# LIMPET lessons: take-homes from 400+ LIMPET tag deployments on 12 species of Hawaiian odontocetes



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Presentation to the ECS Telemetry Workshop, Ponta Delgada, Açores, 12 May 2025

# Initial tag development and testing by Russ Andrews and Greg Schorr



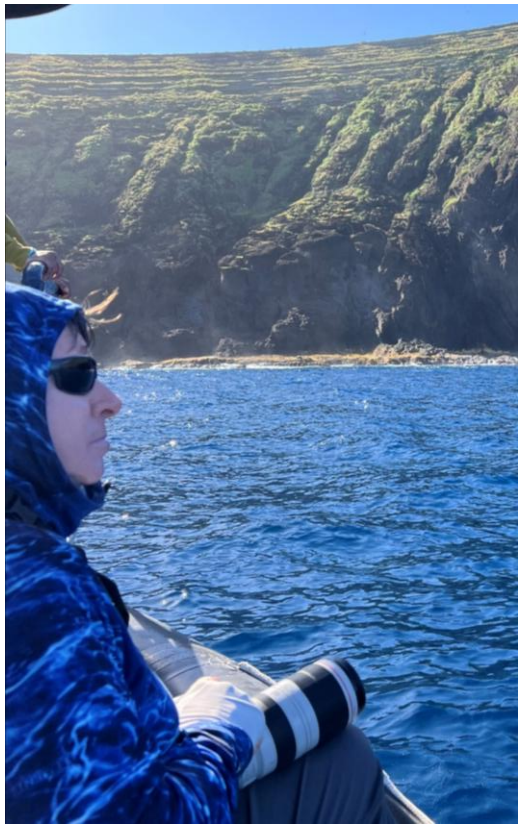
Daniel Webster (206)



Greg Schorr (109)



Colin Cornforth (88)



Russ Andrews (31)

Thanks to Devon Short & Wildlife Computers, Will Cioffi/Duke University

# Some details on our LIMPET tagging

Earliest (2006/2007) tags were LIMPET style VHF (deployed by crossbow)

Subsequent (2006-2025) were Wildlife Computers LIMPET tags (SPOT5, SPOT6, SPLASH10, SPLASH10-F), including prototypes/beta-testing in early years



Since 2007 deployed with Dan-Inject JM or JP Special pneumatic projector (almost all at 25 bar) at distances from ~3-10 m

Some deployments in 2023/2024 with AirForce Texan 0.510 caliber airgun

Wildlife Computers LIMPET tags

- short darts (1 row of petals) for small odontocetes
- long darts (2 rows of petals) for large odontocetes



# Trade-offs between number of transmissions (=battery life), temporal resolution of location data, likelihood of re-locating tagged animals, and data throughput, driven by species, tag types, and questions

**Transmit counts for older models**

SPOT6/SPOT5-240: 32,100 – 42,800

SPLASH10-266: 10,800 – 14,500

SPLASH10-292: 10,800 – 14,500

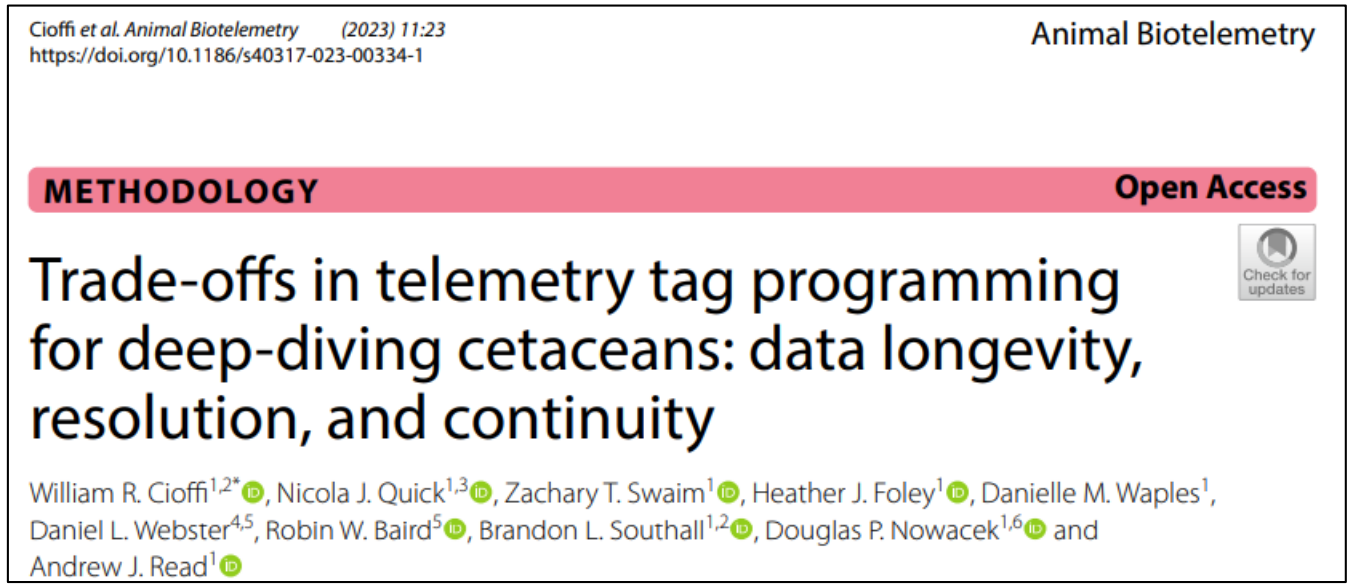
SPLASH10-F-292: 10,100 – 13,500

**Transmit counts for current Wildlife Computers LIMPET tags**

SPOT-365: 64,000 – 85,000

SPLASH10-333: 21,800 – 29,000

SPLASH10-F-333: 20,300 – 27,000



Cioffi *et al. Animal Biotelemetry* (2023) 11:23
https://doi.org/10.1186/s40317-023-00334-1

