Diving and Foraging Behavior of Blue Whales Tracked With Intermediate-duration Advanced Dive Behavior Tags off Southern California

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Advanced Dive Behavior Tags

- **Intermediate attachment duration (3 – 4 wks)**
  - **Modified version of Wildlife Computers Mk-10 TDR**

Image source: Wildlife Computers

Advanced Dive Behavior Tags

- **Intermediate attachment duration (3 – 4 wks)**
  - **Semi-Implantable tags**
  - **Attachments similar to Mate et al 2007**

Image source: Wildlife Computers

Advanced Dive Behavior Tags

- Depth, 3-axis accelerometers and magnetometers at 1 Hz
- GPS quality locations (FastLoc; collected every 7 min)
- Release at scheduled time or if release criteria are met

Dive Summary Metrics

Isolated dives > 10 m depth and > 1 min duration

- Maximum dive depth (m)
- Dive duration (min)

GPS locations matched to each dive

- Location was estimated by linear interpolation between the two closest GPS locations if no location within 10 min of a dive.

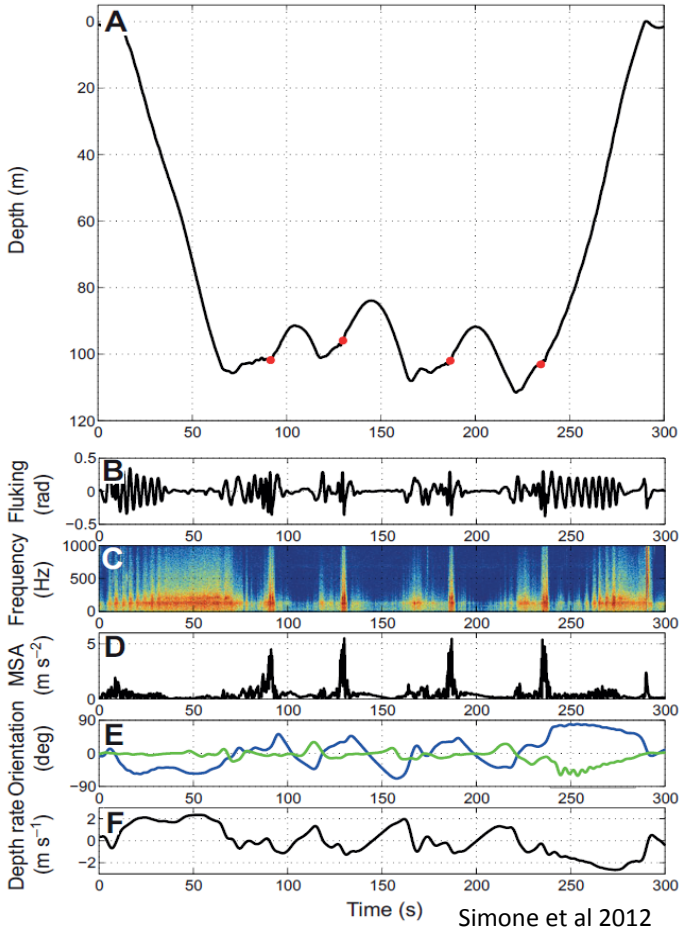
Lunge Detection

Identified peaks in Minimum Specific Acceleration (MSA; Simone et al 2012)

- Misses surface lunge feeding

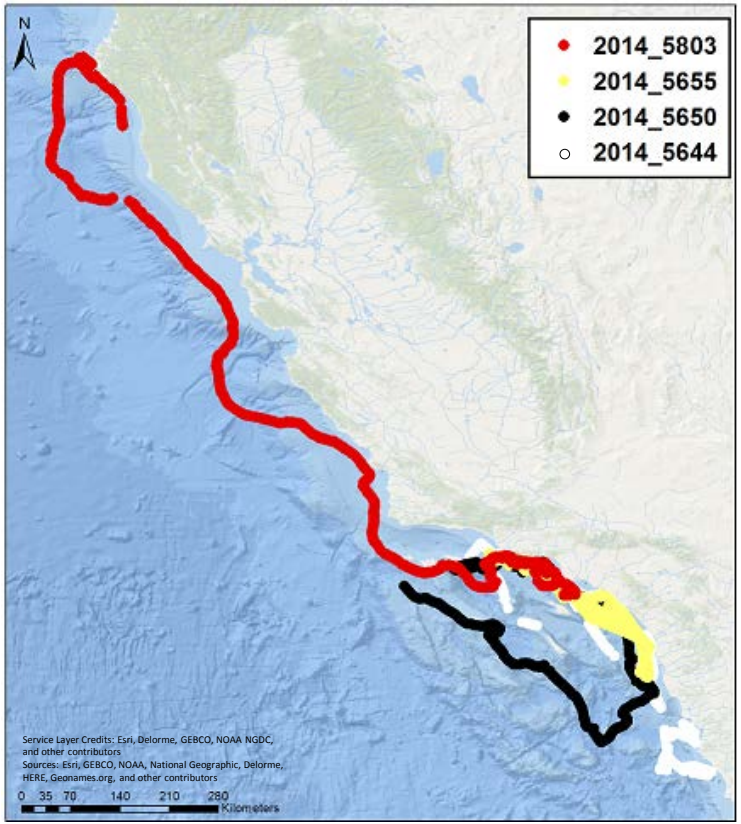
Additional dive summary metrics

- Number of lunges per dive
- Average depth of lunges per dive

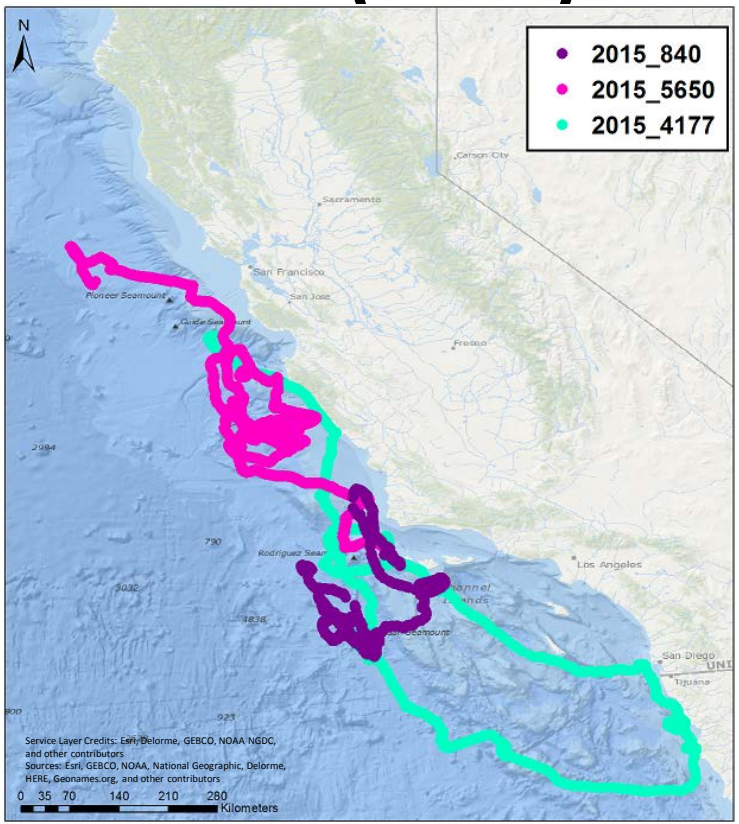


Simone et al 2012

2014 (N = 4)



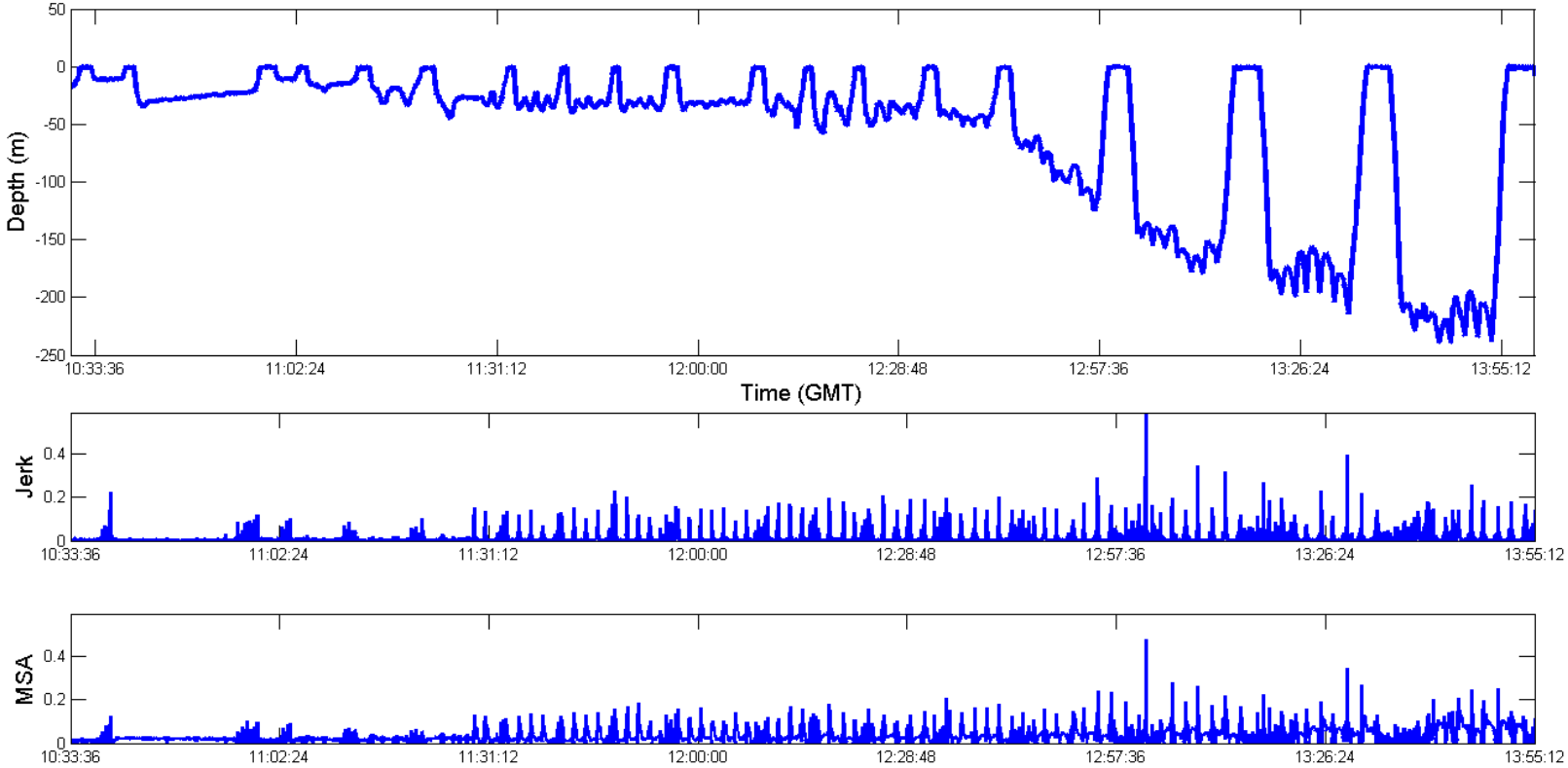
2015 (N = 3)



