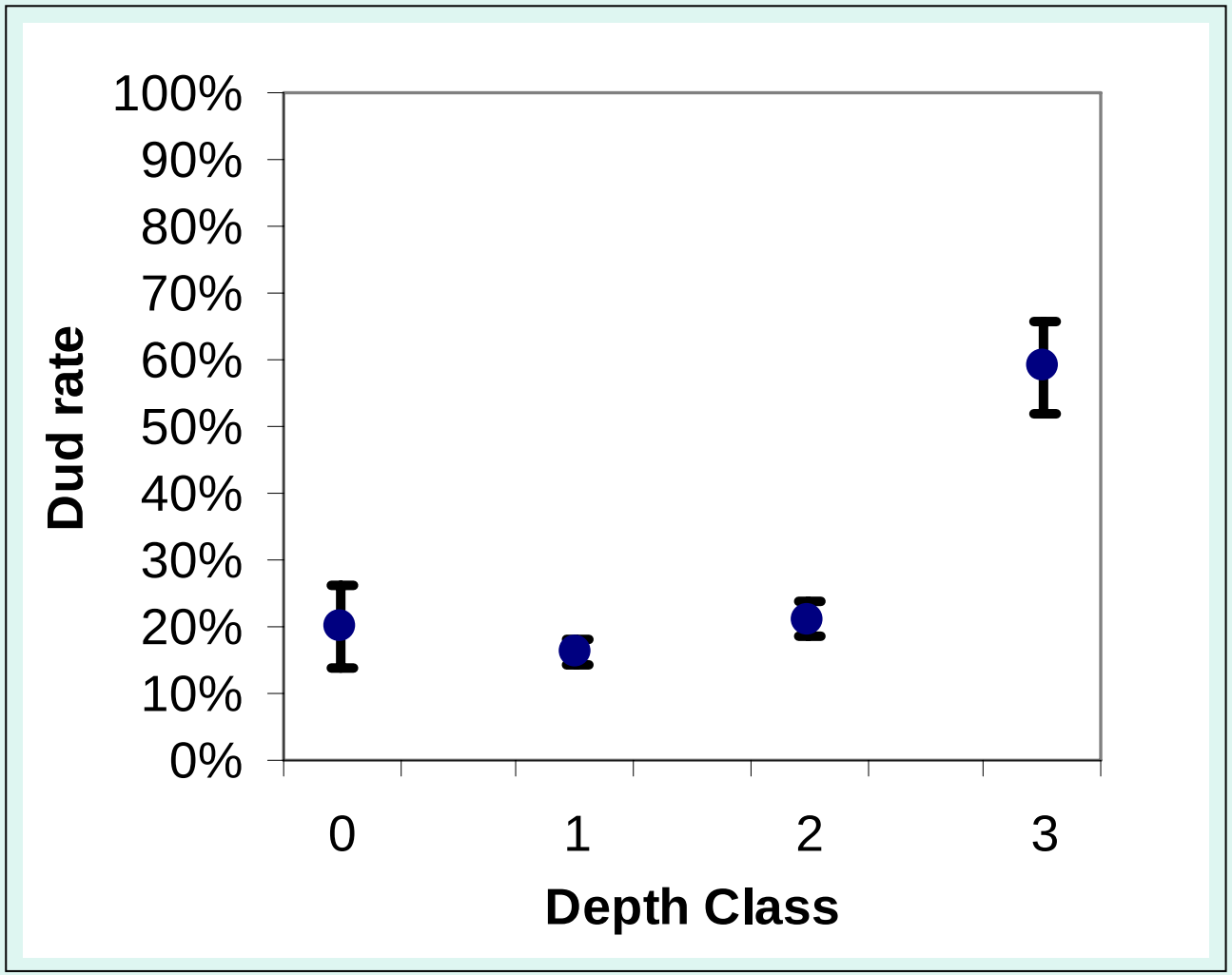
Species	n_s	Depth Class	Response
Big Eye Thresher Shark	1	3	100%
Great White Shark	4	2	0%
Shortfin Mako Shark	2	3	46%
Blue Shark	13	2	80%
Swordfish	9	3	22%

Overall response rate 31%...however depth class is implicated!

PSAT Response Rate

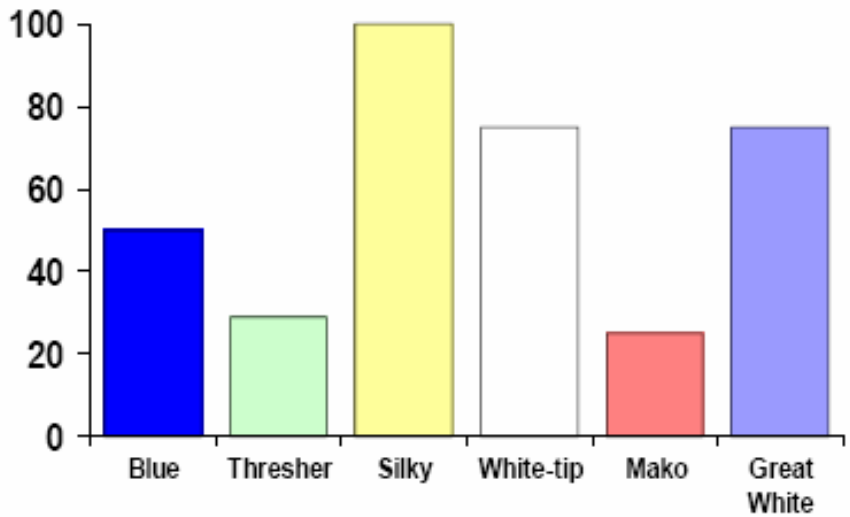
Non-response rates by depth class and manufacturer. **SE in parentheses.**					
Depth class	**Manufacturer**	**PSAT Responded**	**PSAT No Response**	**No response% by depth and manufacturer**	**No Response% by depth class**
0	MT	3	3	50%(20.4%)	20%(6.3%)
	WC	29	5	15%(6.1%)	
1	MT	97	34	26%(3.8%)	16%(2%)
	WC	178	19	10%(2.1%)	
2	MT	137	43	24%(3.2%)	21%(2.6%)
	WC	55	8	13%(4.2%)	
3	MT	18	30	63%(7.0%)	59%(6.9%)
	WC	3	0	0%(0.0%)	
					OVERALL
ALL Depths	BOTH Manufacturers	520	142		21%(1.6%)

PSAT non-response rate by Depth class

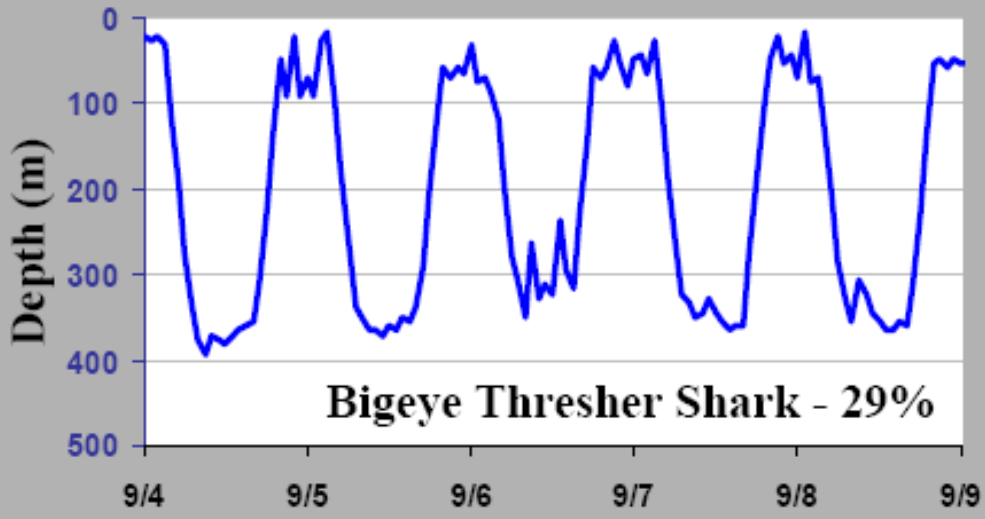


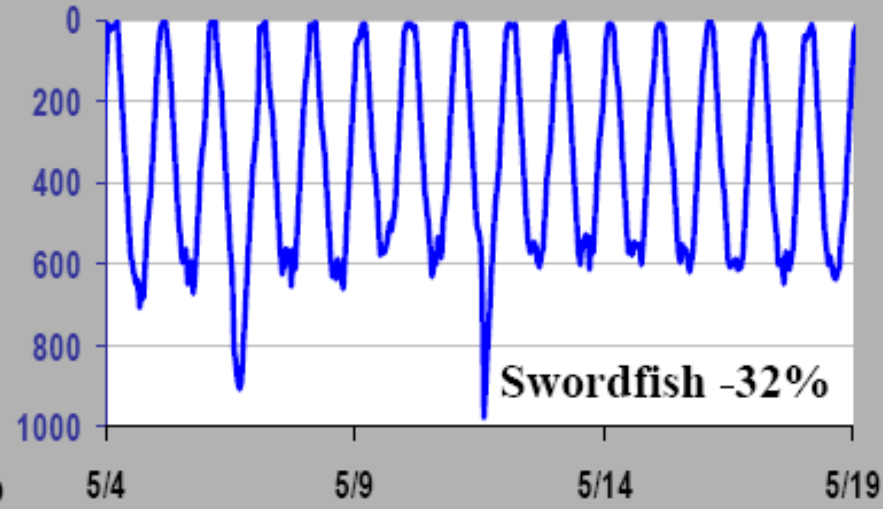
Sharks (n = 104)