Animal Biotelemetry

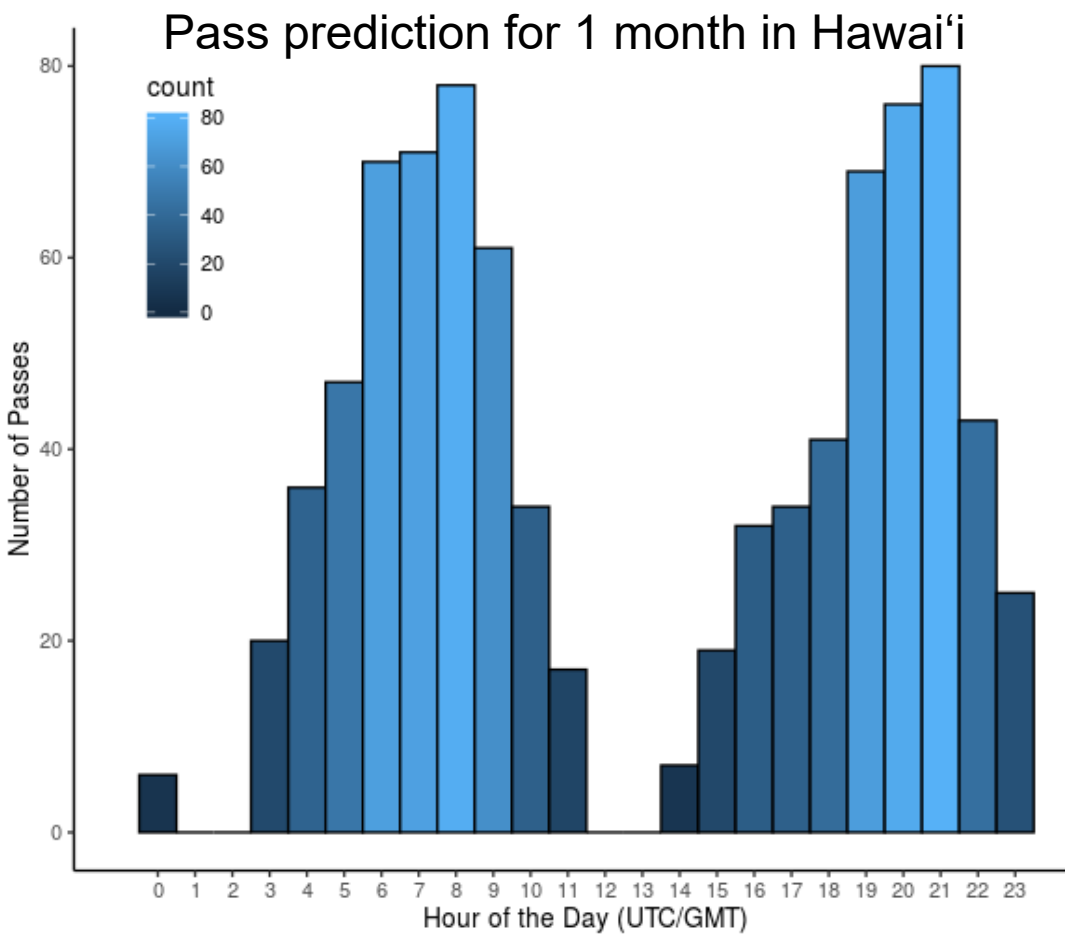
METHODOLOGY Open Access

Trade-offs in telemetry tag programming for deep-diving cetaceans: data longevity, resolution, and continuity

William R. Cioffi[1,2*], Nicola J. Quick[1,3], Zachary T. Swaim[1], Heather J. Foley[1], Danielle M. Waples[1], Daniel L. Webster[4,5], Robin W. Baird[5], Brandon L. Southall[1,2], Douglas P. Nowacek[1,6] and Andrew J. Read[1]

# Our programming varies by species group

| Species groups | Repetition interval (seconds) | # hours transmitting per day* | # transmissions / hour (SPOT)+ |
|---|---|---|---|
| Beaked whales | 15 | 14-18 | 40 |

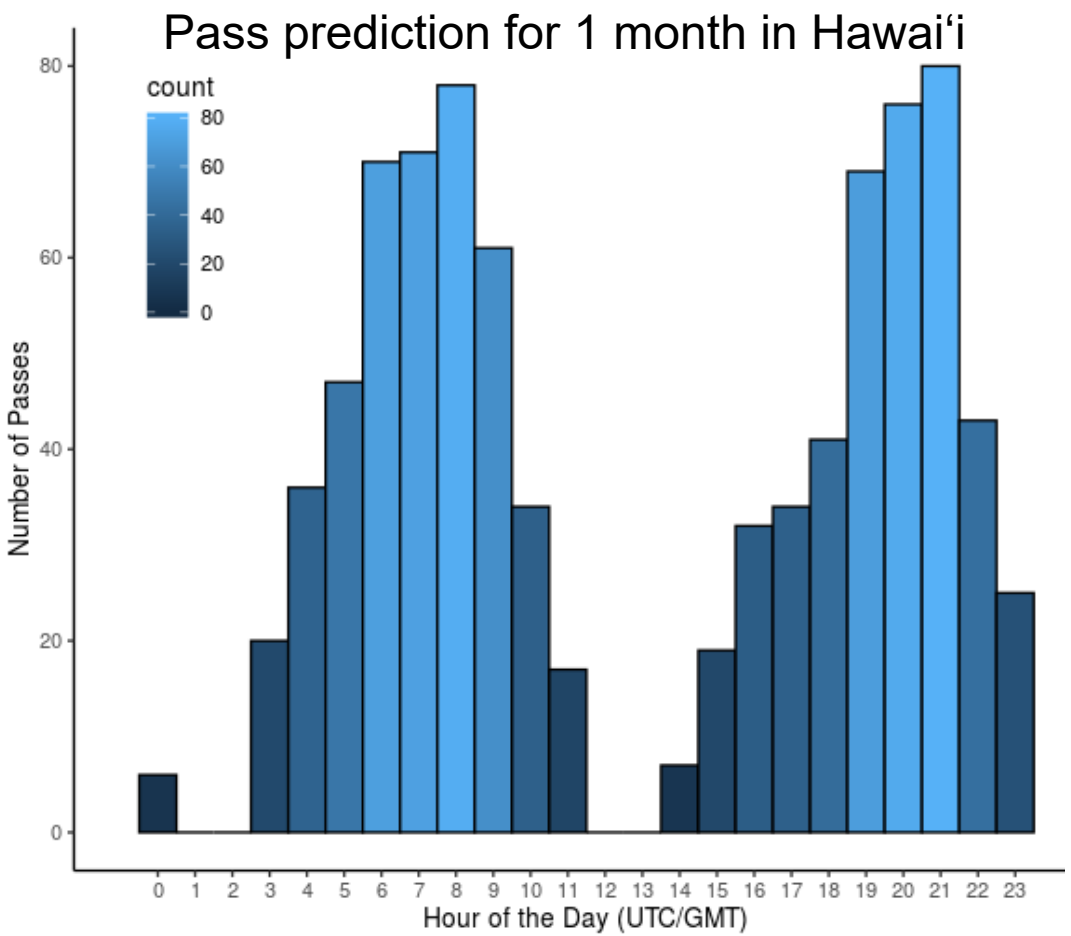



*Number of hours per day after initial day or two, depending on expected tag attachment duration/battery life (SPOT v SPLASH) and need to get behavior data through (SPLASH)

+Transmissions per hour set to avoid running out of transmissions before the end of an hour.

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| Pilot whales | 30 | 10-12 | 60 |