Deployment Summary

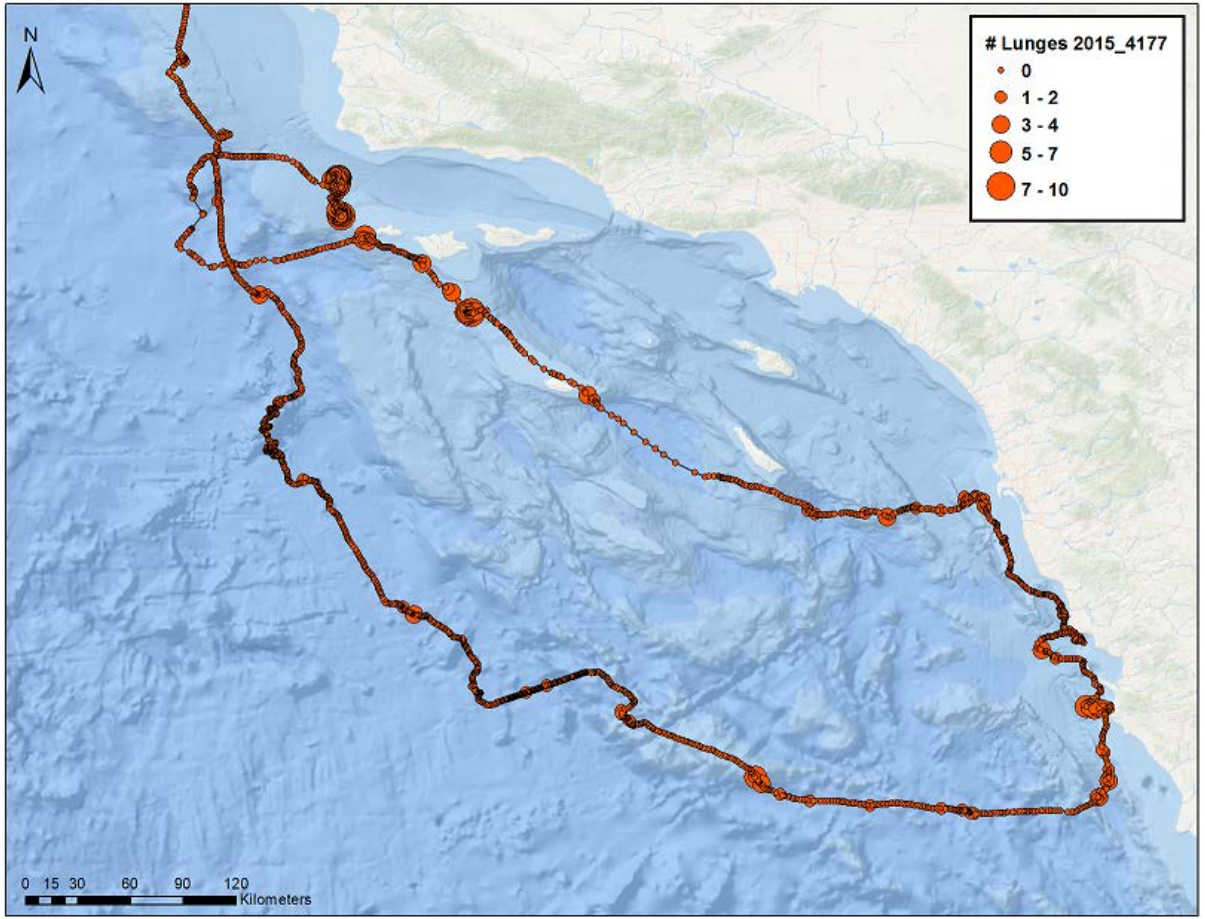
Year	Sex	PTT	Duration (d)	# Dives	# GPS locations	Dives/ day	GPS Locs/day
2014	Female	5644	19	1068	183	56.2	9.7
2014	Male	5650	20	2276	2278	113.9	115
2014	Female	5655	19.8	2918	799	147.3	40.3
2014	Female	5803	18.3	1832	2539	100.3	139.1
2015	Unknown	840	24.8	2075	1633	83.7	62.8
2015	Male	4177	27.5	2794	1520	101.6	53.8
2015	Male	5650	28.9	2280	2246	78.9	80.9

Lunge Detection



Brief foraging bouts after leaving tagging area

- May indicate low prey density or very small scale prey abundance

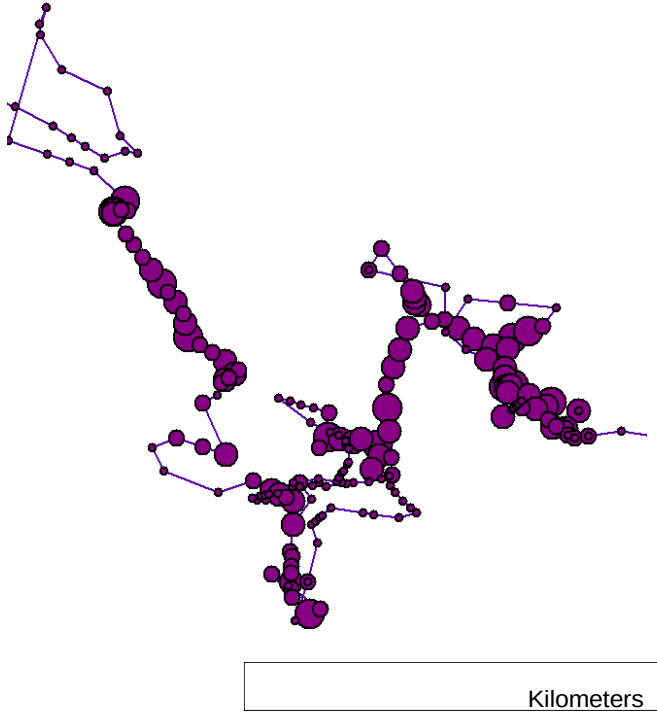


Identification of Foraging Bouts

Foraging Bouts

Sequences of dives with < 3 consecutive non-foraging dives

- Created a minimum convex polygon around each sequence (foraging bout)

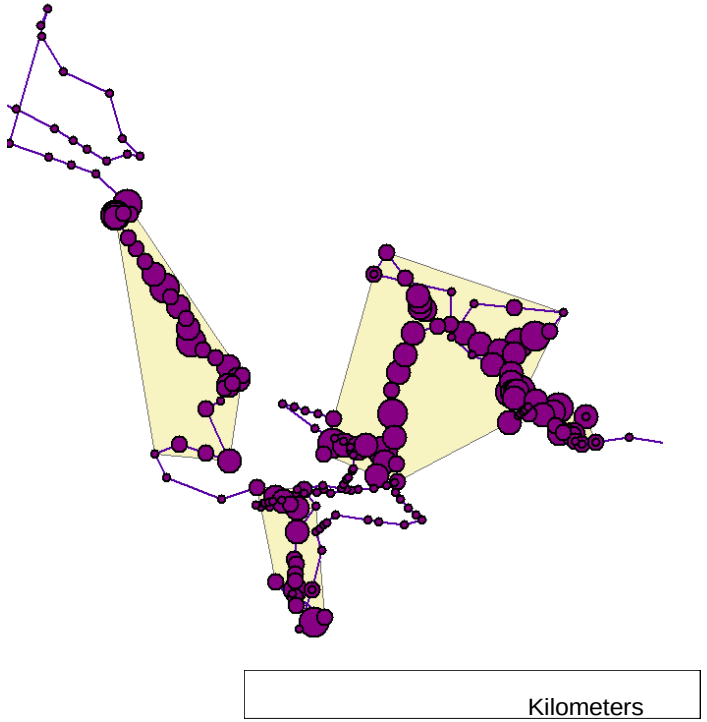


Identification of Foraging Bouts

Foraging Bouts

Sequences of dives with < 3 consecutive non-foraging dives

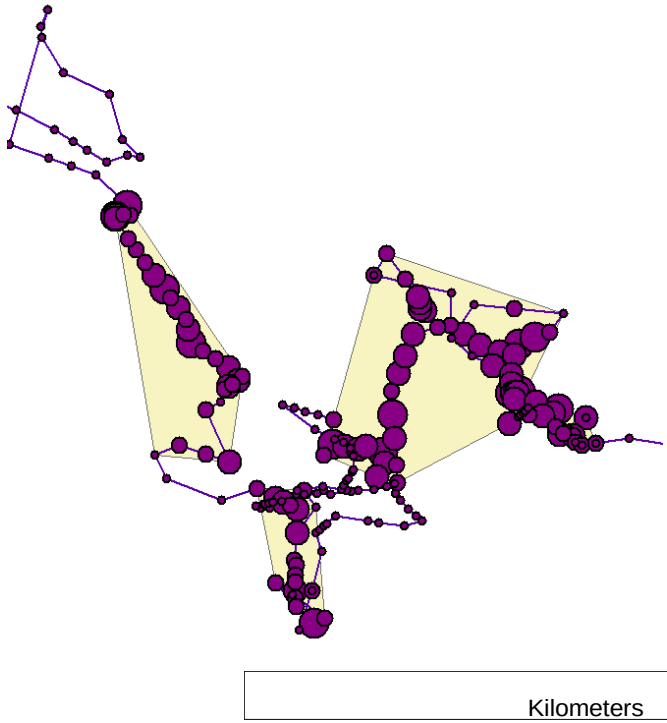
- Created a minimum convex polygon around each sequence (foraging bout)
- Computed a range of summary statistics
  - Bout Duration
  - Average foraging depth
  - Average lunges/dive