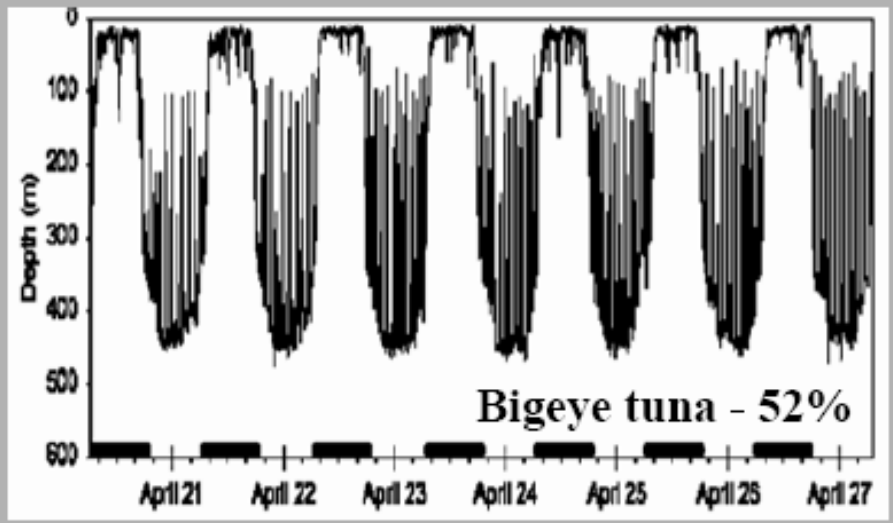
Species	No.Tagged	No. Reporting	Total Days at Liberty	Mean (range)	% PSATs		
					Reporting	Male	Female
Blue Shark (*Prionace glauca*)	32	16	1854	116 (1-247)	50%	21%	72%
Bigeye Thresher Shark (*Alopias superciliosus*)	7	2	480	240 (240)	29%	na	na
Silky Shark (*Carcharhinus falciformis*)	4	4	1087	271 (31-197)	100%	100%	100%
Oceanic White-Tip (*Carcharhinus longimanus*)	8	6	694	115 (10-215)	75%	67%	80%
Shortfin Mako (*Isurus oxyrinchus*)	4	1	155	155	25%	100%	0%
Basking shark (*Cetorhinus maximus*)	1	0					
Great White (Carcharodon carcharias)	48	36	5592	155 (16-366)	75%	75%	67%

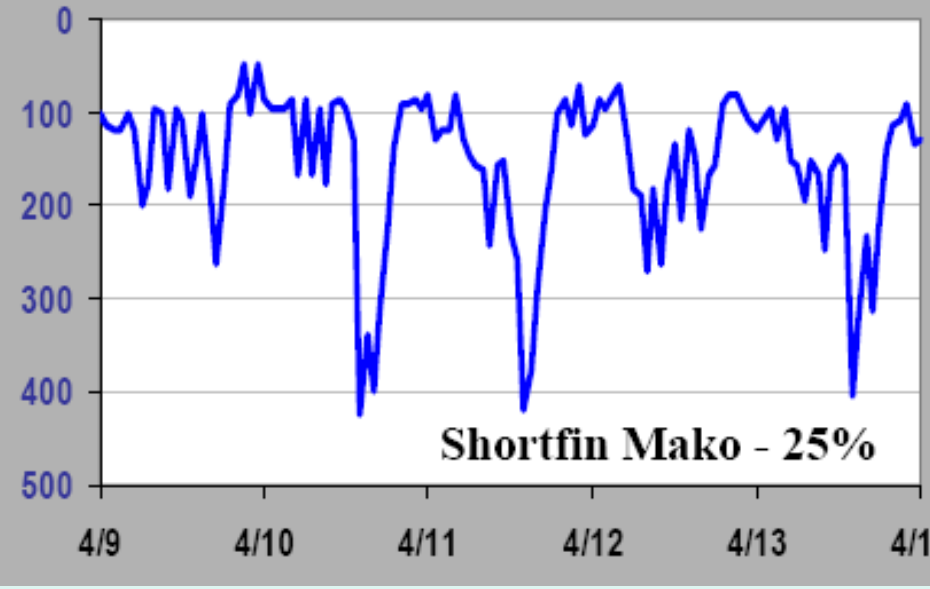


Lowest reporting rates in species with extensive daily vertical movements









Logistic Regression

- **LOGIT or Log Odds**
- **Binary responses with Binomial distribution**
- **X can be categorical, ordinal or continuous**
- **Maximum likelihood estimates of parameters β**
- **Exp(β) is ODDS of the event.**
- **Categories are compared to baseline.**

$$\log\left(\frac{\pi}{1-\pi}\right) = \alpha + \beta x$$

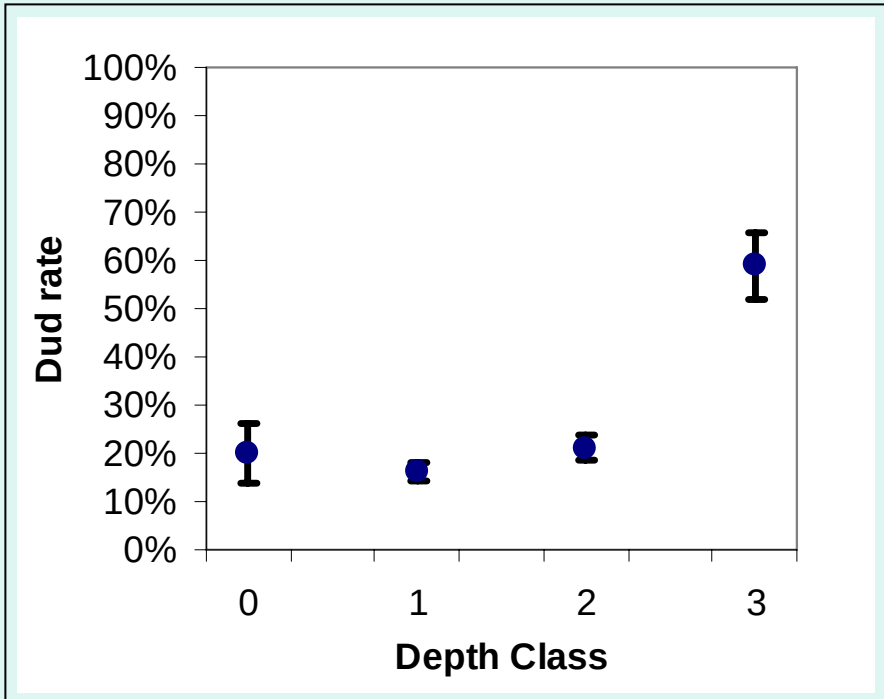
Comment on Interpretations

- Parameters β are ‘log odds’
- Exp(β) of parameters are ODDS of the event.
- Comparisons to LAST category.

Response Rate model

Logit(Response rate)~
depthclass depthclass^2 manufacturer tagger

- Likelihood ratio tests
- Plots of rates vs interesting variables
- Residual plots



Logistic Regression:

PSAT Reporting Rate

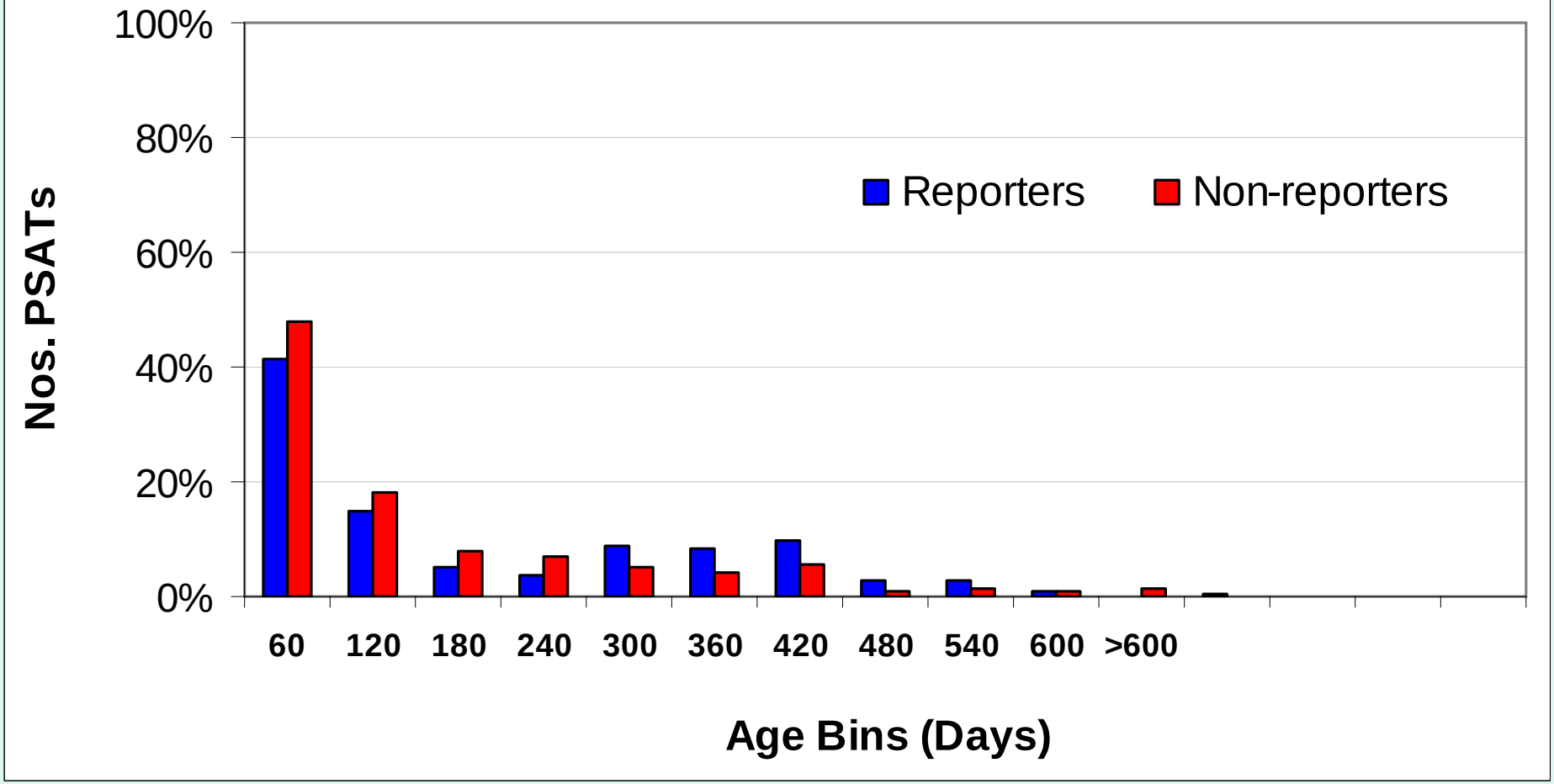
Parameter	β^	SE	p-value
Intercept	1.60	0.45	0.0004
Depthclass (0,1,2,3)	0.66	0.52	0.2
Depthclass^2	-0.34	0.15	0.02
Manufacturer: MT vs WC	-0.70	0.13	<0.0001
Tagger:BrMus vs Swimmer	-0.41	0.24	0.09
Tagger:Domeier vs Swimmer	-0.38	0.22	0.078
Tagger:Lutcavage vs Swimmer	0.89	0.26	0.0006