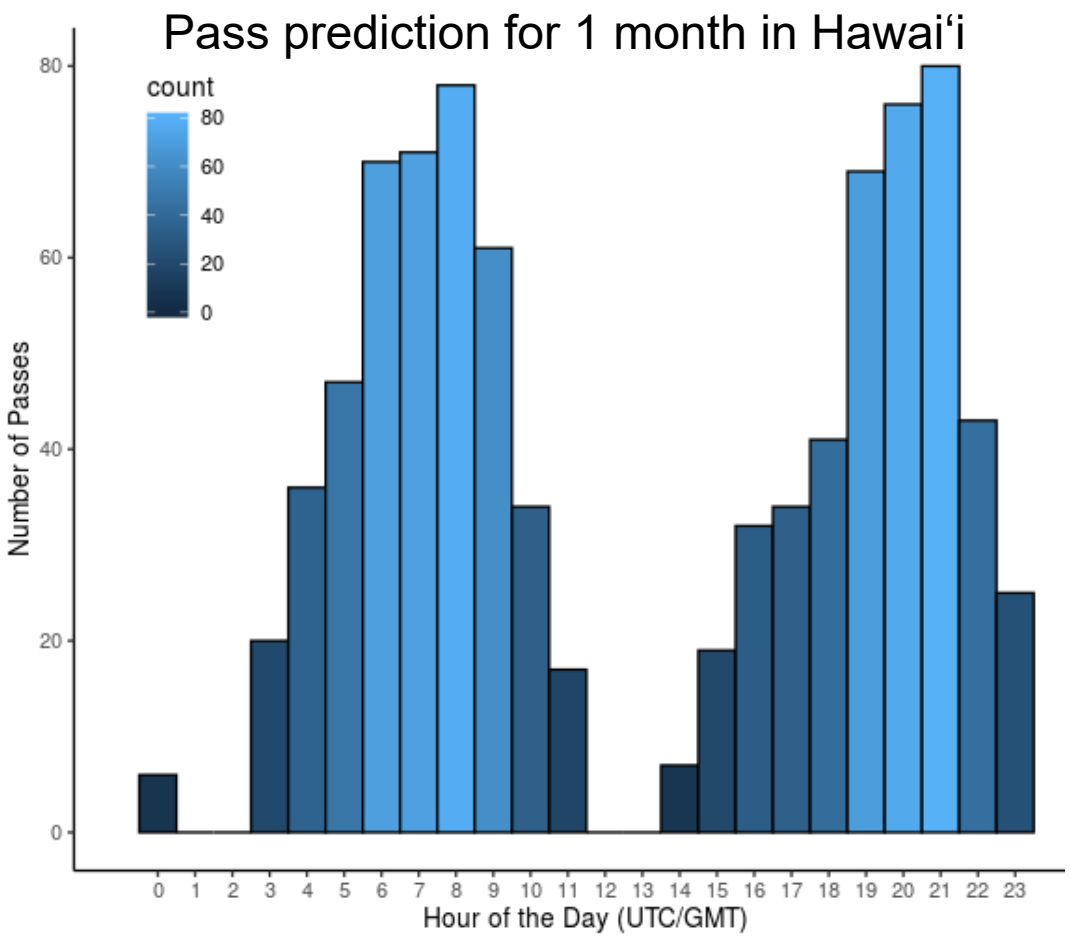



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| Bottlenose & other small dolphins | 30 | 10-12 | 75-100 |

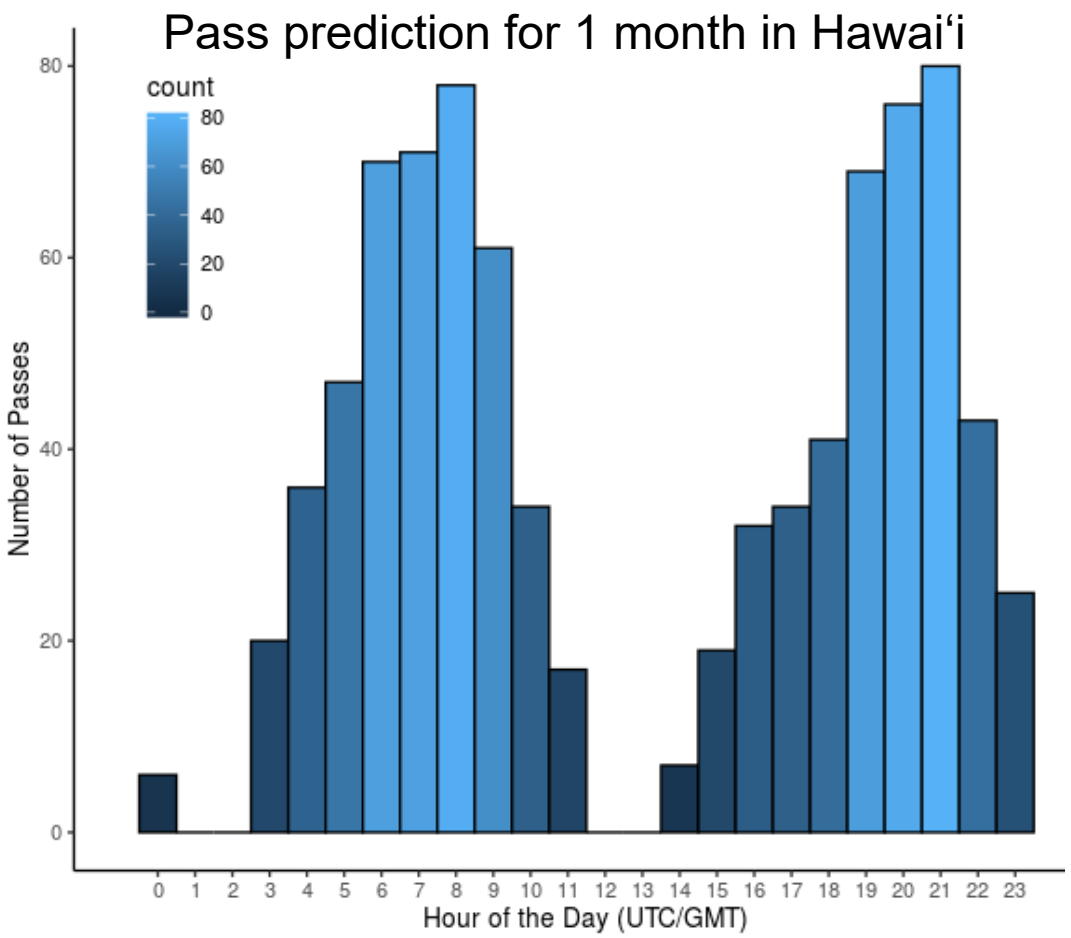



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| Beaked whales | 15 | 14-18 | 40 |
| Pilot whales | 30 | 10-12 | 60 |
| Bottlenose & other small dolphins | 30 | 10-12 | 75-100 |
| False killer whales | 45 | 10-12 | 60 |




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+Transmissions per hour set to avoid running out of transmissions before the end of an hour.

# Tags should be programmed based (in part) on expected attachment durations

| Species | Dart type | # LIMPET tags (all types) | Transmission duration (mean –median - max) |
|---|---|---|---|
| Short-finned pilot whale | Long | 159 | 33.0 – 28.0 – 228.5 |
| False killer whale | Long | 84 | 49.1 – 31.6 – 236.0 |





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| False killer whale | Long | 84 | 49.1 – 31.6 – 236.0 |
| Melon-headed whale | Short | 35 | 12.6 – 11.2 – 25.4 |
| Common bottlenose dolphin | Short | 32 | 16.1 – 15.3 – 34.3 |
| Rough-toothed dolphin | Short | 26 | 11.4 – 10.2 – 27.7 |



# Tags should be programmed based (in part) on expected attachment durations

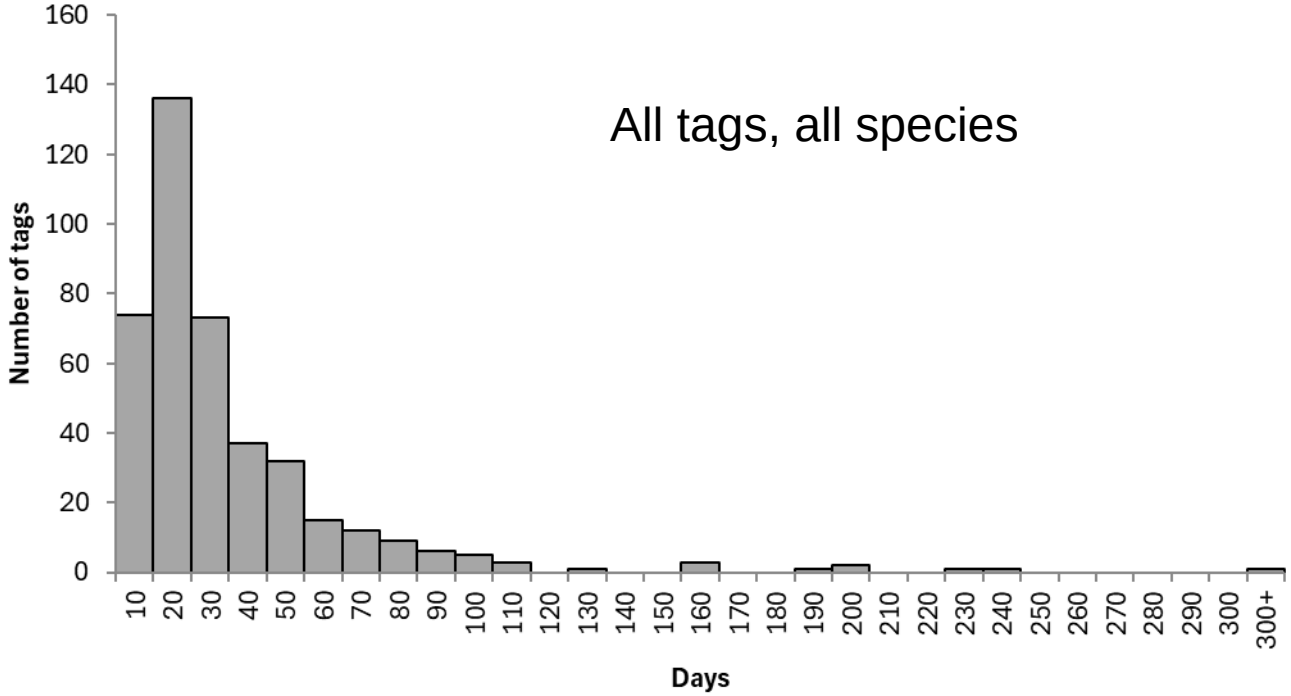
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| Blainville's beaked whale | Long (to 2012) - Short (since 2014) | 21 | 36.9 – 22.7 – 158.8 |
| Goose-beaked whale | Long | 15 | 56.1 – 16.0 – 550 |
| Sperm whale | Long | 13 | 9.8 – 10.5 – 14.6 |
| Pantropical spotted dolphin | Short | 9 | 12.2 – 11.3 – 21.4 |
| Pygmy killer whale | Short | 6* | 13.7 – 11.1 – 25.5 |
| Killer whale | Long | 5 | 16.4 – 15.7 – 28.0 |
| Humpback whale | Long | 3 | 3.7 – 3.0 – 5.3 |
| Risso's dolphin | Short | 1 | 13.5 |