Foraging Bouts: Area

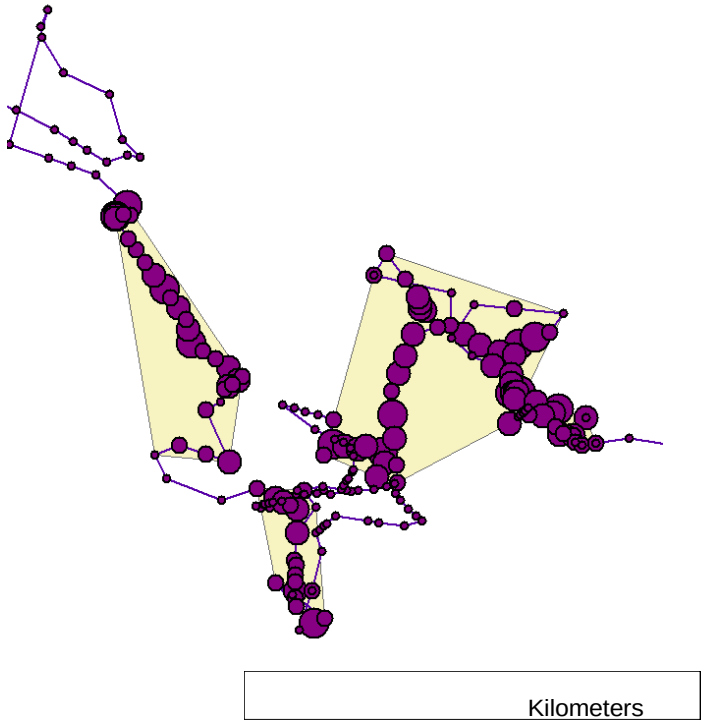
Foraging Bouts were temporally distinct (median = 2.2 h apart) and generally small (median = 1.7 km^2)

- Sizes of Foraging Bout areas are likely an overestimate
- Many foraging segments were generally linear



Foraging Bouts

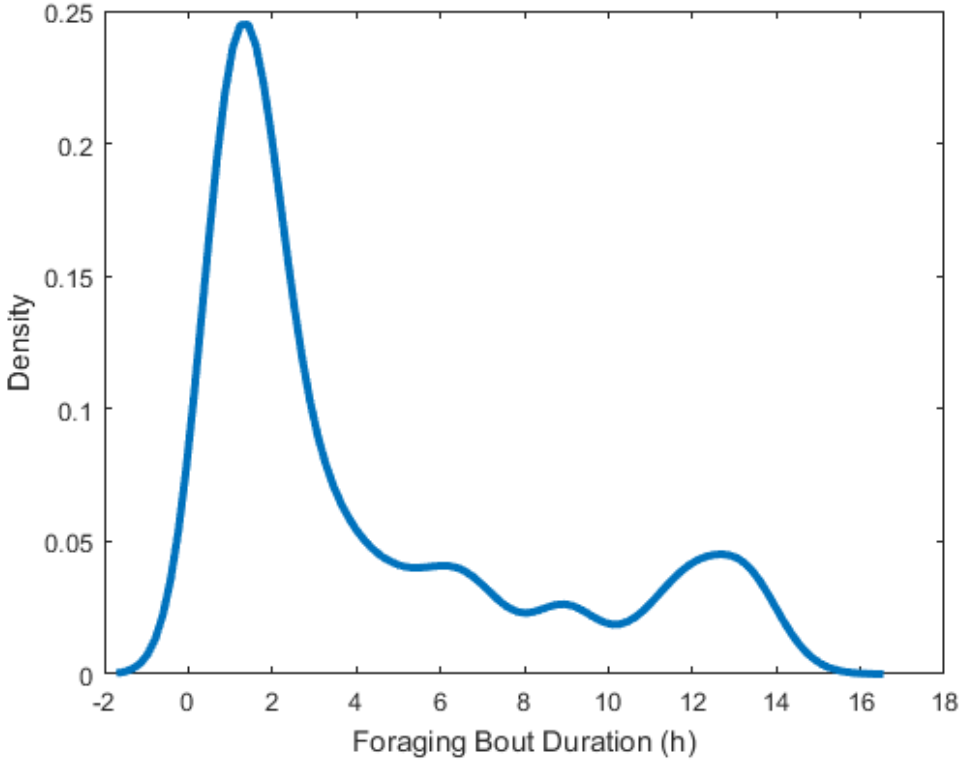
Median foraging bout across individuals contained 11 dives over 2.2 h (max = 77 dives over 14.4 h)



Foraging Bouts: Duration

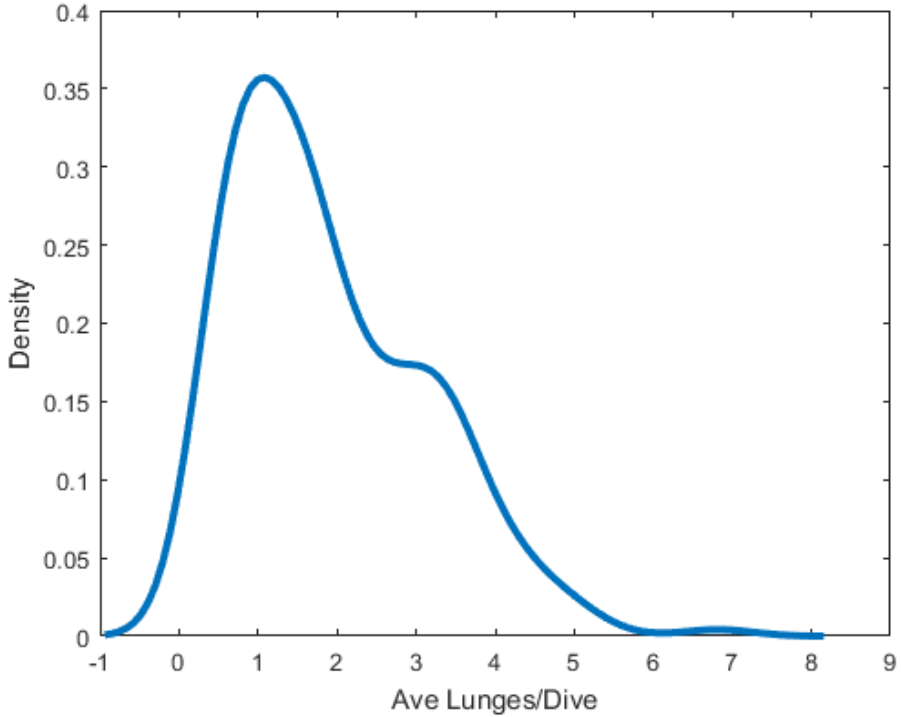
Most foraging bout duration distributions were bimodal

Suggests they left low quality prey patches quickly (Hazen et al 2015)