Age at Deployment

- **Older PSATs have fewer non-reporters.**
- **Tag age effect disappears with depth class.**
- **Why?**

  Older tags on Epi-Pelagic species.
- **Depth class is the key variable.**

PSATs Reporting by Tag Age at Deployment
Reporters Avg. Age 172 +/- 7.4 se (6-940)
Non-reporters Avg. Age 134 +/- 12.3 se (15-671)

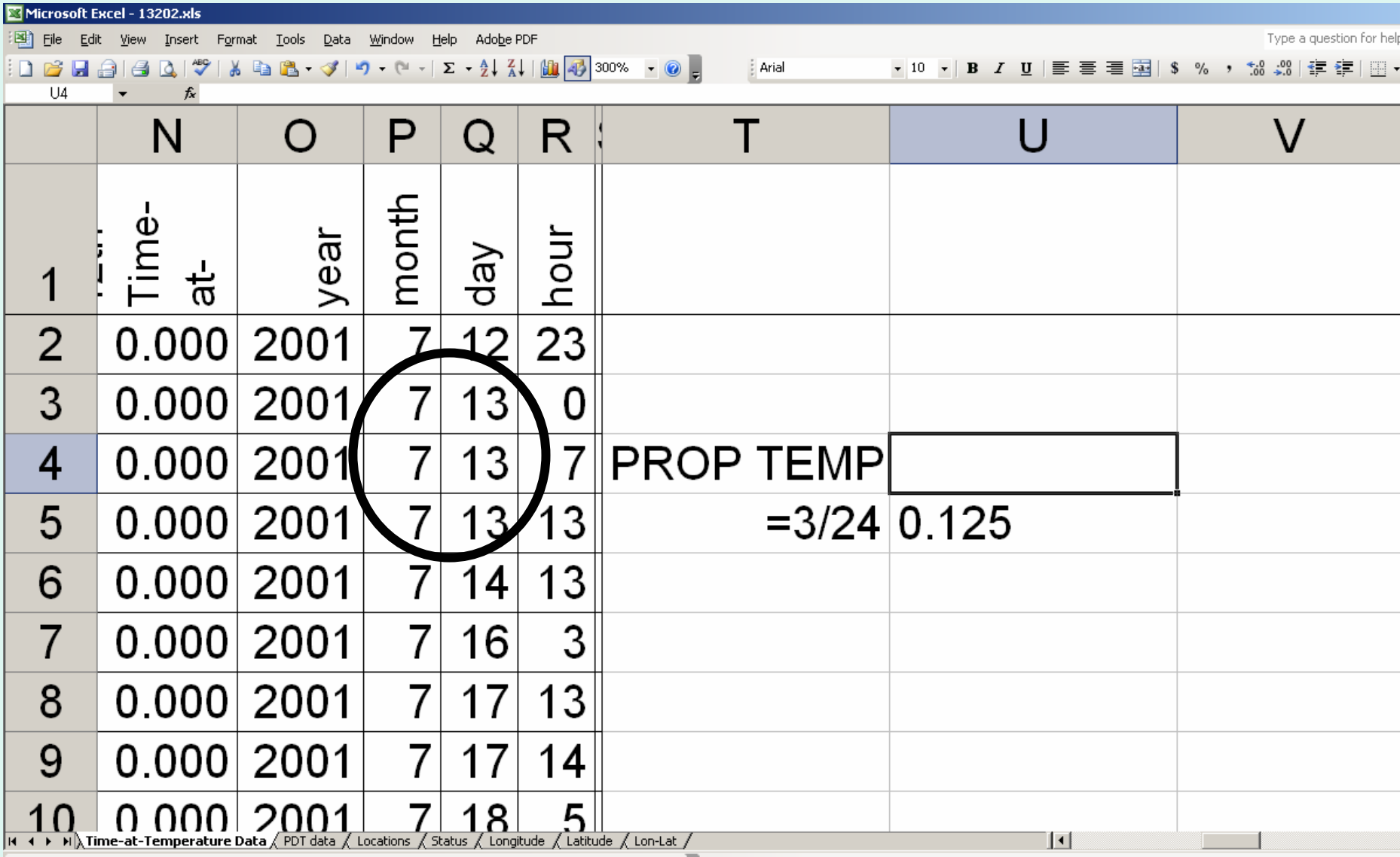


Conclusions
PSAT Response Rate

- **Depth class is implicated in non-responding PSATS.**
- **Age at deployment is a non-issue.**
- **Tagger team is a stand in for regional differences.**

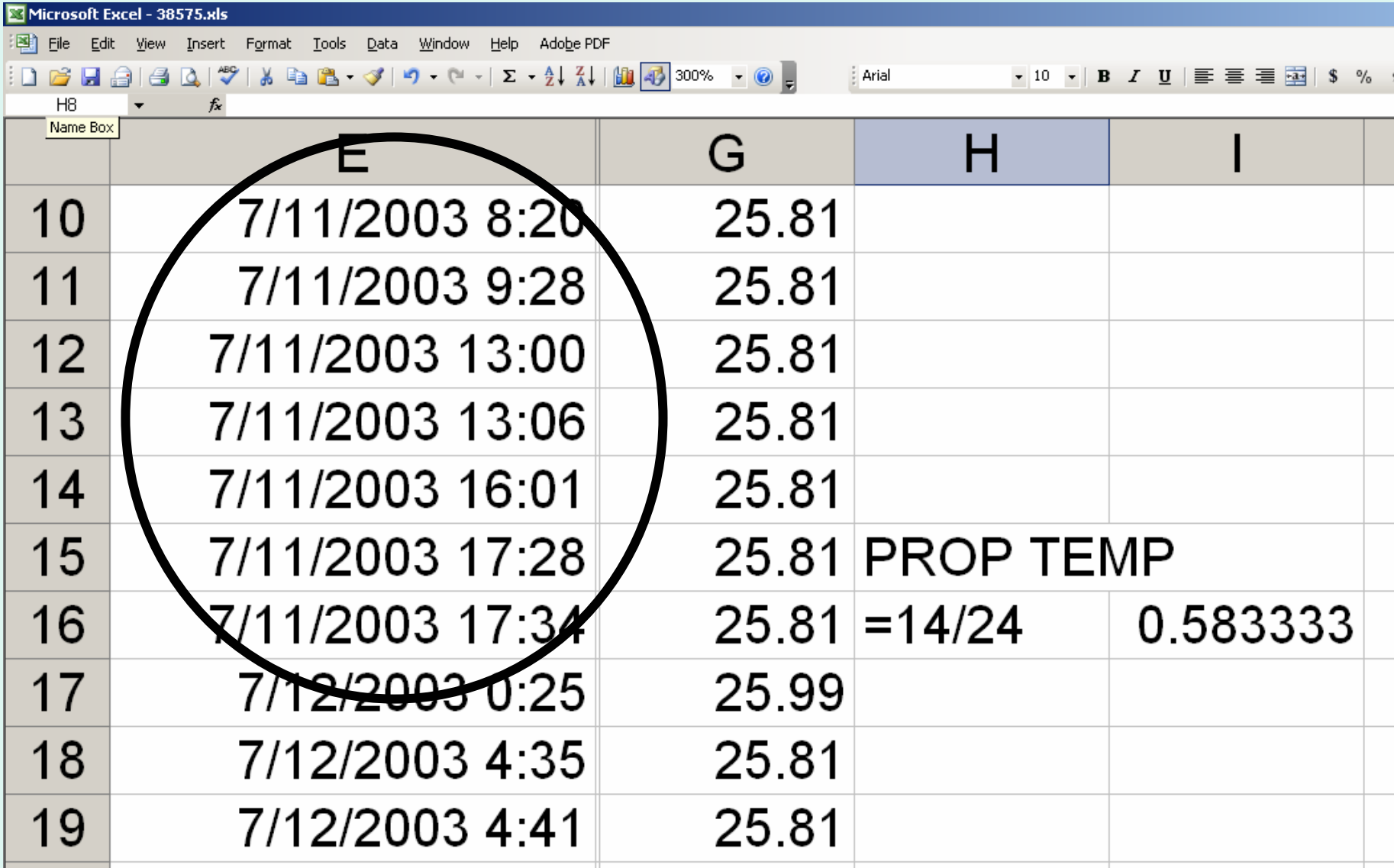
PSAT %data returned

Difference in types of data: WC



	N	O	P	Q	R	T	U	V
1	Time-at-	year	month	day	hour			
2	0.000	2001	7	12	23			
3	0.000	2001	7	13	0			
4	0.000	2001	7	13	7	PROP TEMP		
5	0.000	2001	7	13	13	=3/24	0.125	
6	0.000	2001	7	14	13			
7	0.000	2001	7	16	3			
8	0.000	2001	7	17	13			
9	0.000	2001	7	17	14			
10	0.000	2001	7	18	5			

Differences in types of data
MT



	E	G	H	I
10	7/11/2003 8:20	25.81		
11	7/11/2003 9:28	25.81		
12	7/11/2003 13:00	25.81		
13	7/11/2003 13:06	25.81		
14	7/11/2003 16:01	25.81		
15	7/11/2003 17:28	25.81	PROP TEMP	
16	7/11/2003 17:34	25.81	=14/24	0.583333
17	7/12/2003 0:25	25.99		
18	7/12/2003 4:35	25.81		
19	7/12/2003 4:41	25.81		