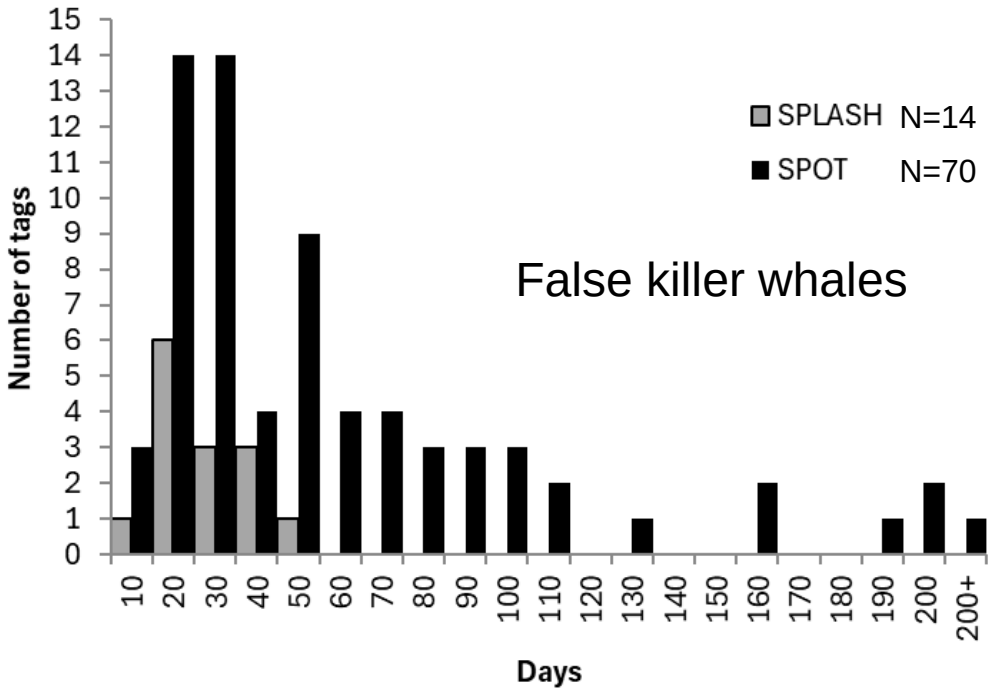
*For those that remain attached >1 h (see upcoming slide)

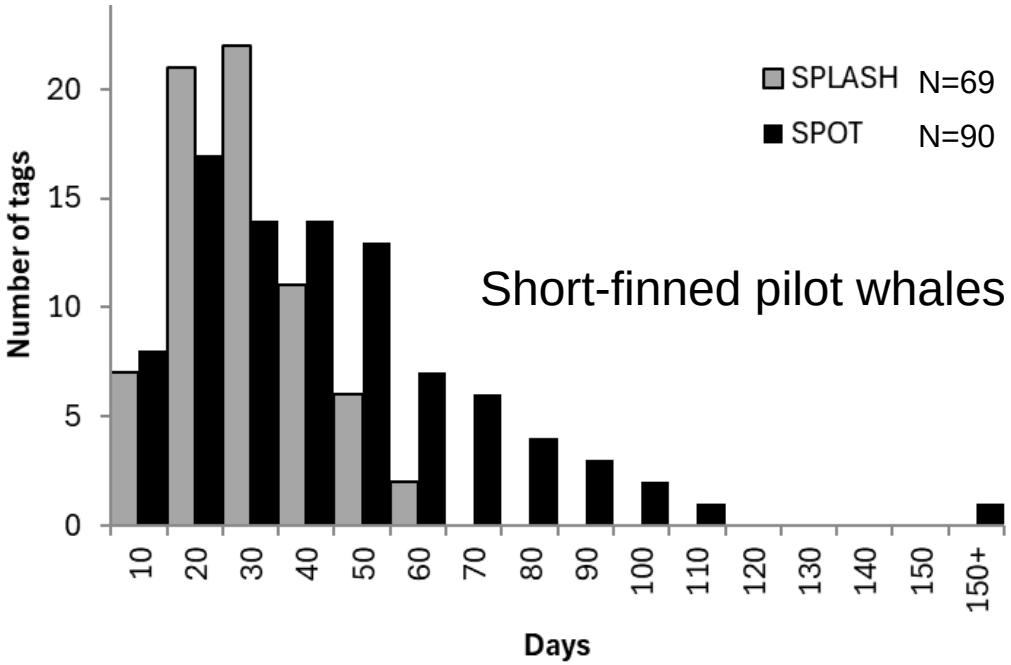
# Some species remove tags from conspecifics

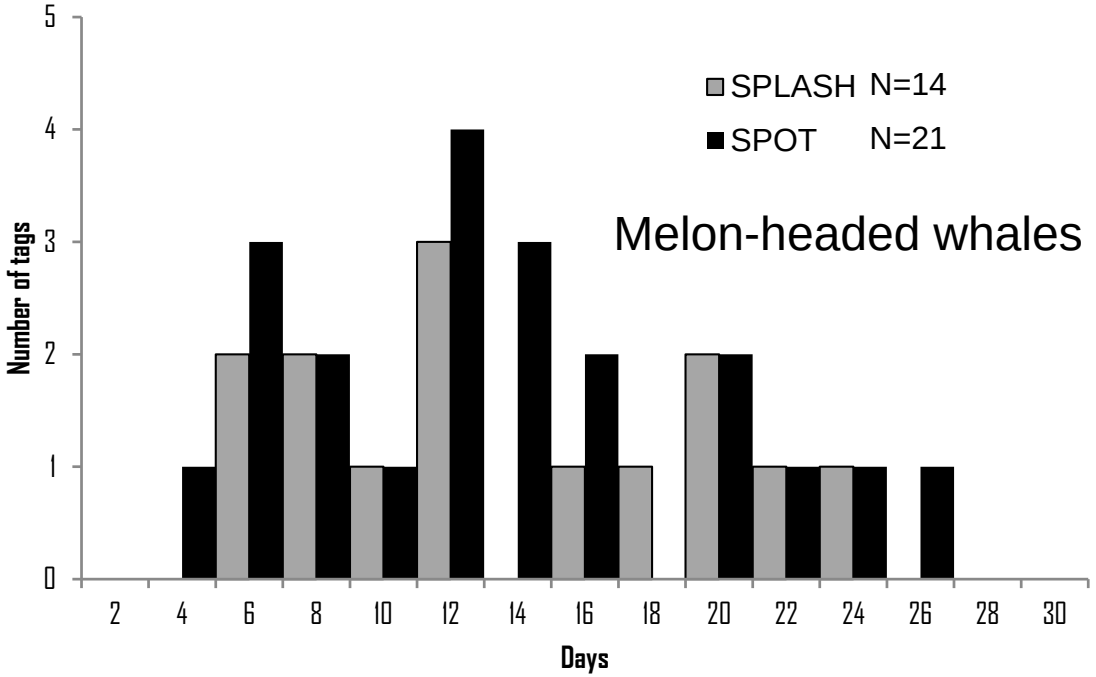
- Pygmy killer whales – 5 of 11 tags known (n=4) or suspected (n=1) to have been removed in <1 h
- Short-finned pilot whales – 1 of 169 known to have been removed in <1 h, one other suspected after ~16 days