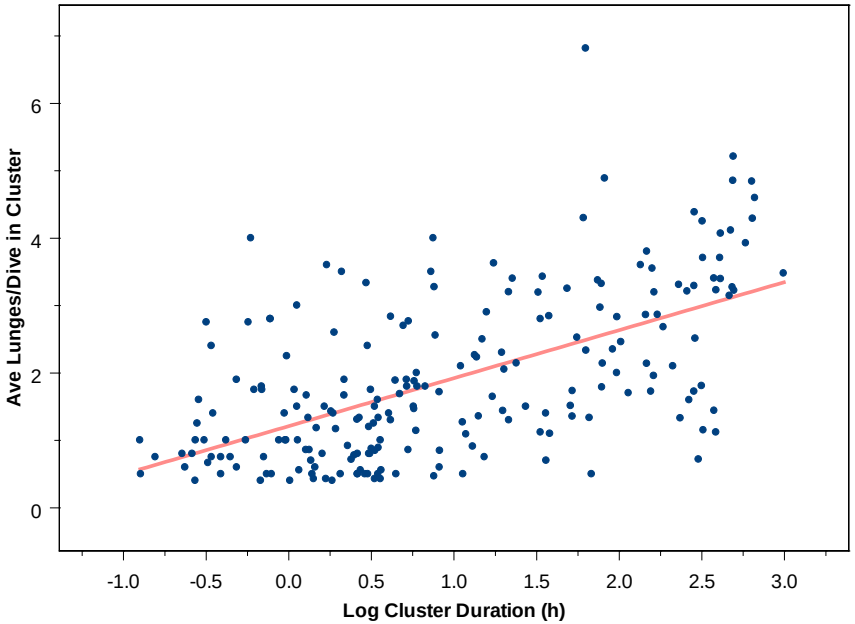
Foraging Bouts: Lunges per Dive

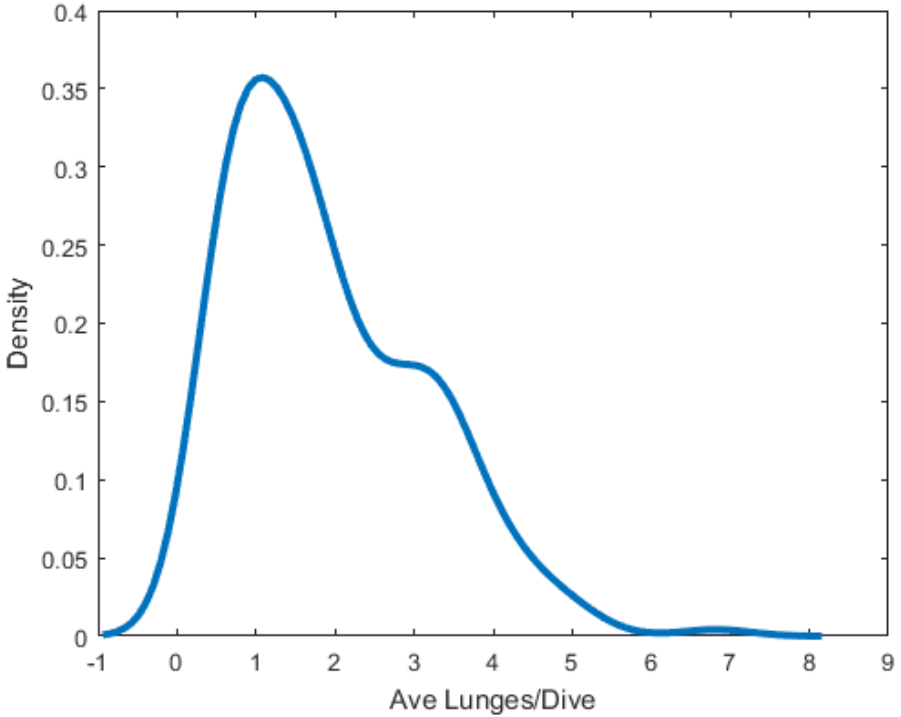
Lunges per dive in a foraging bout somewhat bimodal



Foraging Bouts: Lunges per Dive

Average lunges per dive was correlated to bout duration ($p < 0.001$, $R^2 = 0.37$)

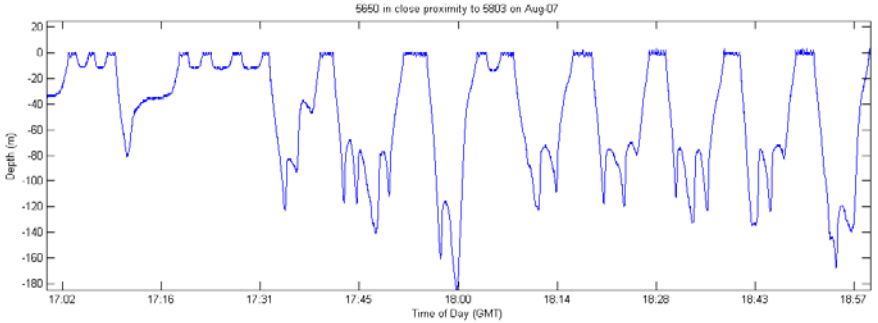




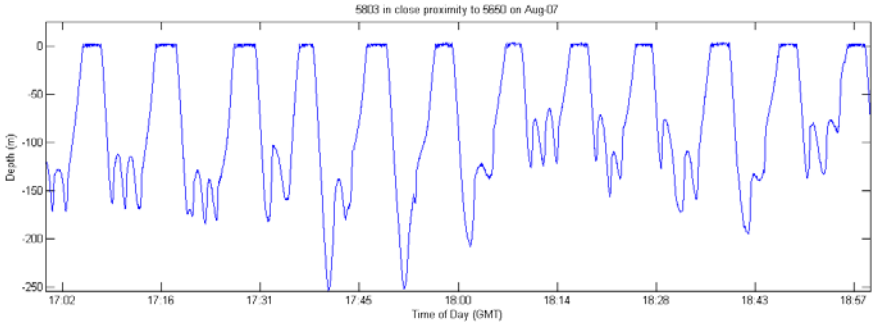
Foraging Bouts: Dive Depth

Median Values							
PTT	Year	Bout Duration (h)	n Dives	Ave Max Dive Depth (m)	Ave Dive Duration (min)	Ave # Lunges	Area Of Bout (km^2)
5644	2014	2.2	11.0	99.4	8.0	1.7	1.7
5650	2014	1.6	10.0	88.2	6.3	1.4	1.4
5803	2014	1.6	8.5	131.6	7.3	1.3	1.8
5655	2014	2.5	14.5	148.4	7.5	1.7	0.7
840	2015	7.5	36.0	130.8	9.9	3.2	8.3
4177	2015	1.6	9.0	91.5	9.5	1.3	0.8
5650	2015	2.7	10.5	93.8	11.5	1.9	3.3

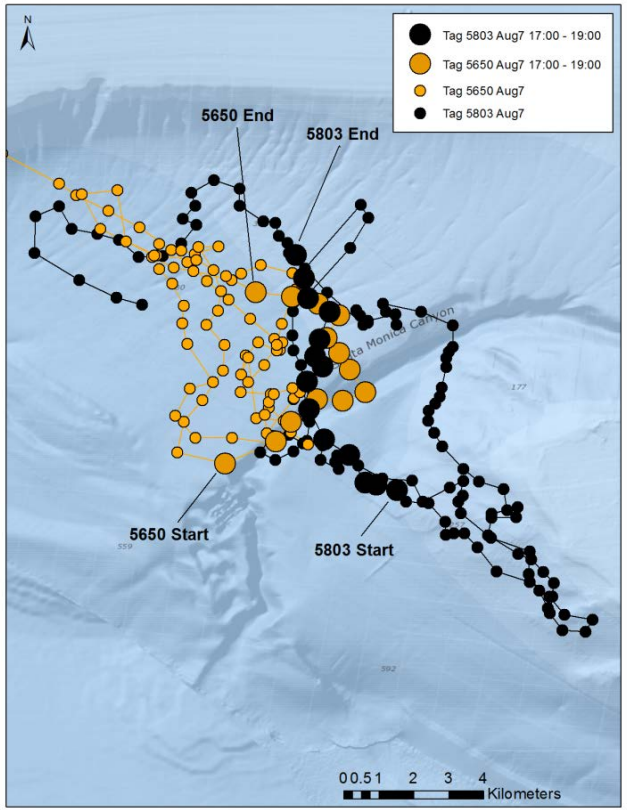
Foraging in Close Proximity (2014)



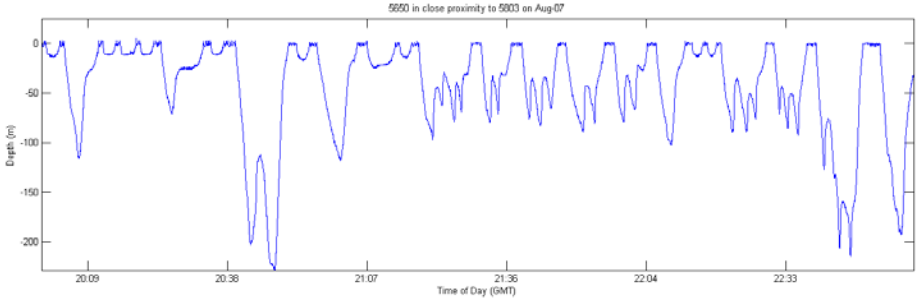
Tag #5650



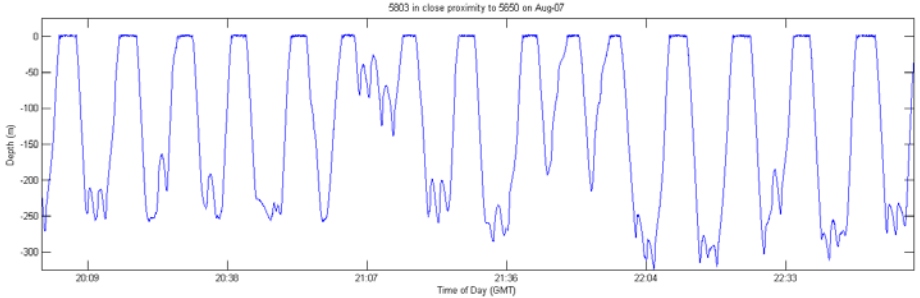
Tag #5803



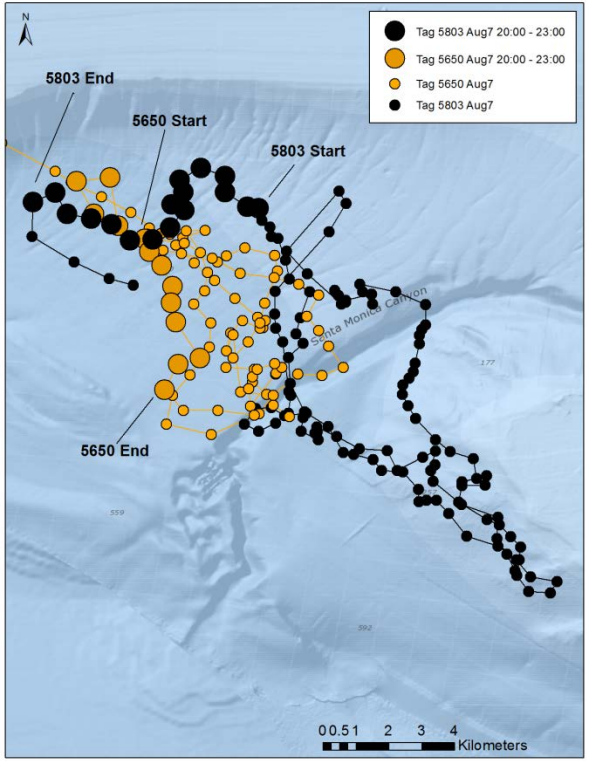
Foraging in Close Proximity (2014)