Example

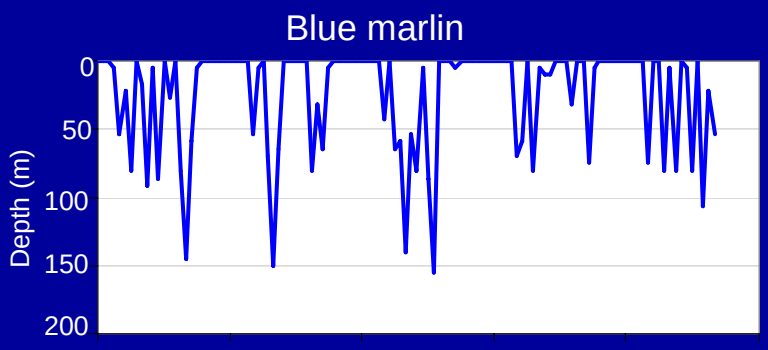
propTemp=Ntemp/(setpopdays*24/interval)

Ntemp=101; Setpop=184 days; 6hr intervals

propTemp=101/(184*24/6)=0.137

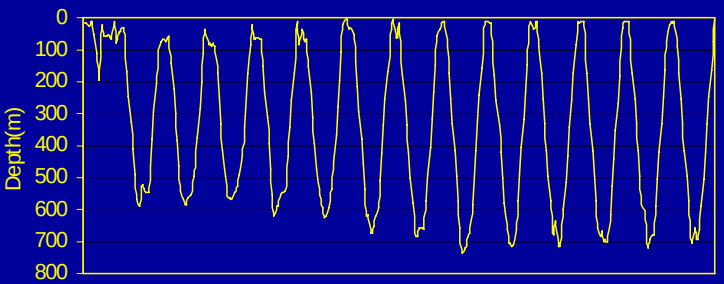
We assert: Equivalent.

Comparison is valid.