All tags, all species
Number of tags
Days
0
20
40
60
80
100
120
140
160
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 300+

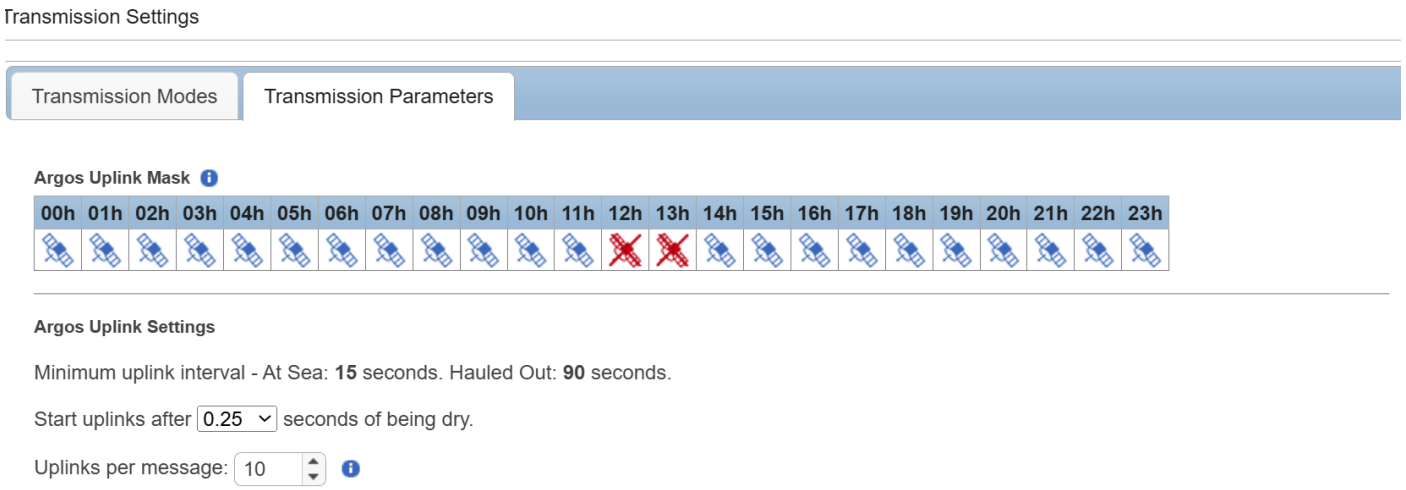

False killer whales
SPLASH N=14
SPOT N=70
Number of tags
Days
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 200+

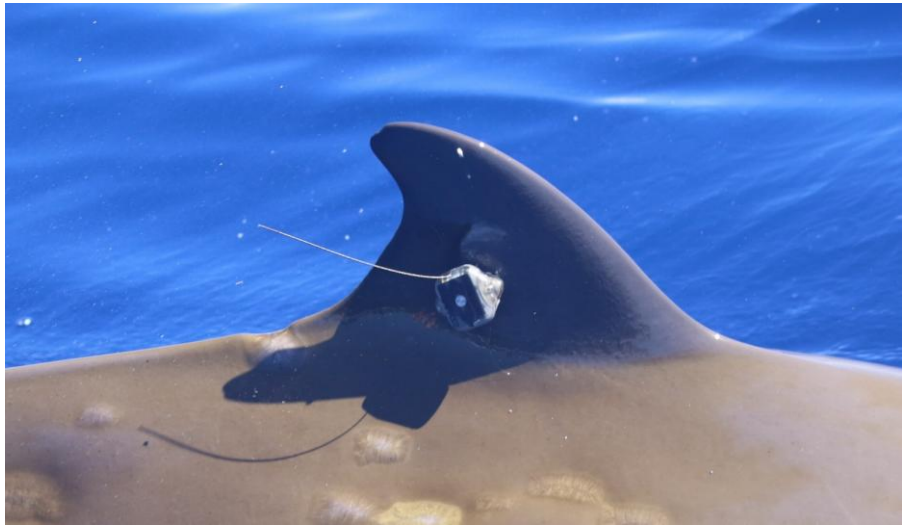

Short-finned pilot whales
SPLASH N=69
SPOT N=90
Number of tags
Days
0
5
10
15
20
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 150+


Melon-headed whales
SPLASH N=14
SPOT N=21
Number of tags
Days
0
1
2
3
4
5
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

# Varying schedule for number of hours transmitting per day depending on expected longevity

- Initially transmit first 24 hours (or to the end of the day UTC), with an input mask for middle of night hours with no Argos

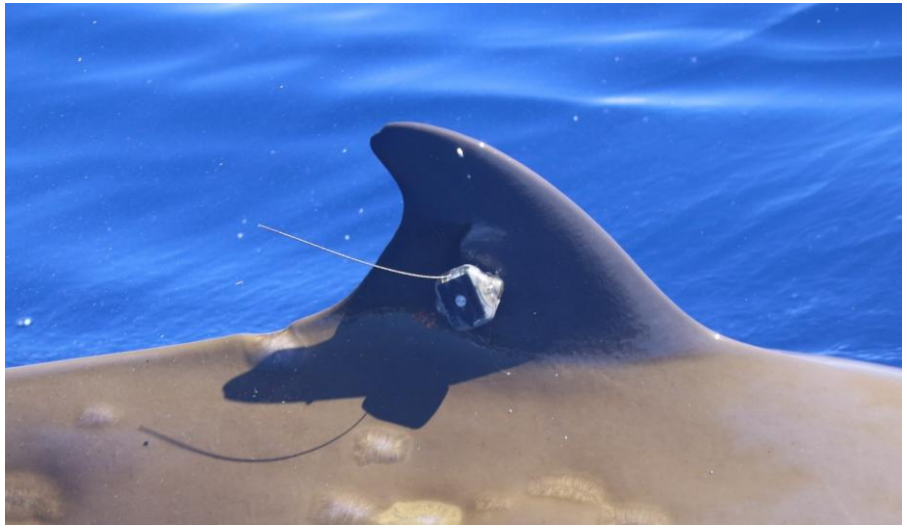


| | # hours per day |
|---|---|
| Initial pattern | 24 (22 with mask) |

# Varying schedule for number of hours transmitting per day depending on expected longevity

- Initially transmit first 24 hours (or to the end of the day UTC), with an input mask for middle of night hours with no Argos
- If in area where you may tag just prior to end of day UTC, different settings on Day 1 (if using a goniometer or uplink receiver to re-locate tagged individual)



| | # hours per day |
|---|---|
| Initial pattern | 24 (22 with mask) |
| On Day 1 | 19 |

Transmission Modes | Transmission Parameters

Location uplinks are scheduled per step and data product uplinks occur automatically. Added together, they determine total transmissions per day.