Tag #5650



Tag #5803



Foraging Bouts

Median Values							
PTT	Year	Bout Duration (h)	n Dives	Ave Max Dive Depth (m)	Ave Dive Duration (min)	Ave # Lunges	Area Of Bout (km^2)
5644	2014	2.2	11.0	99.4	8.0	1.7	1.7
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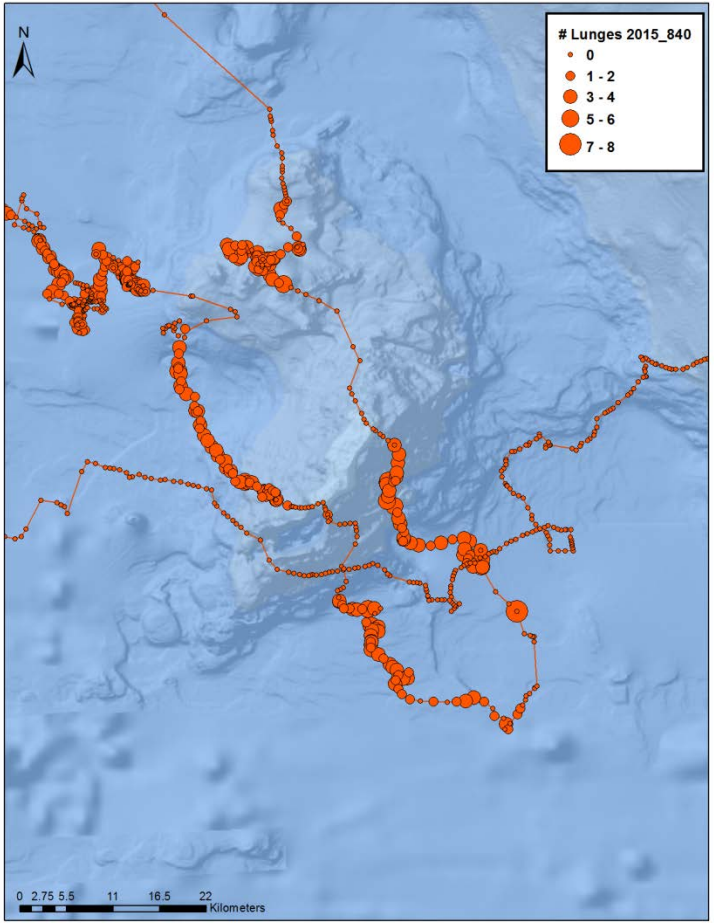
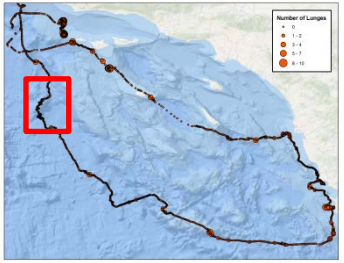
4177	2015	1.6	9.0	91.5	9.5	1.3	0.8
5650	2015	2.7	10.5	93.8	11.5	1.9	3.3

Tag # 2015_840 Foraged throughout the area for days

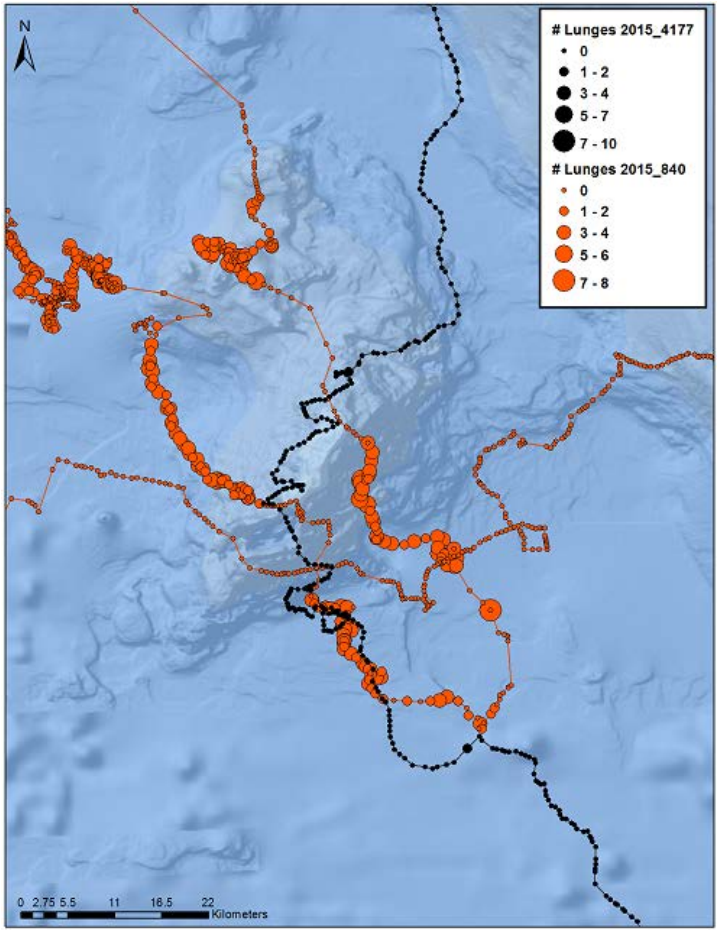
- Foraged majority of daylight hours

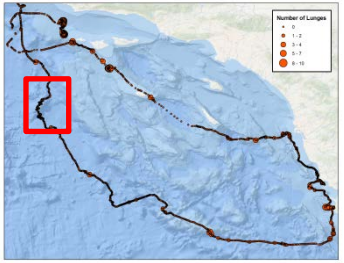




Tag # 2015_4177 Appears to be searching the seamount

- No foraging behavior
- Passed through an area 1 d before 2015_840 foraged there

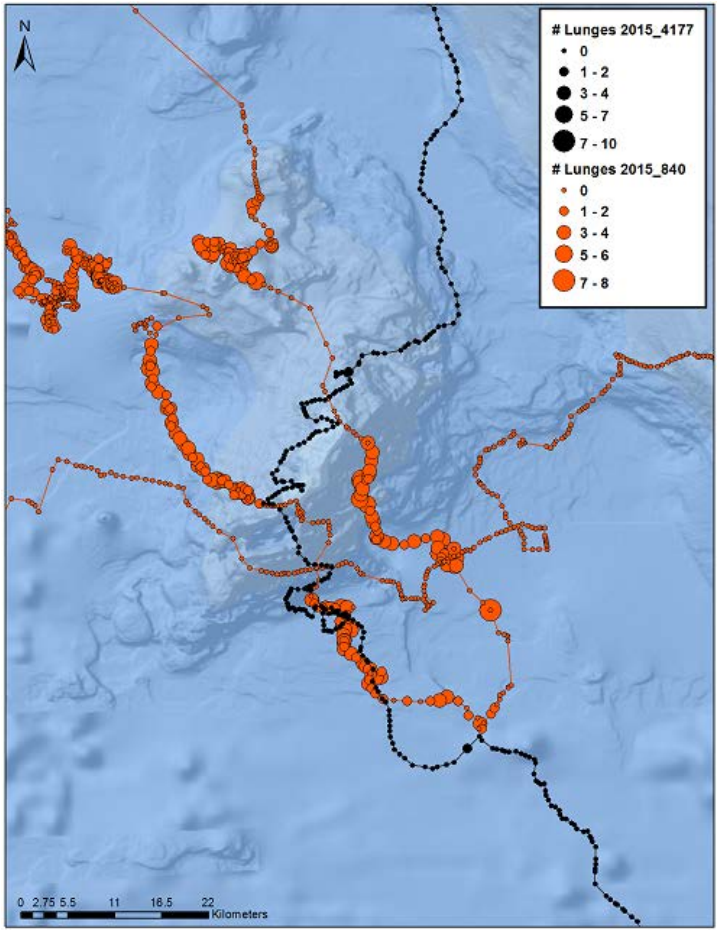


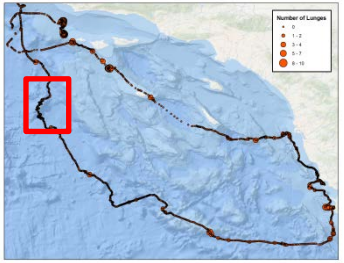


How can one whale forage constantly and another not?

- Unlikely prey increased abundance
- Unlikely 2015_4177 couldn't find prey if available

- Suggests tag # 2015_840 can exploit prey that is not dense enough for other whales
- Tag 2015_4177 = better body condition?