80%
= Geolocations

Swordfish - fraction of days at liberty with geolocations = 9%

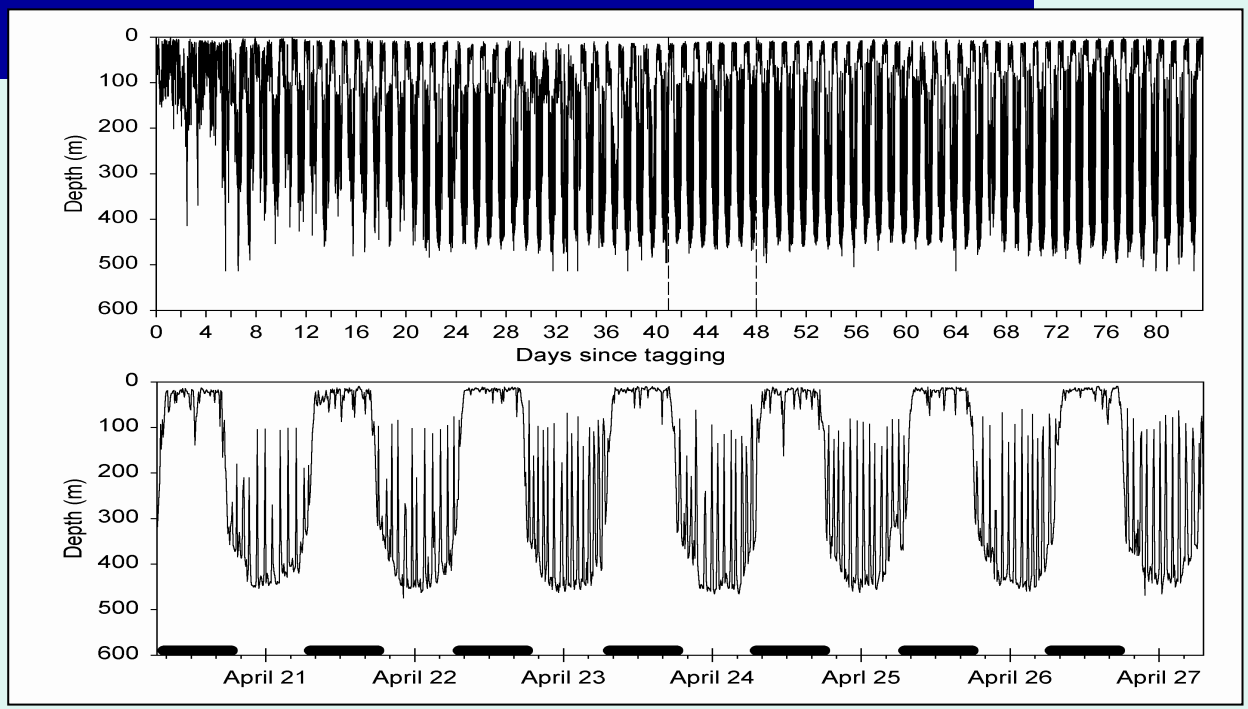


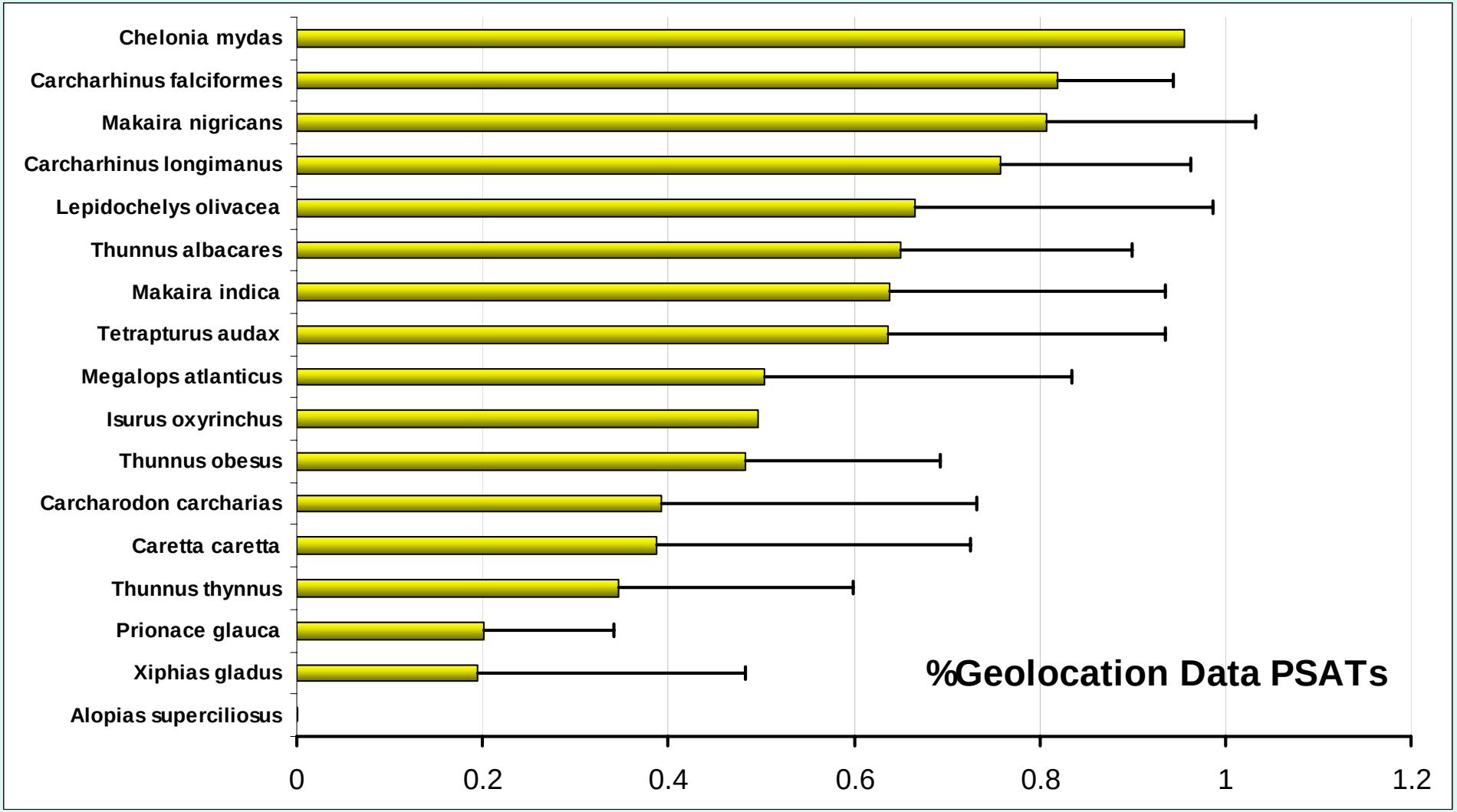
<13%

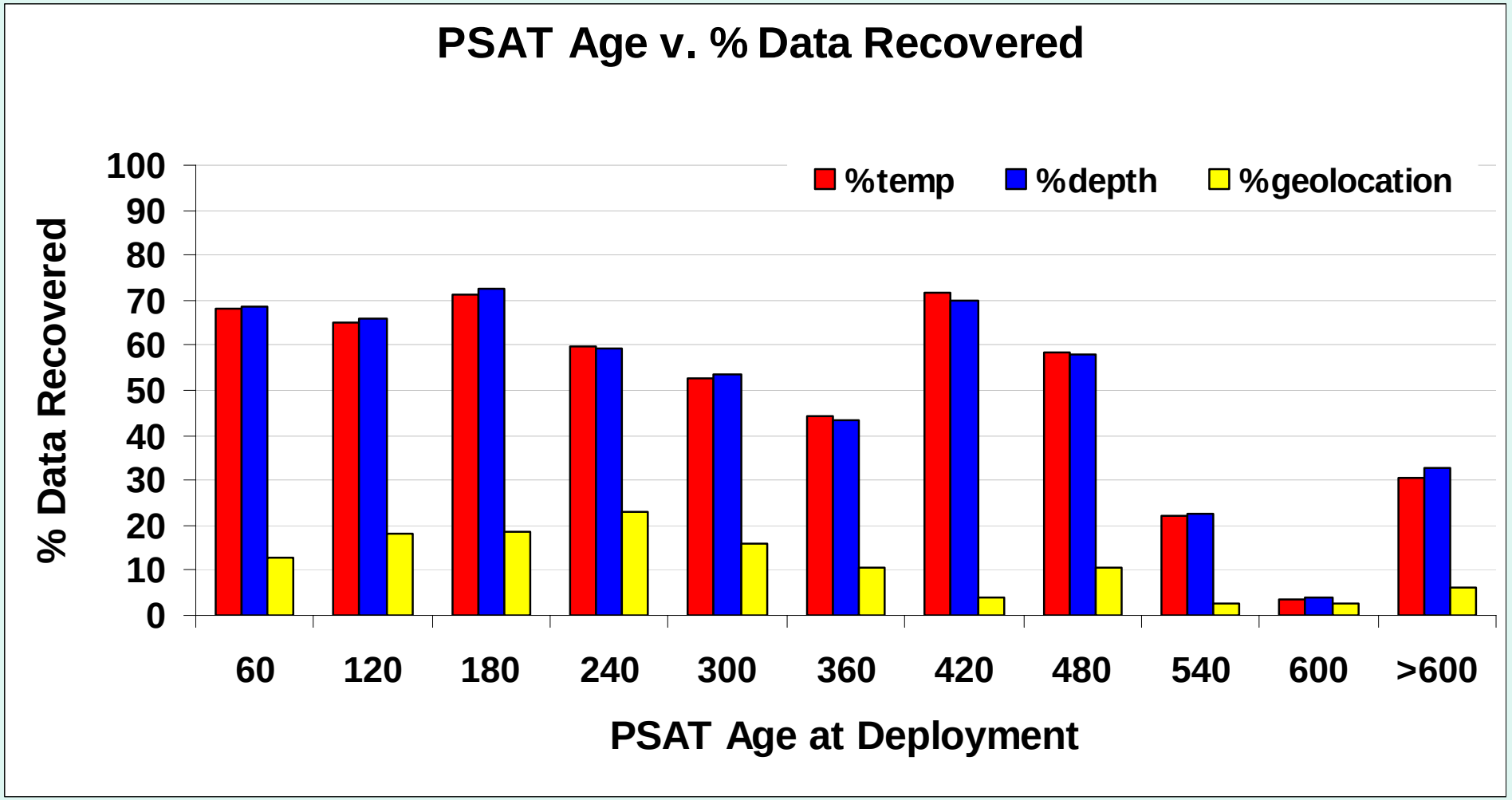
= No geolocations

bigeye tuna and
bigeye thresher sharks

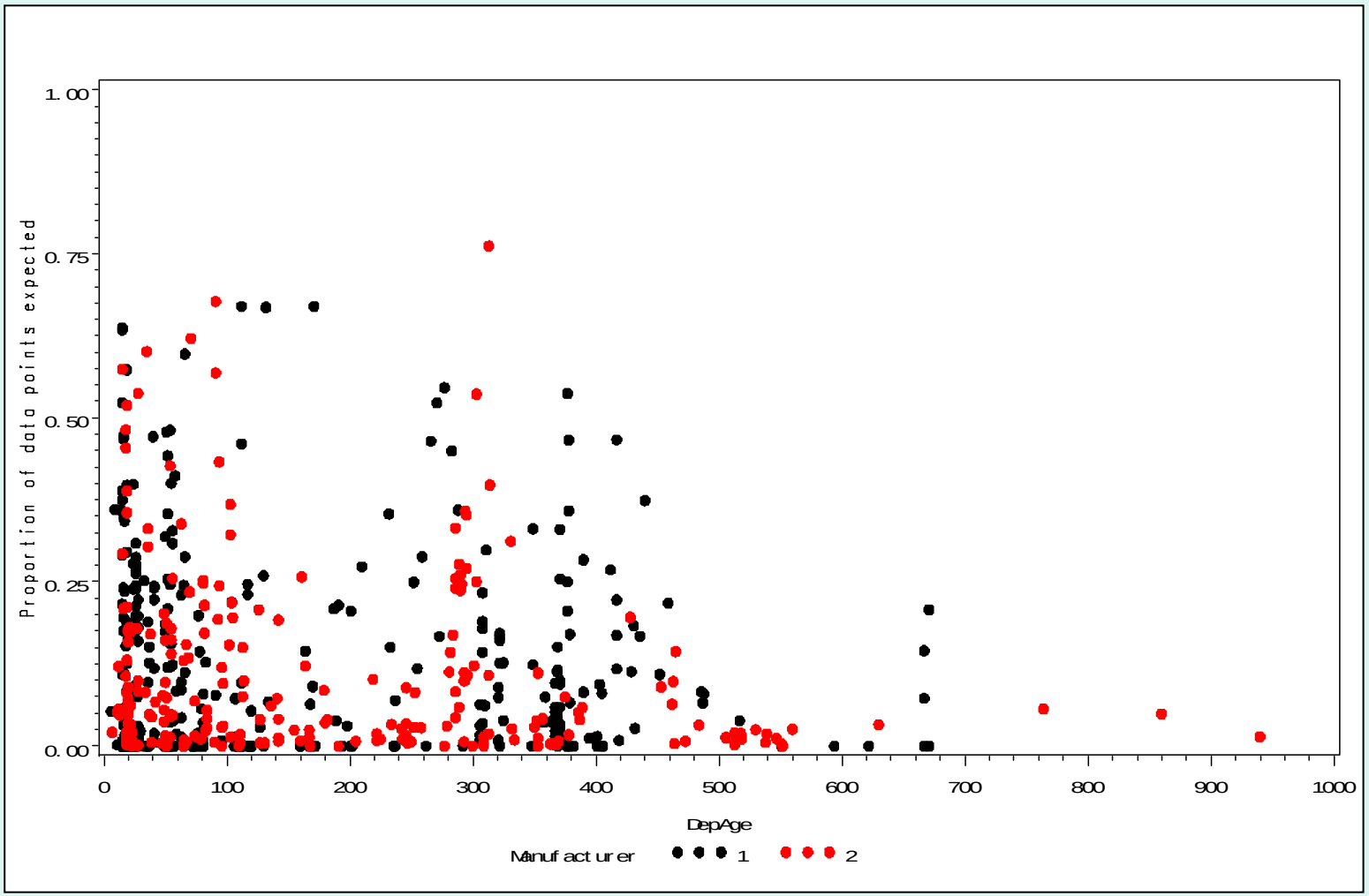
Deep diving species rarely return good geo location data.



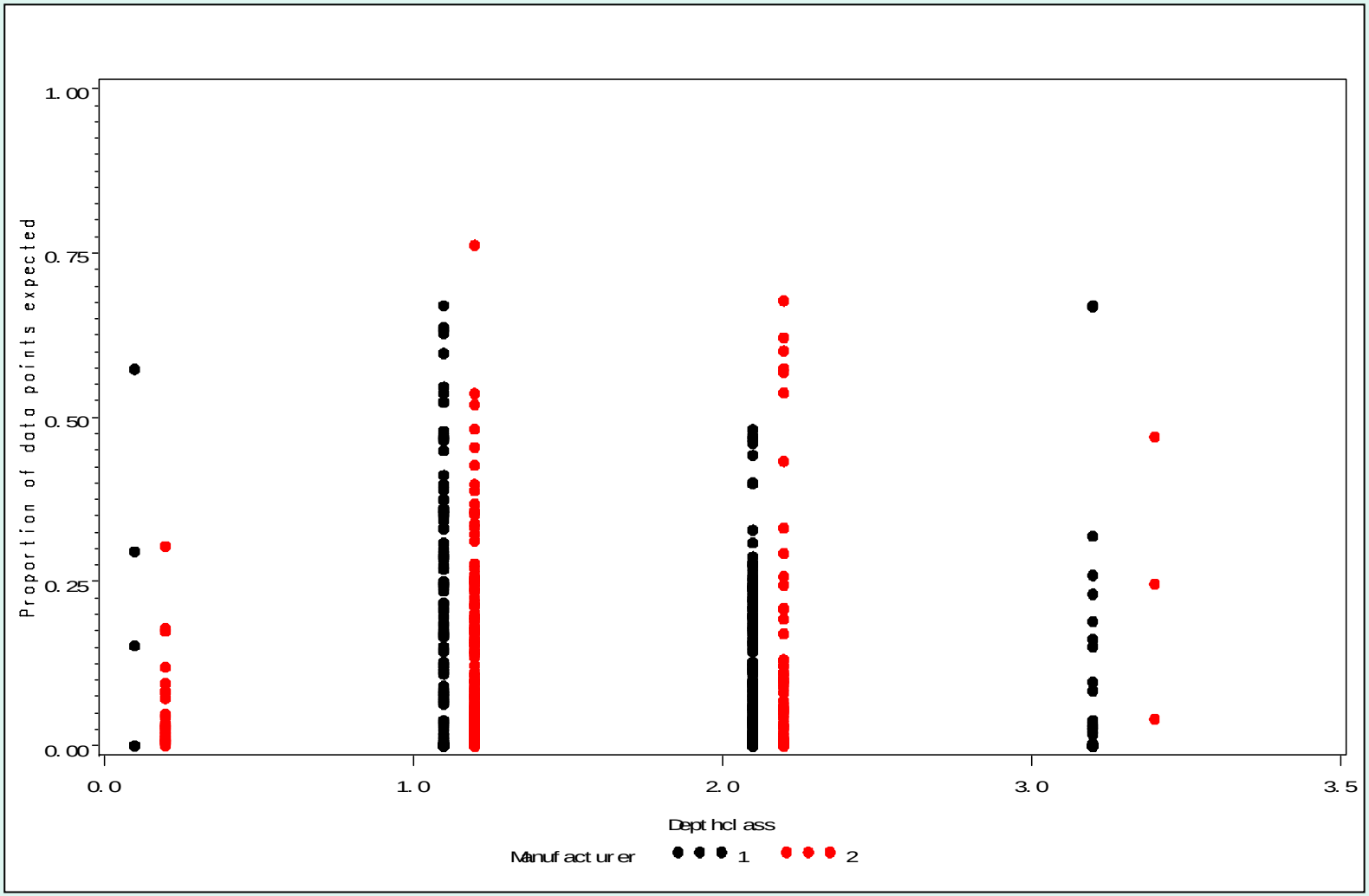

Chelonia mydas
Carcharhinus falciformes
Makaira nigricans
Carcharhinus longimanus
Lepidochelys olivacea
Thunnus albacares
Makaira indica
Tetrapturus audax
Megalops atlanticus
Isurus oxyrinchus
Thunnus obesus
Carcharodon carcharias
Caretta caretta
Thunnus thynnus
Prionace glauca
Xiphias gladus
Alopias superciliosus
%Geolocation Data PSATs
0
0.2
0.4
0.6
0.8
1
1.2