**At Sea Mode**

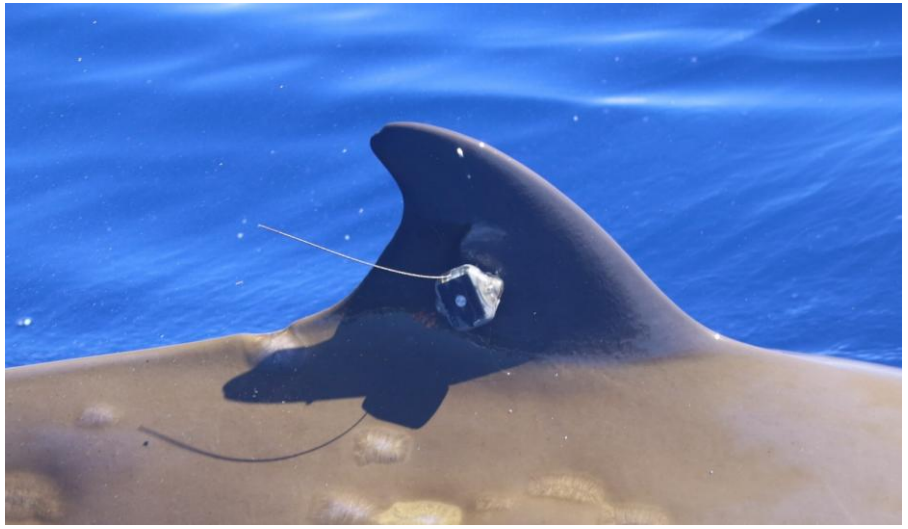
Initial Pattern | On Day 1 | On Day 2 | On Day 61 | On Day 106 | (add pattern)

| Duration | Location Uplink Limit | Limit Type | Pinger | Prevent Data Uplink | Step Lock | Stay Until Midnight | Actions |
|---|---|---|---|---|---|---|---|
| 11 Hours *(11 Hours)* | 60 | Hourly | ✖ | ✖ | ✖ | ✖ | |
| 4 Hours *(4 Hours)* | 0 | Hourly | ✖ | ✖ | ✖ | ✖ | |
| 8 Hours *(8 Hours)* | 60 | Hourly | ✖ | ✖ | ✖ | ✖ | |
| 1 Hour *(1 Hour)* | 10 | Hourly | ✖ | ✖ | ✖ | ✖ | |

Add Step

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- Day 2 programming through expected attachment duration



| | # hours per day |
|---|---|
| Initial pattern | 24 (22 with mask) |
| On Day 1 | 19 |
| On Day 2 | 16 |

# Varying schedule for number of hours transmitting per day depending on expected longevity

- Initially transmit first 24 hours (or to the end of the day UTC), with an input mask for middle of night hours with no Argos
- If in area where you may tag just prior to end of day UTC, different settings on Day 1 (if using a goniometer or uplink receiver to re-locate tagged individual)
- Day 2 programming through expected attachment duration
- Subsequent programming to reflect possible long attachment duration




| | # hours per day |
|---|---|
| Initial pattern | 24 (22 with mask) |
| On Day 1 | 19 |
| On Day 2 | 16 |
| On Day 51 | 11 |
| On Day 106 | 6 |

# Varying schedule for number of hours transmitting per day depending on expected longevity

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- Day 2 programming through expected attachment duration
- Subsequent programming to reflect possible long attachment duration




| | # hours per day |
|---|---|
| Initial pattern | 24 (19 with mask) |
| On Day 1 | 16 |
| On Day 2 | 12 |
| On Day 51 | 7 |
| On Day 106 | 2 |

# Is it important to be able to re-locate SPOT tagged animals during periods with limited Argos coverage?

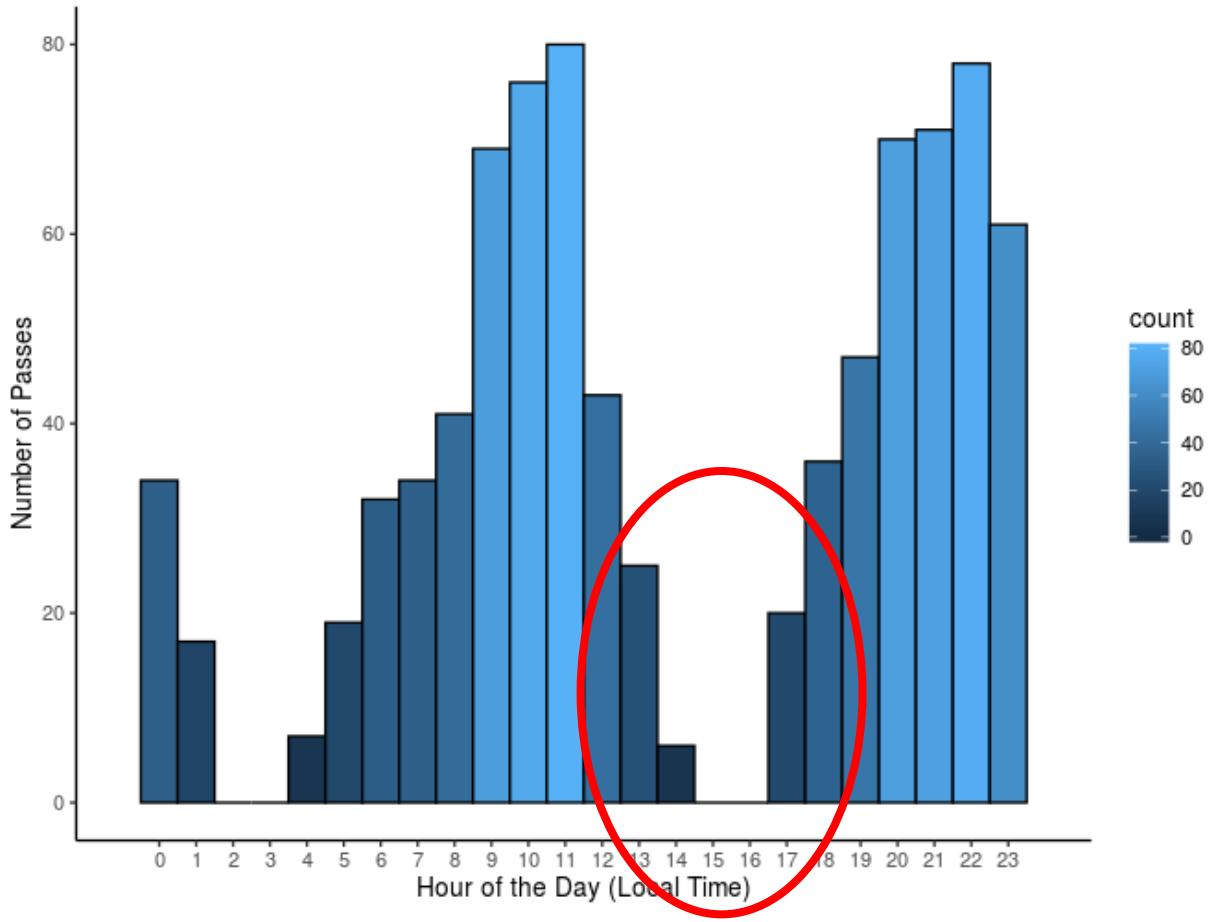


**At Sea Mode**

| Initial Pattern | On Day 1 | On Day 2 | On Day 61 | On Day |
|---|---|---|---|---|