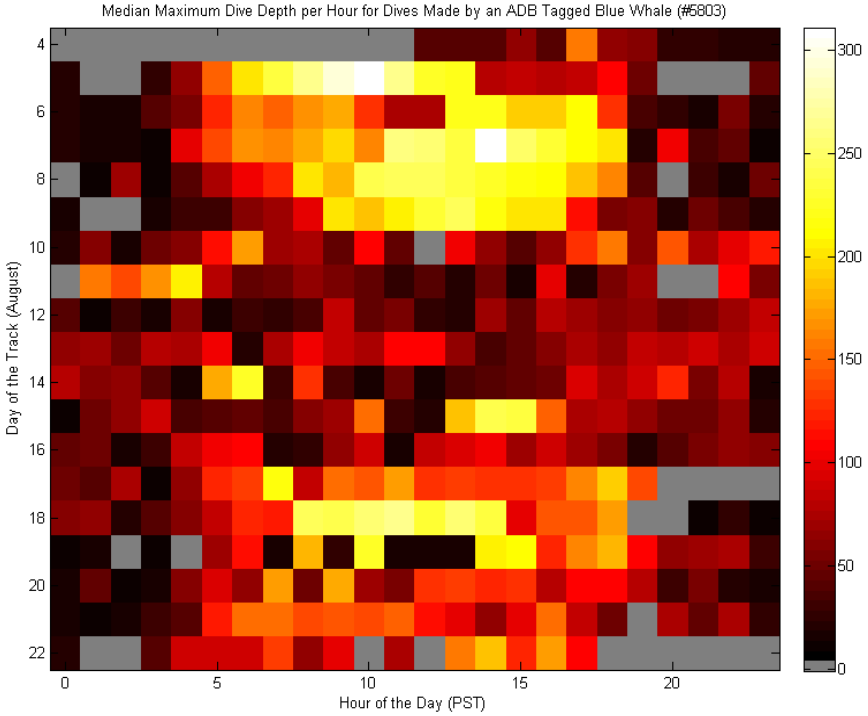
Summary

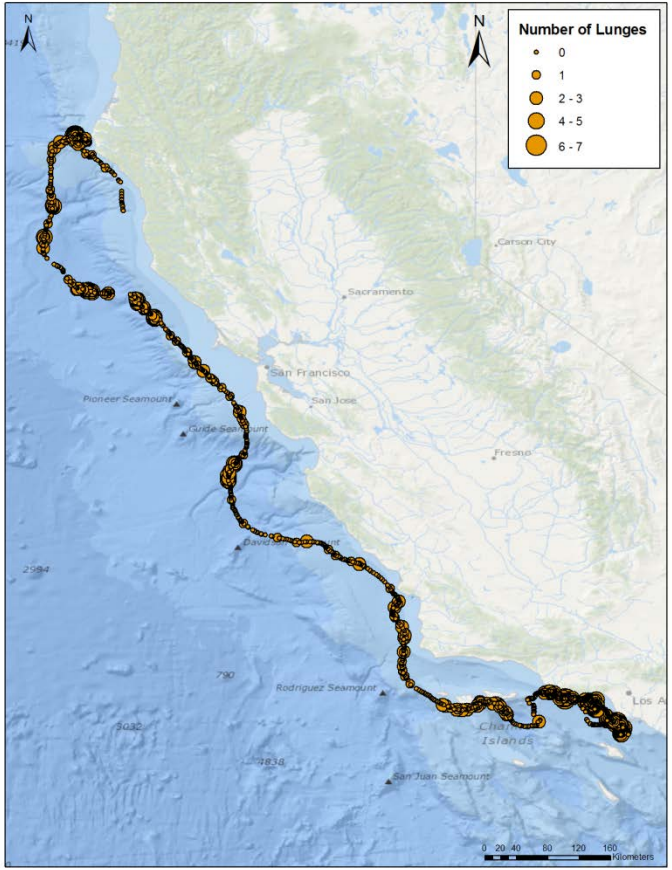
- Tagged whales made many relatively short foraging bouts with less frequent long ones
  - Exception with tag #2015_840
- Duration of foraging bouts was related to the number of lunges
- Differences in dive depths between individuals
  - Evidence of two whales using different parts of the prey patch
- Possibility of different foraging strategies?

Acknowledgements

- **NMFS Permit # 14856 (2013 – 2018)**
- **U.S. Navy Pacific Fleet Commander for funding**
- **NAVFAC Pacific & HDR for project/contract management**
- Dr. Scott Baker and Debbie Steel of the OSU/MMI Cetacean Conservation and Genomics Lab for sex determination
- Craig Hayslip, Tomas Follett, Martha Winsor, Barb Lagerquist, Theresa Kirchner, Natalie Mastick for field and laboratory assistance
- R/V Pacific Storm crew for field support
- Steve and Roxanne Parker for aerial surveys
- Kathy Minta and Minda Stiles for project and contract management