PSAT Age v. % Data Recovered
%temp
%depth
%geolocation
% Data Recovered
100
90
80
70
60
50
40
30
20
10
0
60
120
180
240
300
360
420
480
540
600
>600
PSAT Age at Deployment

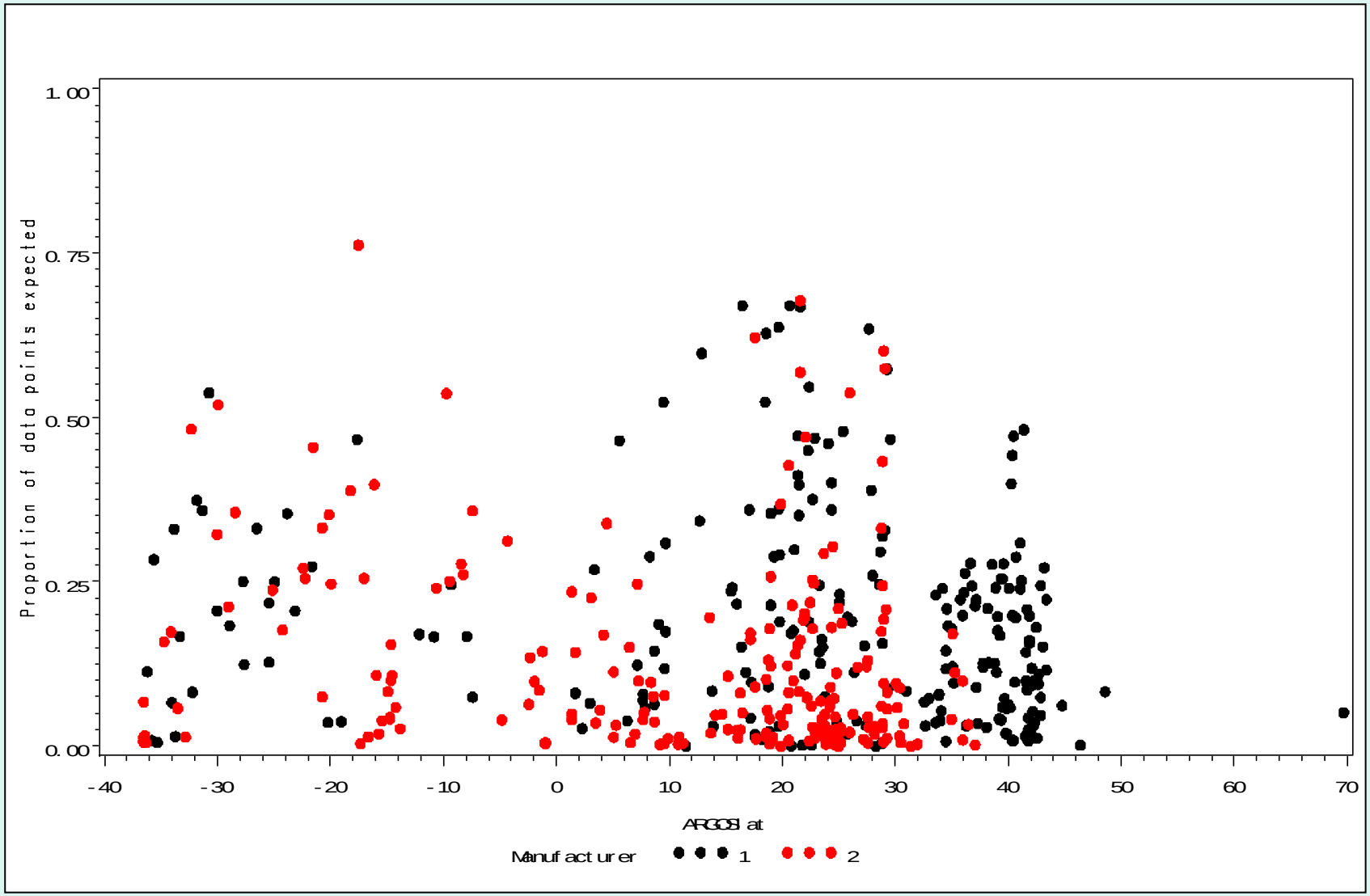
Proportion of data points vs PSAT age at deployment



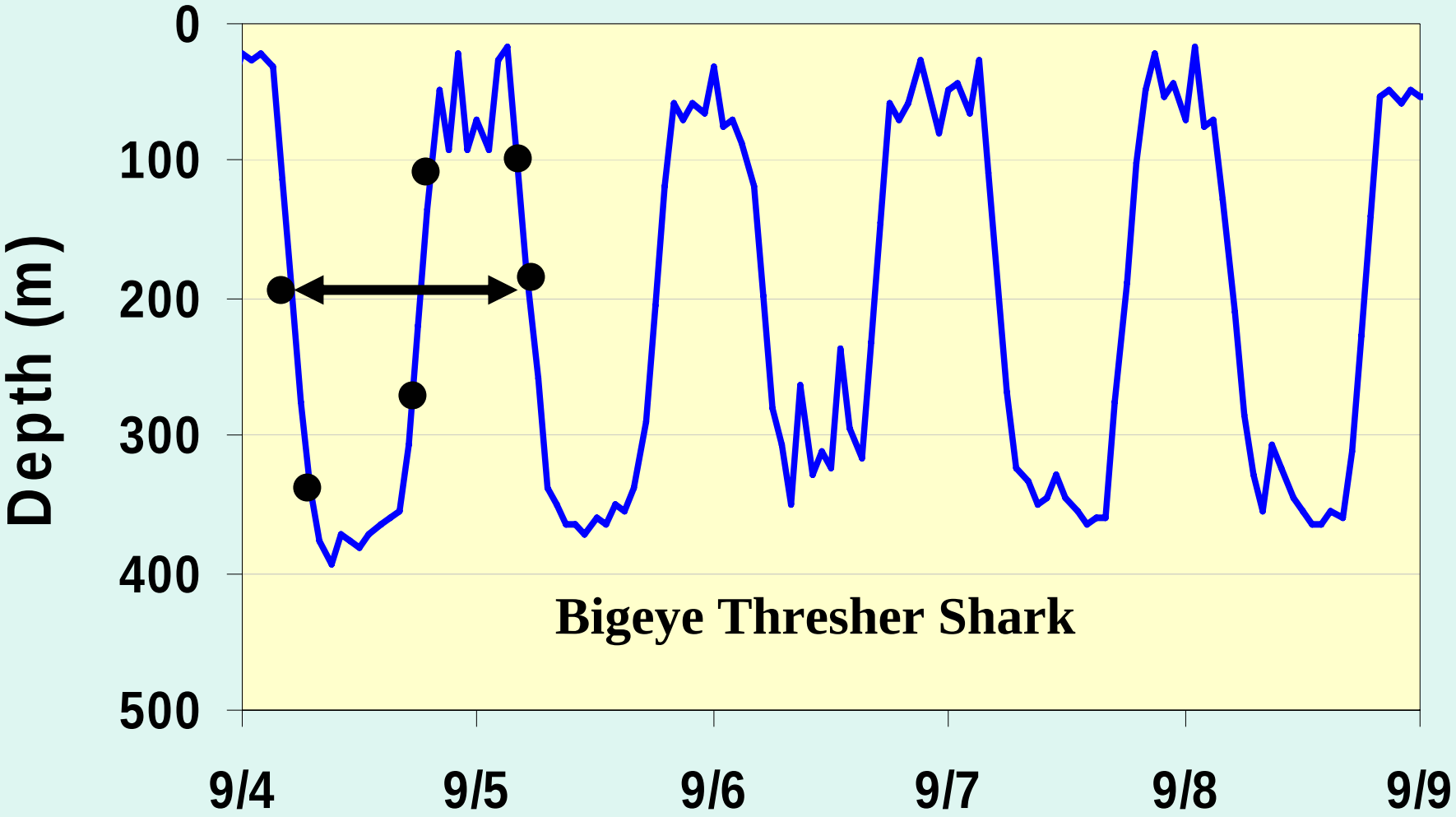
Proportion of data points vs. Depth class



Proportion of data points vs Latitude



Why is missing-ness important?



Optimal Set pop days: Thought experiment

- Suppose you argued set pop off days=10?
  Few days at liberty, so then data value could be improved with optimal set pop>10.
- Suppose you argued set pop off days=1000?
  Then battery wears out...no data.
  Optimal set pop off must be less than1000.

CONCLUSION: There exists an optimal set pop off days >10 and <1000.