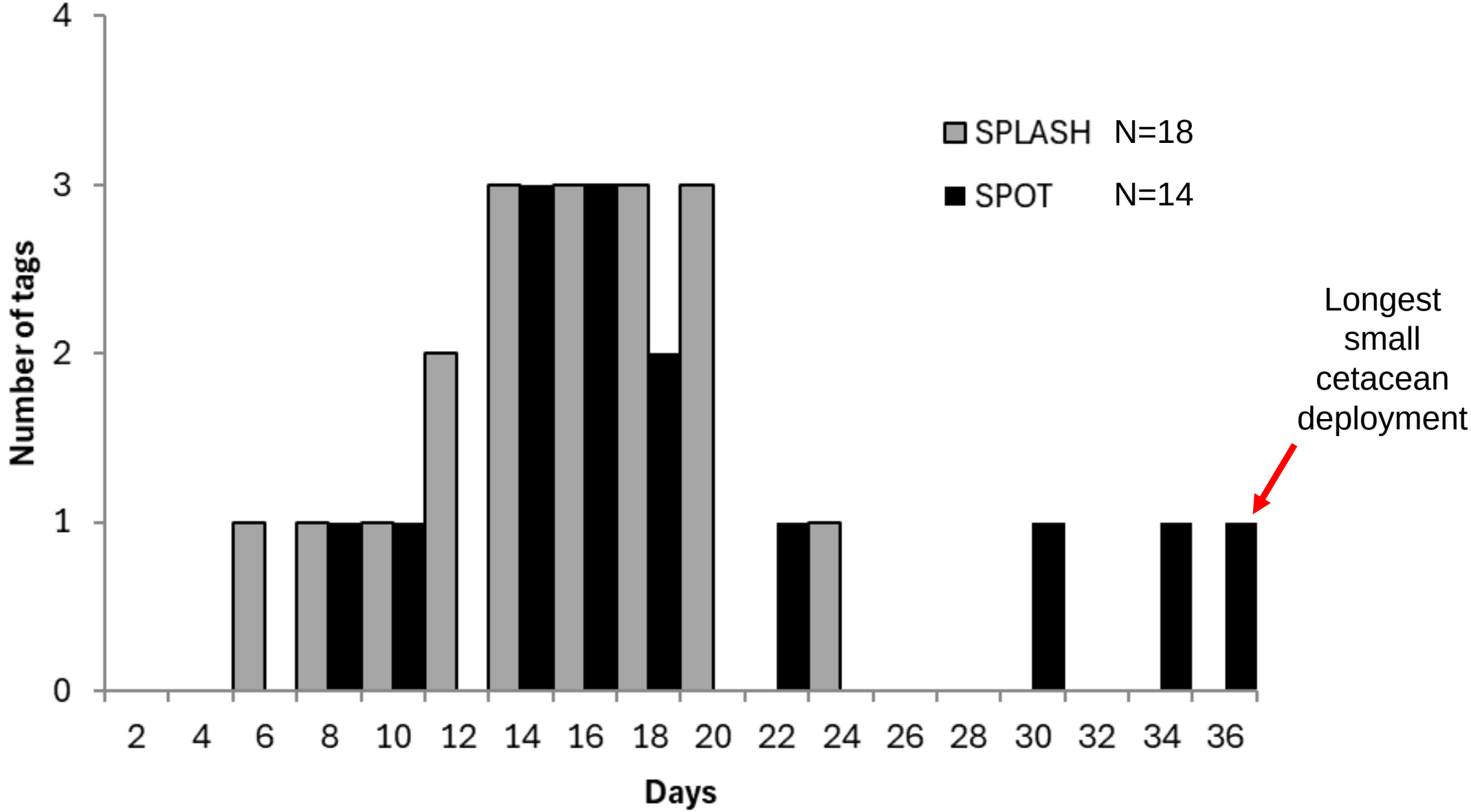
| Duration | Location Uplink Limit | Limit Type | Pinger | Prevent Data Up |
|---|---|---|---|---|
| 4 Hours *(4 Hours)* | 10 | Hourly | ✖ | ✖ |
| 6 Hours *(6 Hours)* | 60 | Hourly | ✖ | ✖ |
| 5 Hours *(5 Hours)* | 0 | Hourly | ✖ | ✖ |
| 7 Hours *(7 Hours)* | 60 | Hourly | ✖ | ✖ |
| 2 Hours *(2 Hours)* | 10 | Hourly | ✖ | ✖ |

Add Step




Hours in mid-afternoon (HST) with few or no satellites

# ~1/3 of bottlenose dolphin SPLASH tags had battery voltage drop off prior to ending transmissions (but primarily older models)



# SPLASH10 programming tradeoffs (=how to minimize gaps in behavior data while still getting the data you need/want)

**limitations/problems**

- One Behavior Log contains up to five dives, and occupies full Argos transmission
- One Time-Series summary is 48 data points, will take a full Argos transmission
- Two Histogram summaries take up a full Argos transmission

**(our) solutions**

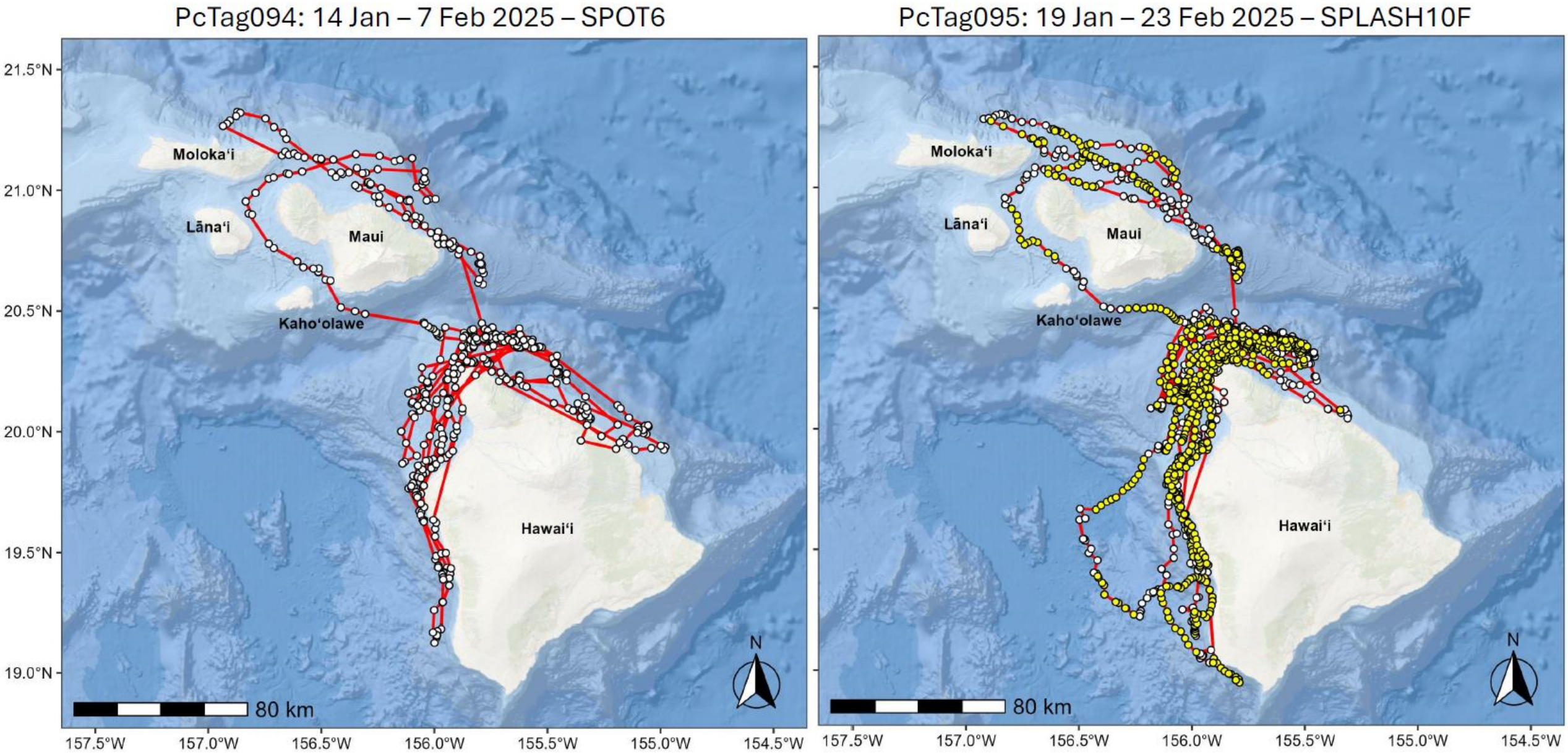
- Prioritize Behavior Logs
- Ignore dives <50 m and <30 seconds
- Time-Series at long intervals (5 minutes) and only once every six days to validate behavior data and characterize time at depth
- Transmit data collected over short (2 days) or long (6 days) period depending on need to avoid gaps/concentrate on experimental periods
- Increase the number of hours per day transmitting