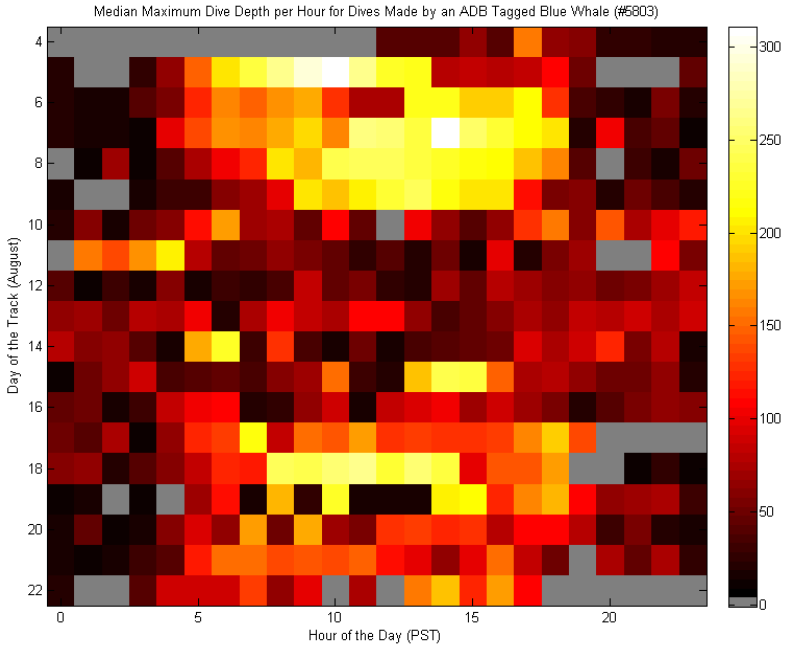
Results

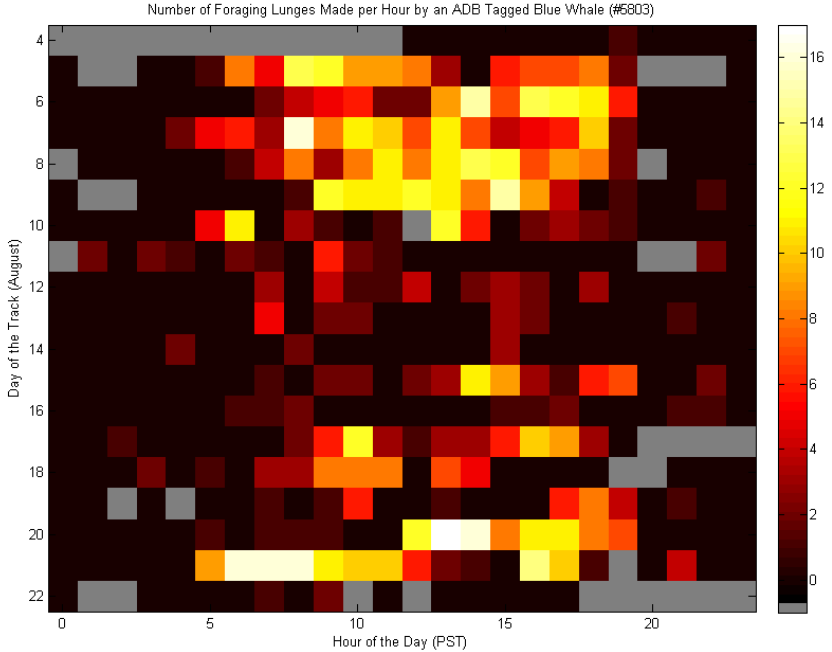




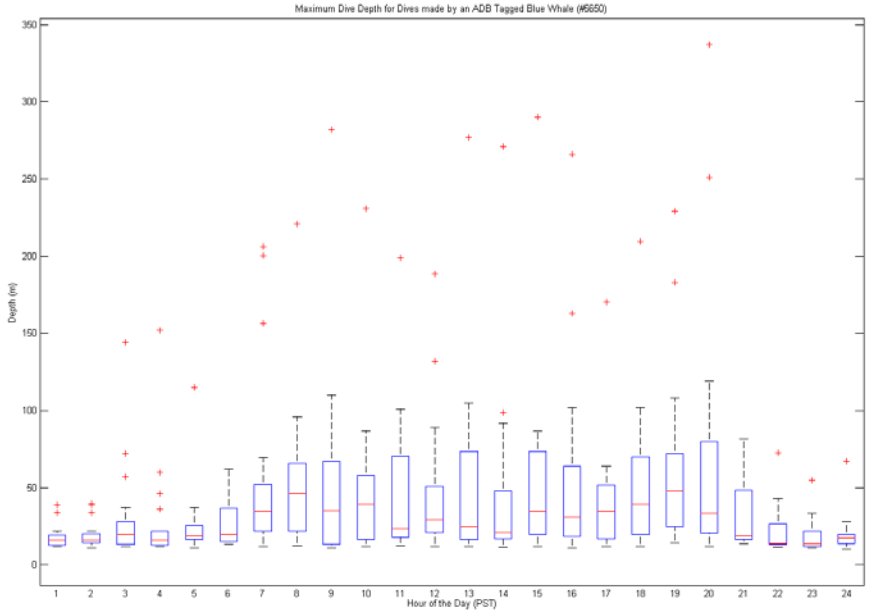
Outline Methods XXXXXX XXXXX Summary

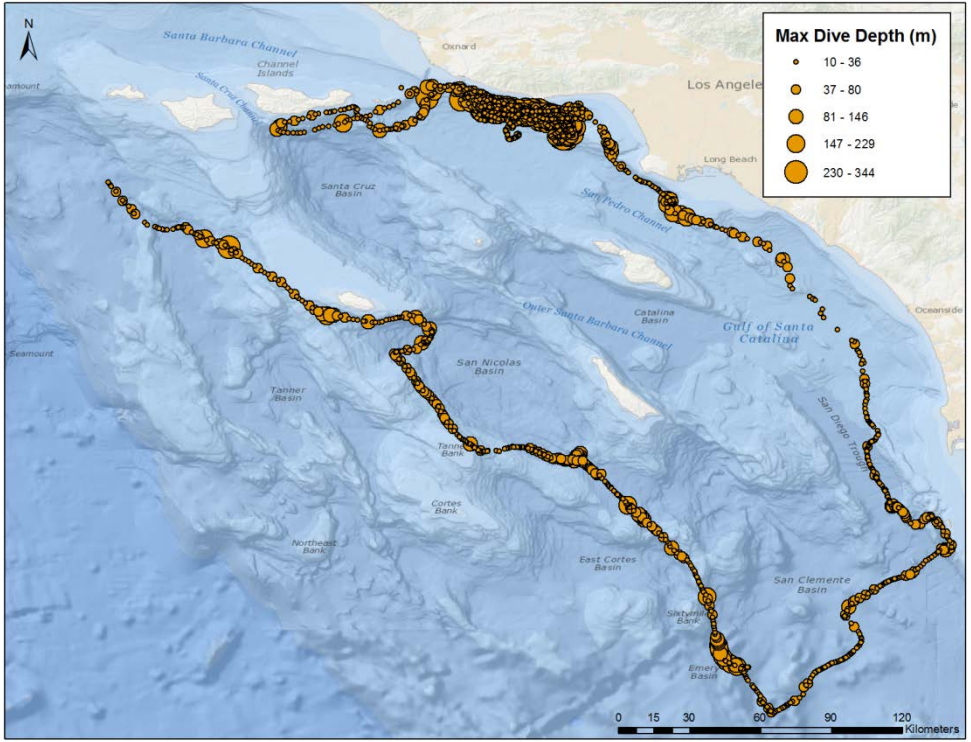
Results: Diel and Temporal Variation



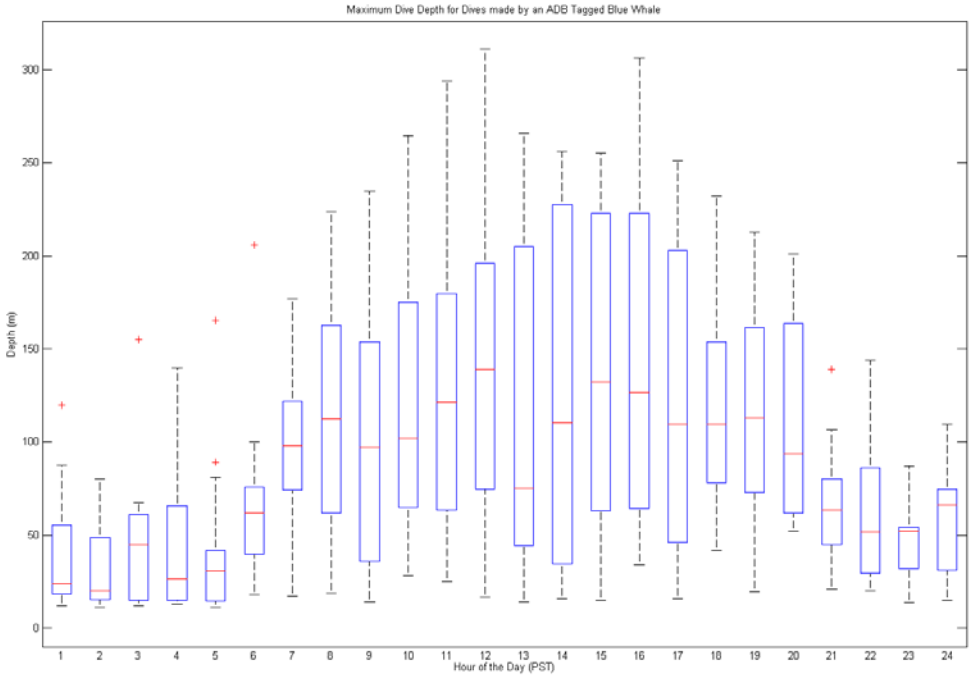


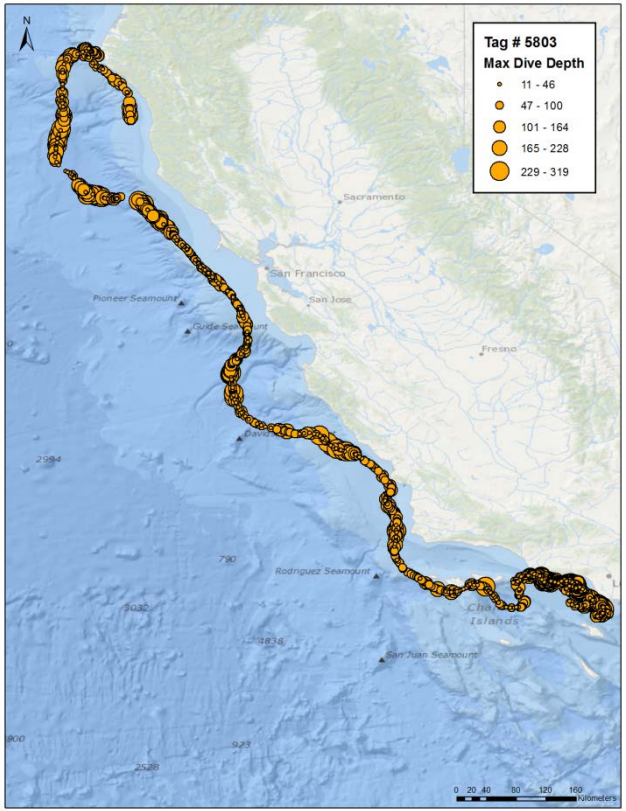
Diel and Temporal Variation



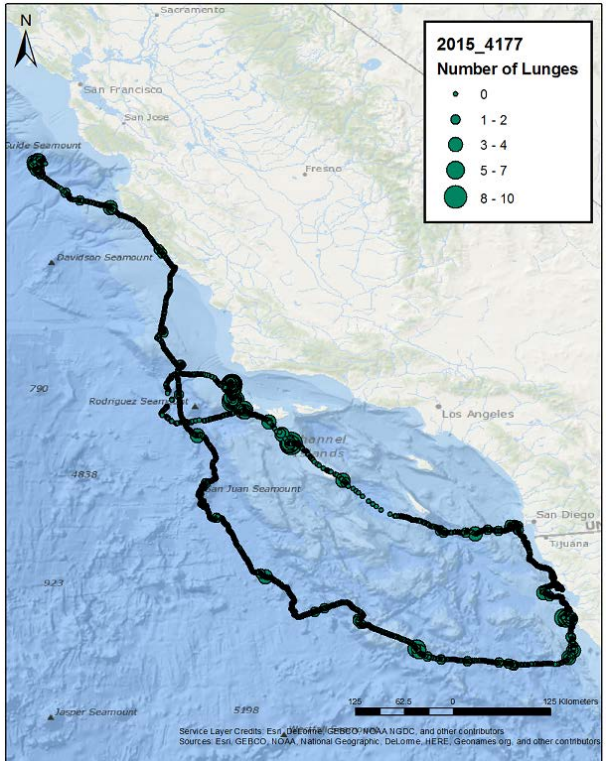


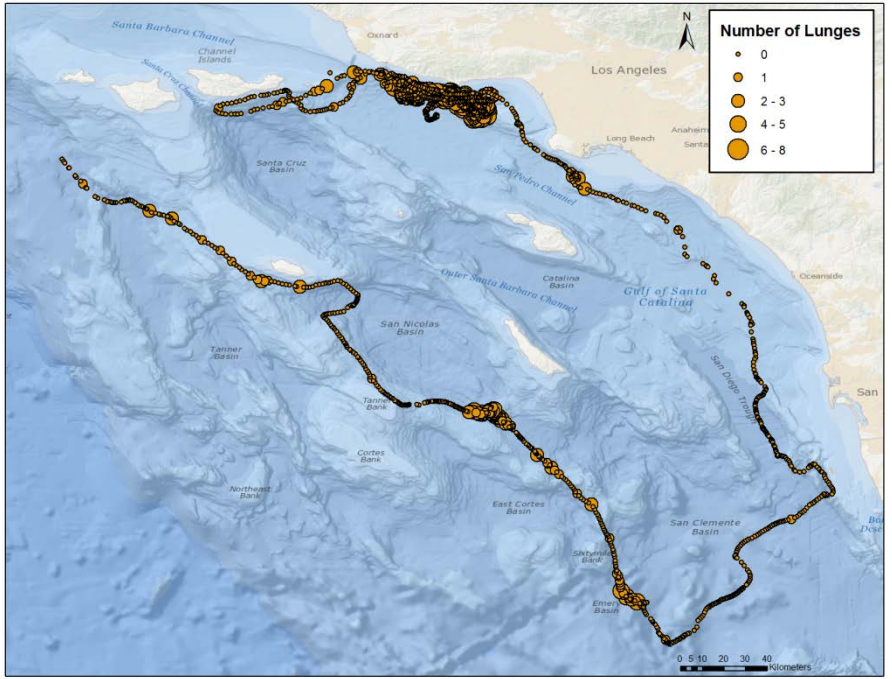
Diel and Temporal Variation





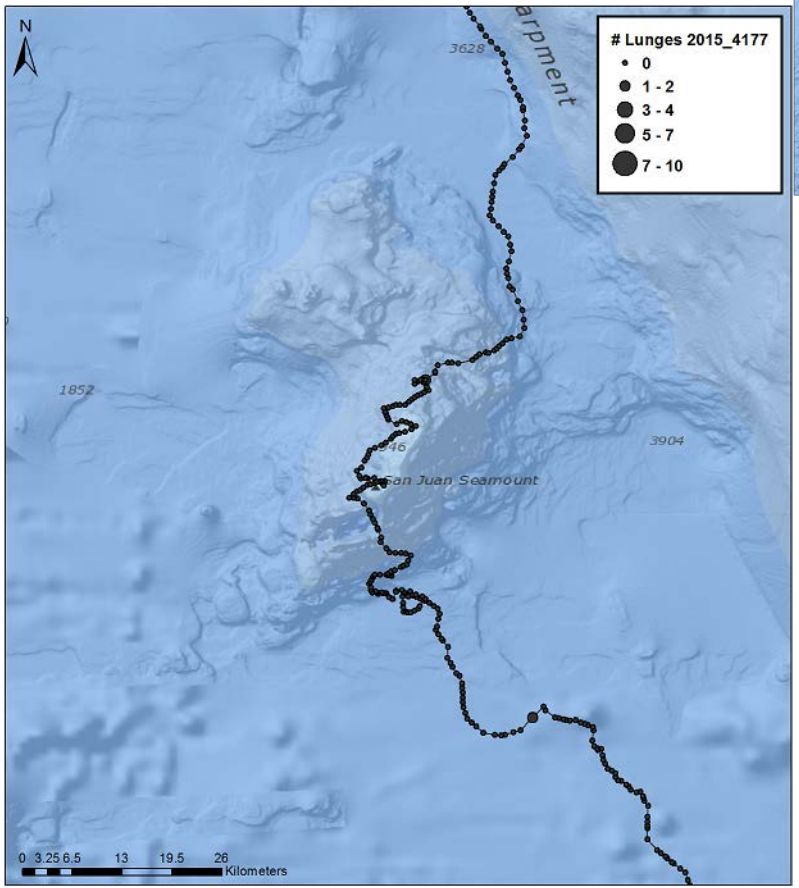
Spatial Variation of Foraging Behavior

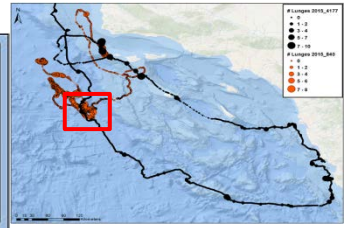




Tag # 2015_4177 Appears to be searching the seamount

- No foraging behavior
- Other examples of similar behavior in other tracks.

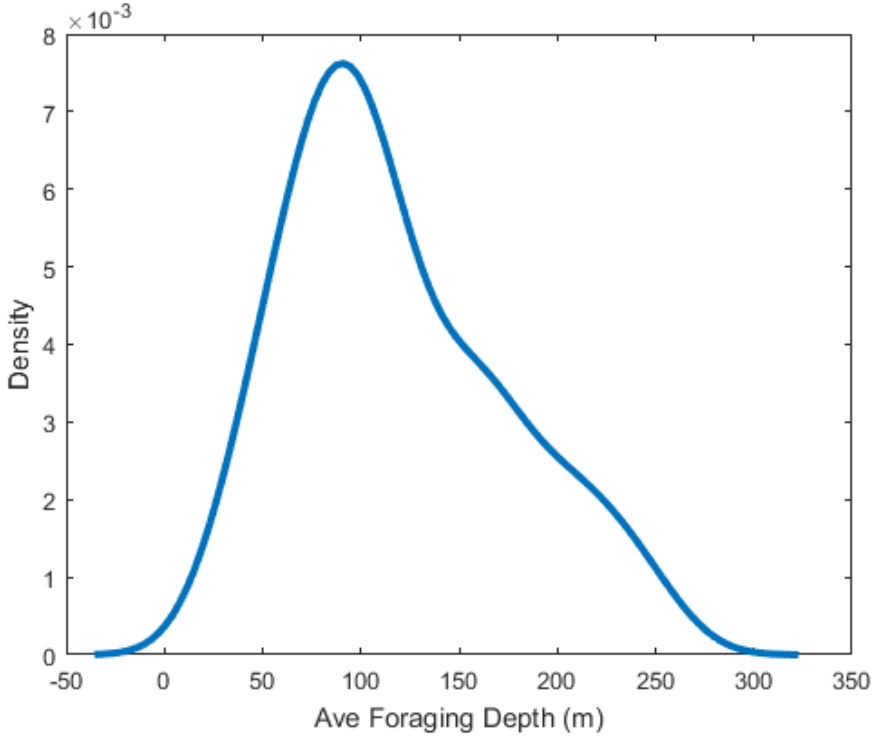




Foraging Bouts

Ave lunge depth of foraging bouts was unimodal but with a bit of a shoulder

- **All but one tag had at least a small shoulder of deeper foraging**
- **Two tags had a distribution centered closer to 130 m depth**



Foraging in Close Proximity

Summary of dive behavior when whales were within 1 km of each other.

Tag #	Overlap Tag #	Bout #	Overlap Duration (h)	Number of Dives	Median Dive Duration (min)	Median Max Dive Depth	Median # of Lunges
5650	5803	1	5.2	42	3.8	23	0