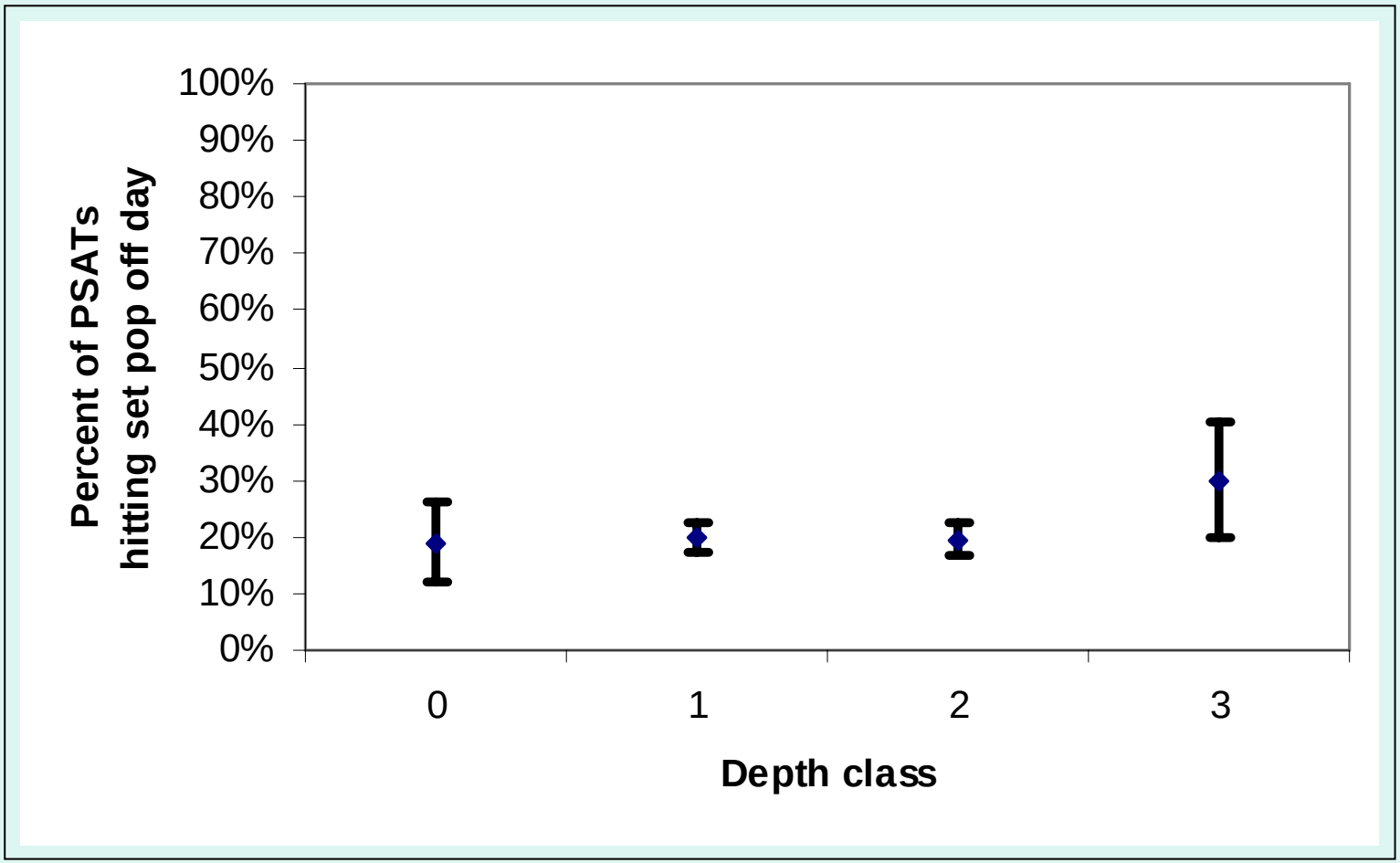
Answer depends on species, manufacturer and latitude.

Conclusions on PSAT data returned

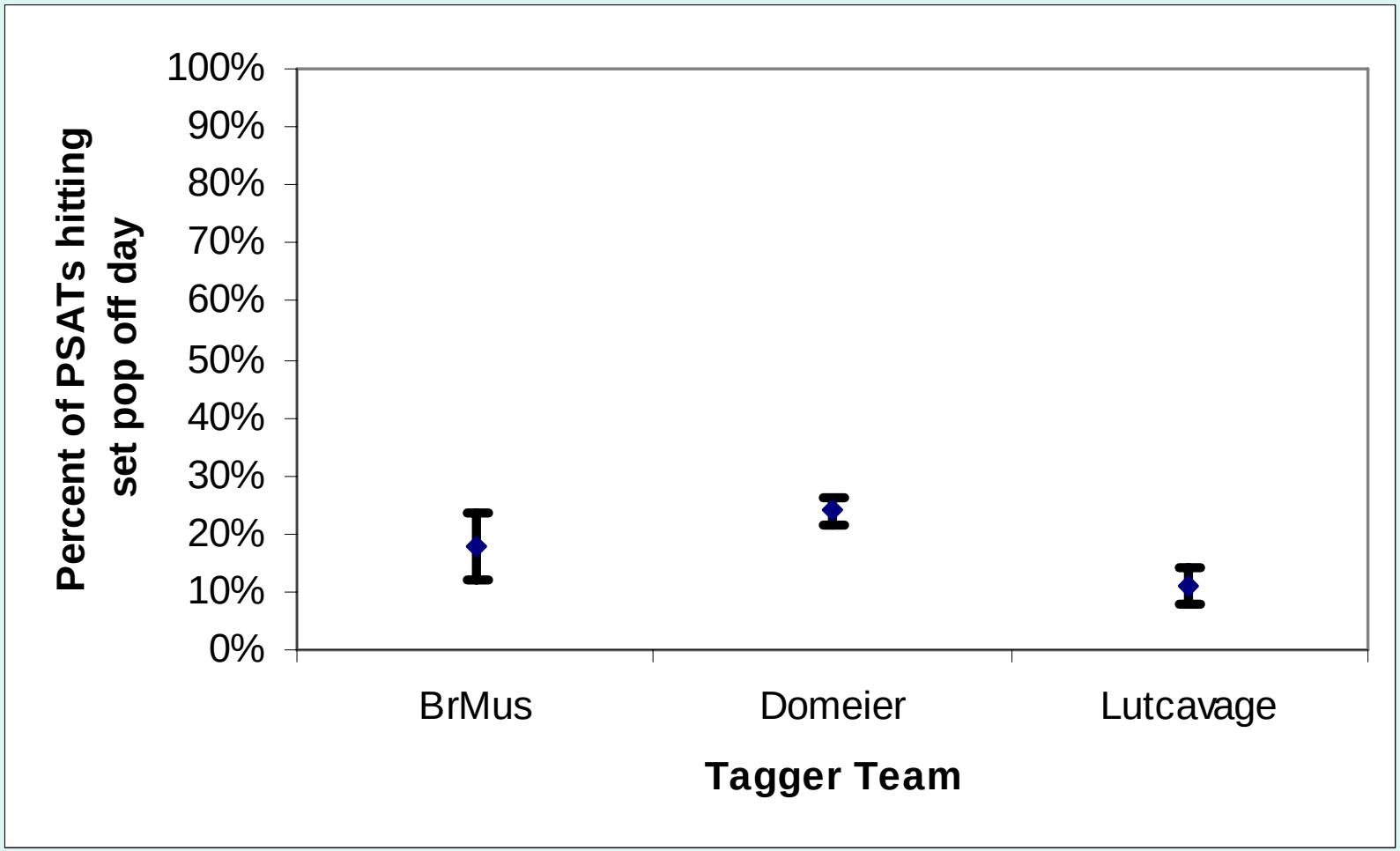
- Deep diving species poor candidates for geo-location data.
- Age at deployment, depth class, species and latitude are all influential.
- Microwave Telemetry returns larger proportion of expected data points than Wildlife Computers.
- Large gaps in time series are problematic.