# SPLASH10-F programming

- SPLASH10-F tags prioritize taking a new Fastloc snapshot over transmitting data (i.e., behavior/time series/histograms)
- One Fastloc-GPS snapshot will take a full Argos transmission
- Our solution has been to only attempt Fastloc shapshots during hours when not transmitting to Argos (or with poor Argos coverage)

| **Fastloc Control** | |
|---|---|
| Maximum successful Fastloc attempts | 3 per hour; 24 per day |
| Maximum failed Fastloc attempts | Unlimited per hour |
| Overall maximum Fastloc attempts | Unlimited per day |
| Supress Fastloc after good haulout location | is disabled |
| Abort Fastloc processing if tag measures wet on next wakeup | is disabled |
| Always transmit latest location message | is disabled |

(main downside is having different errors associated with Argos versus Fastloc transmission hours)

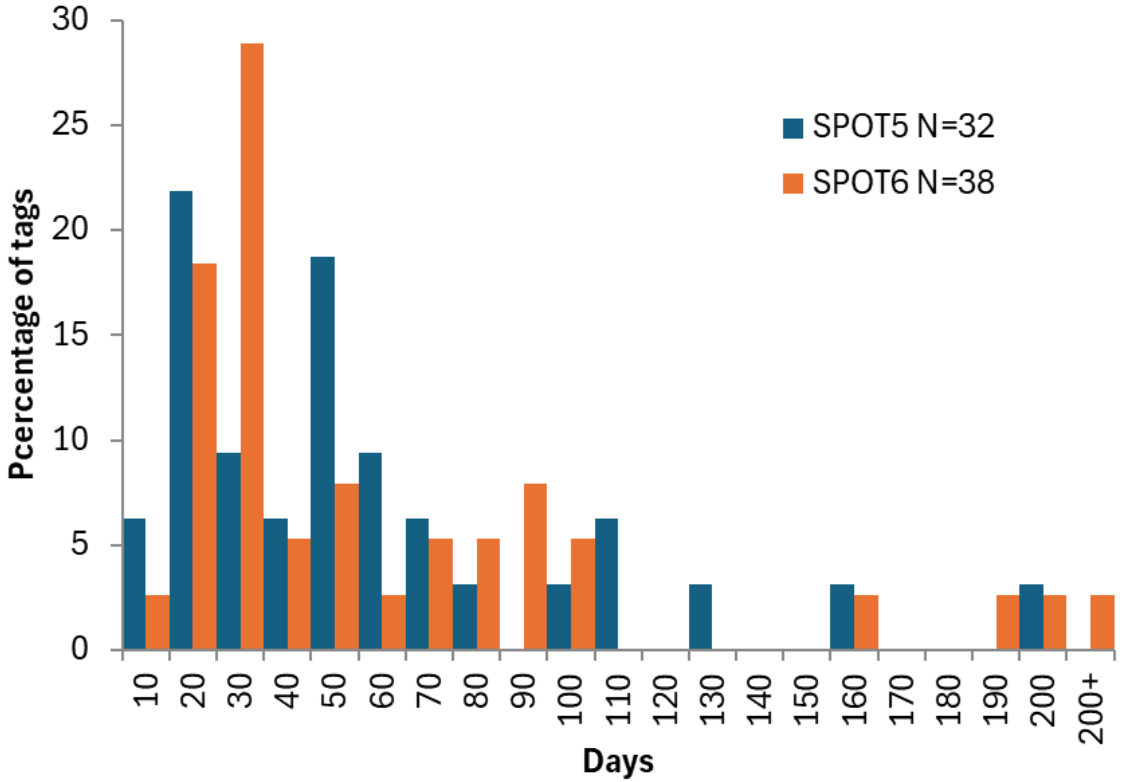



# Main Hawaiian Islands false killer whales

Baird et al. 2025 PSRG

# Comparison of SPOT5 versus SPOT6 transmission durations

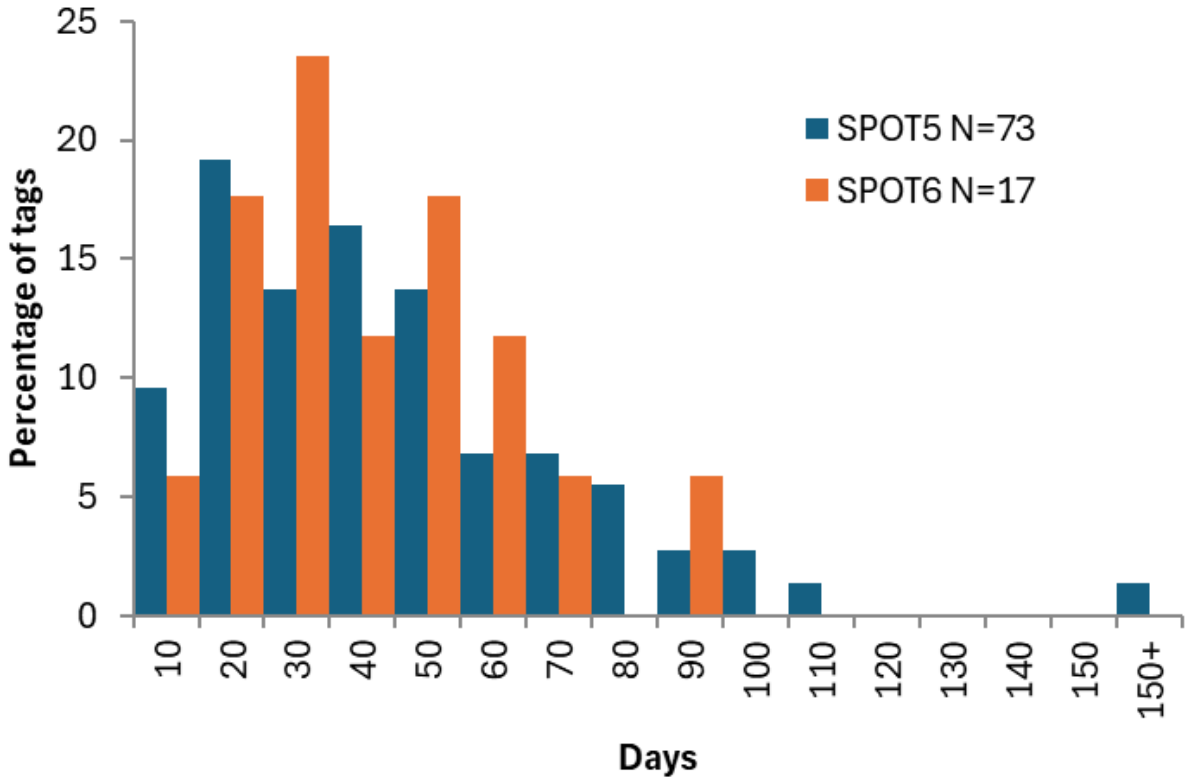
## False killer whales




SPOT5
Mean 52.0
Median 41.4
Max 199.1

SPOT6
Mean 56.5
Median 31.1
Max 236.0

## Short-finned pilot whales




SPOT5
Mean 40.5
Median 33.0
Max 228.5

SPOT6
Mean 35.9
Median 30.5
Max 88.8