5803	5650	1	3.9	27	2.8	40	0
5650	5803	2	3.9	34	3.2	19	0
5803	5650	2	2.3	9	2.3	57	0
5650	5803	3	11.1	80	4.1	51	0
5803	5650	3	10.0	57	7.4	231	1
5650	5803	4	6.1	40	3.8	30	0
5803	5650	4	6.1	32	3.2	18.5	0
5650	5803	5	6.1	34	7.2	97.5	1
5803	5650	5	6.8	37	8.1	227	2
5650	5803	6	2.1	10	9.2	201	3
5803	5650	6	1.6	9	7.8	241	1
5650	5803	7	1.6	13	6.0	39	0
5803	5650	7	2.5	11	2.9	67	0
5650	5803	8	9.1	22	2.9	31.5	0
5803	5650	8	10.2	38	3.7	75.5	0

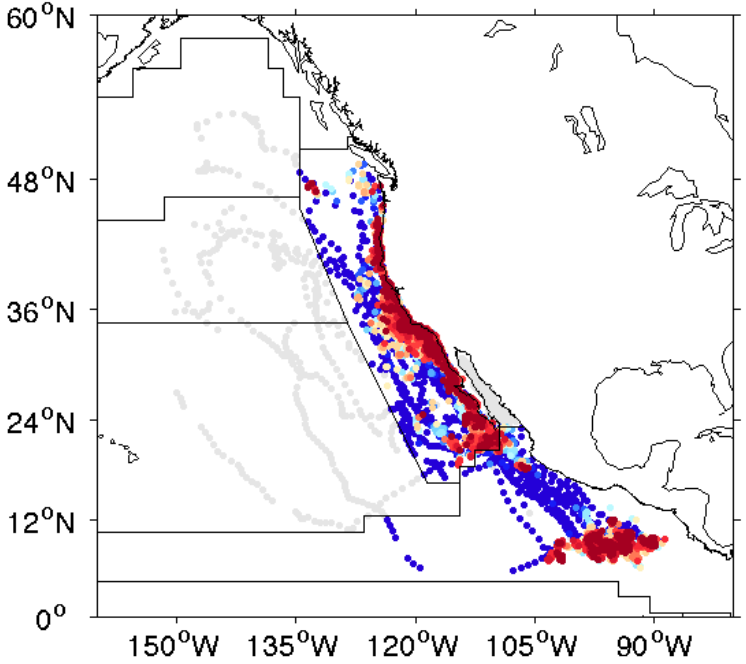
Turn into bullet points

Tag 5650 preferentially feeds at shallower depths?

Remote Tracking of Large Whales

Implantable location-only tags

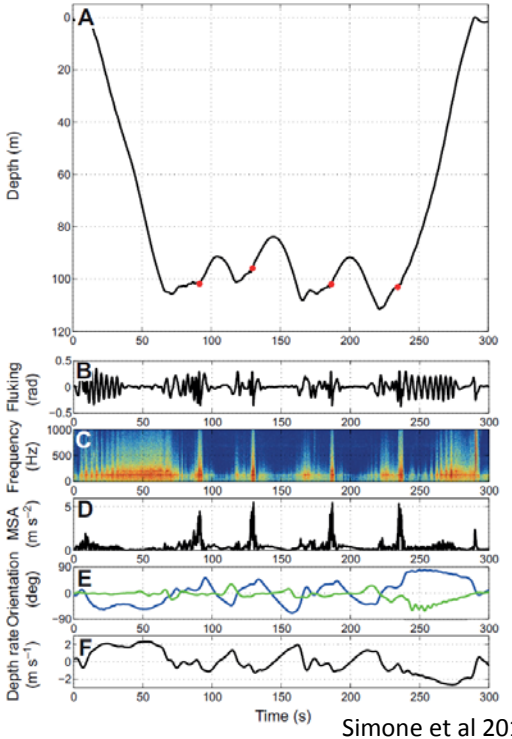
- Long attachment duration
- Limited data throughput



Remote Tracking of Large Whales

Time Depth Recorder/Data logger

- Many sensors
- Very high resolution data
- Short attachment duration (suction cup)



Simone et al 2012

Tag Deployment

- Tags deployed using an air powered applicator (methods in Mate et al 2007)
- 2-4 m away to deploy a tag
- Biopsy samples collected simultaneous to tagging

Remote Tracking of Large Whales

What's Missing?

High resolution behavior data over intermediate time periods

Group tracks (3 grps) by what they did: Offshore loop, coastal movements, moved to N. California