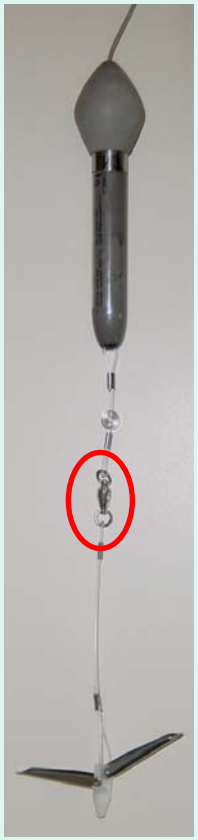
PSAT RETENTION

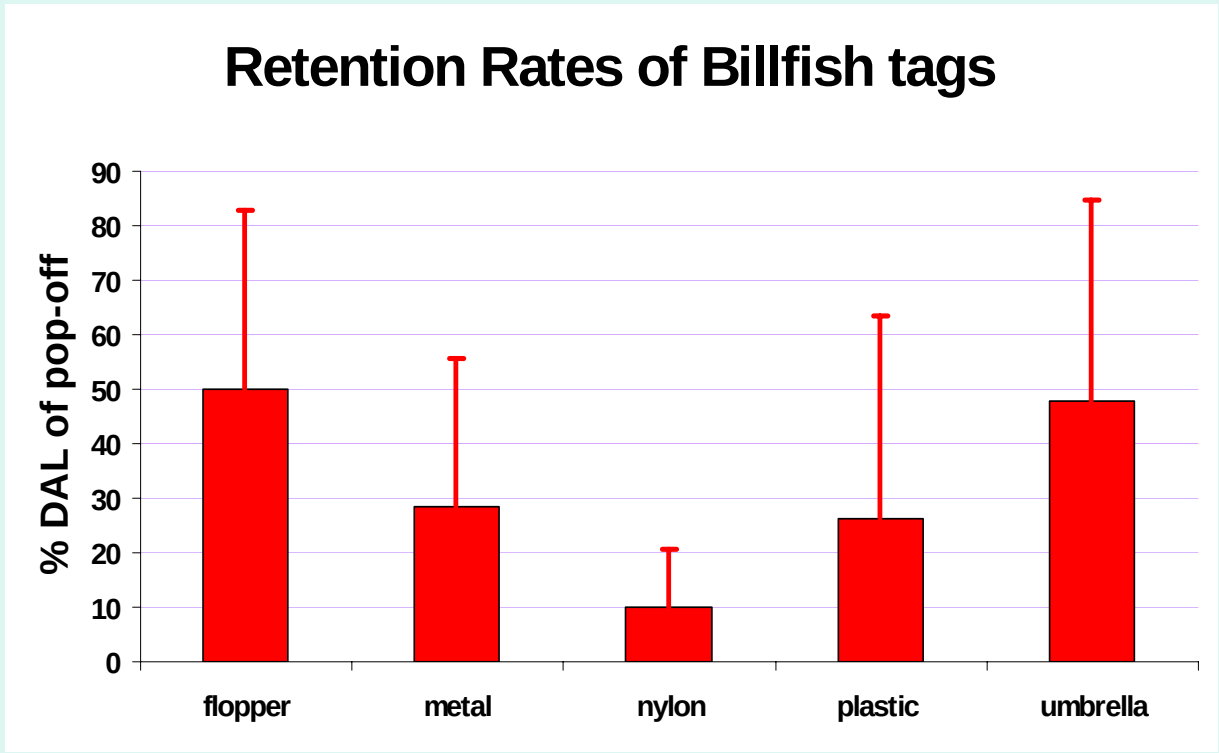
PSAT Retention rates by depth class

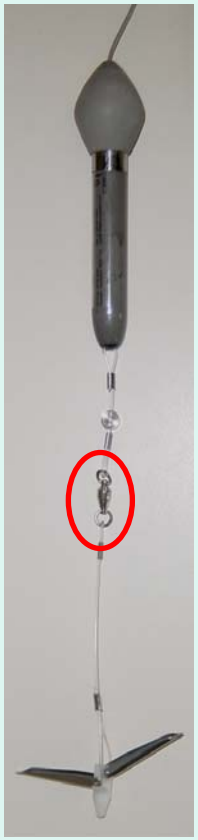


PSAT Retention rates by tagger team

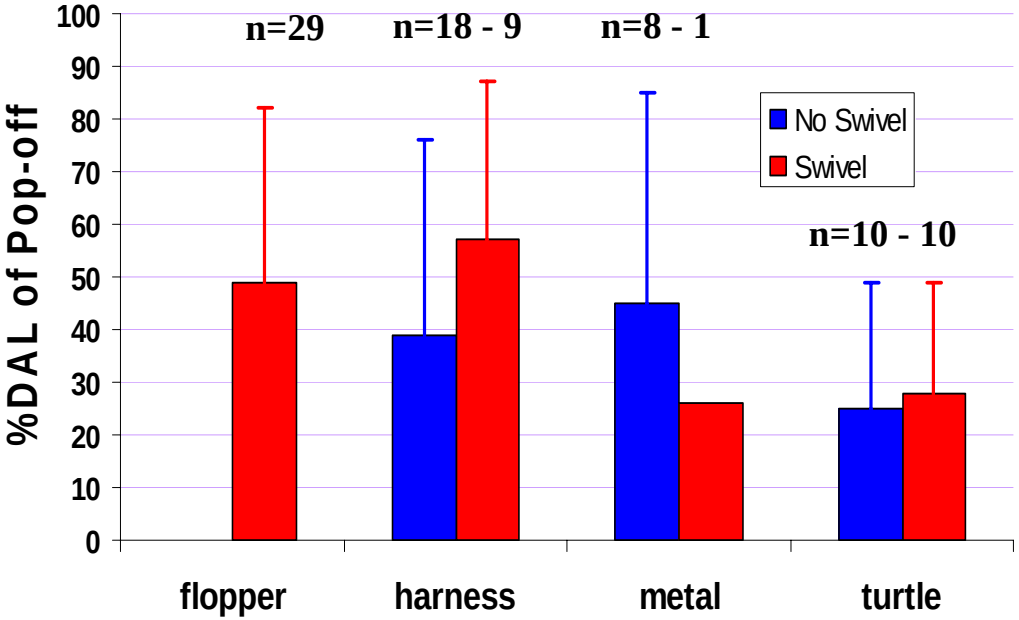





Retention Rates of Billfish tags
% DAL of pop-off
90
80
70
60
50
40
30
20
10
0
flopper
metal
nylon
plastic
umbrella



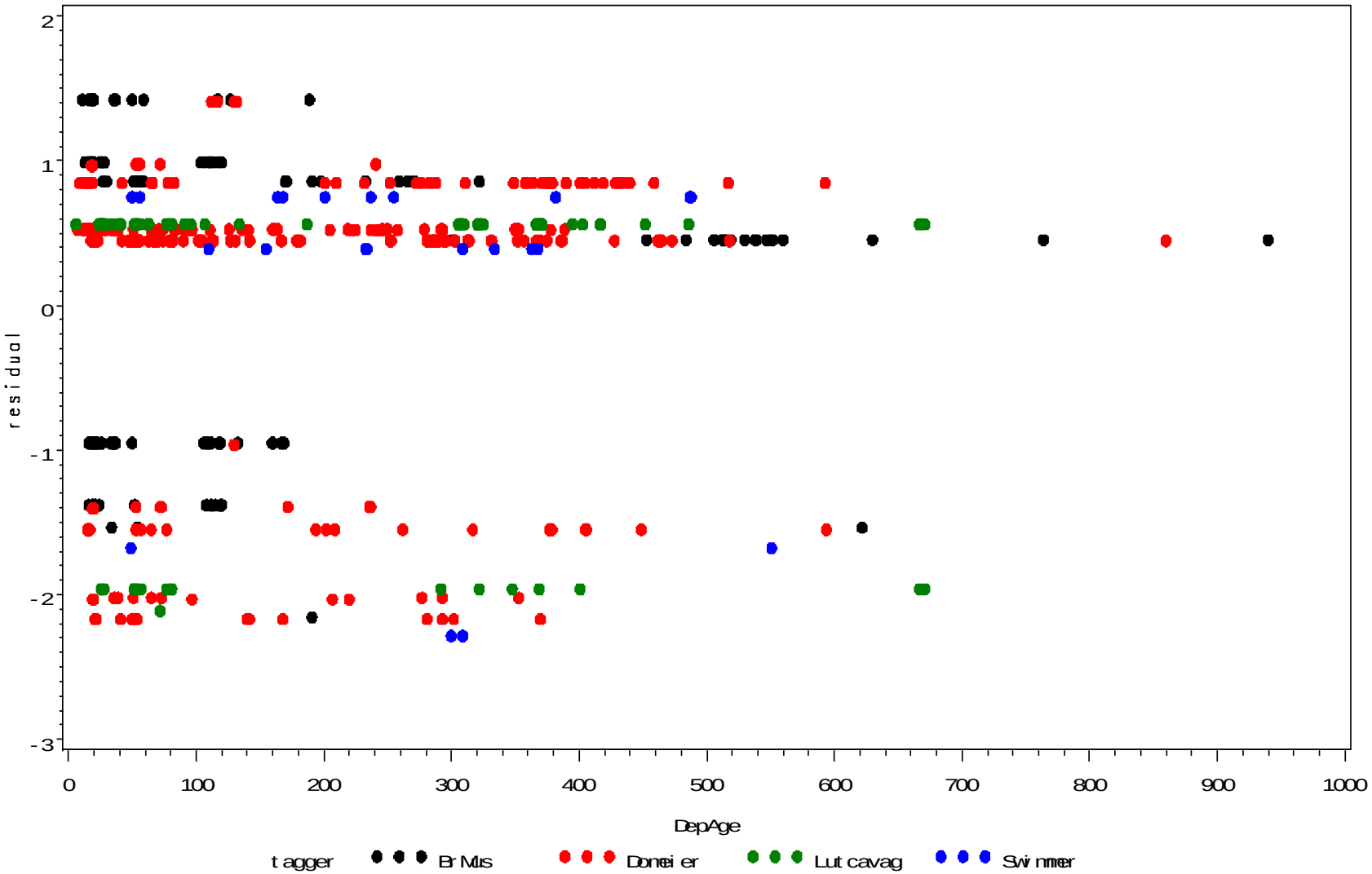
Swivel Augmentation on DAL



Logistic Model for Retention Success

Parameter	β^	SE	p
Intercept	**-3.21**	**0.48**	**<0.0001**
Depth class	**0.54**	**0.23**	**0.0203**
Tagger BrMus vs Lutcavage	**-0.75**	**0.59**	**0.2069**
Tagger Domeier vs Lutcavage	**1.27**	**0.36**	**0.0005**
Tag-head Flopper vs Umbrella	**1.75**	**0.82**	**0.0319**
Tag-head Nylon vs Umbrella	**-0.85**	**0.38**	**0.0233**
Tag-head Stainless vs Umbrella	**0.53**	**0.39**	**0.1733**
Tag-head Titan. vs Umbrella	**-1.63**	**0.66**	**0.0130**
Latitude	**0.02**	**0.008**	**0.0182**

Residual Plots



Parameter	ODDS
Intercept	0.04
Depth class	1.72
Tagger BrMus vs Lutcavage	0.47
Tagger Domeier vs Lutcavage	3.56
Tag-head Flopper vs Umbrella	5.75
Tag-head Nylon vs Umbrella	0.43
Tag-head Stainless vs Umbrella	1.70
Tag-head Titan. vs Umbrella	0.20
Latitude	1.02

ODDS of Retention

Odds of retention increases with each depth class by a multiplicative factor of 1.72.

Odds of retention increases with flopper/swivel tag-heads by a multiplicative factor of 5.75 compared to umbrellas.

Odds of retention increases with each degree of latitude by a multiplicative factor of 1.02.

PSAT Retention Conclusions

- **Deeper diving species more likely to retain the tags.**
- **Floppers increase probability of tag retention.**
- **Species in colder Latitudes more like to retain tag.**
- **Domeier's tagger team has best retention rates.**

Overall Conclusions

- **Bathy-Pelagic has higher non-response rate. Implicates pressure.**
- **More data returned for MT tags.**
- **There exists an optimal set pop days dependent on species.**
- **Floppers increase tag retention.**
- **Depth, Latitude increase retention.**

Implicating temperature.

Mahalo's To:

- **John Sibert**
- **Michael Laurs**
- **Scientists, Crew and Officers of the NOAA RV *Townsend Cromwell* and the *Elton Oscar Sette***
- **JIMAR**
- **PIFSC/NOAA**