Development of new techniques for monitoring the behavior of SSL and their main predator, killer whales

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windows to the sea

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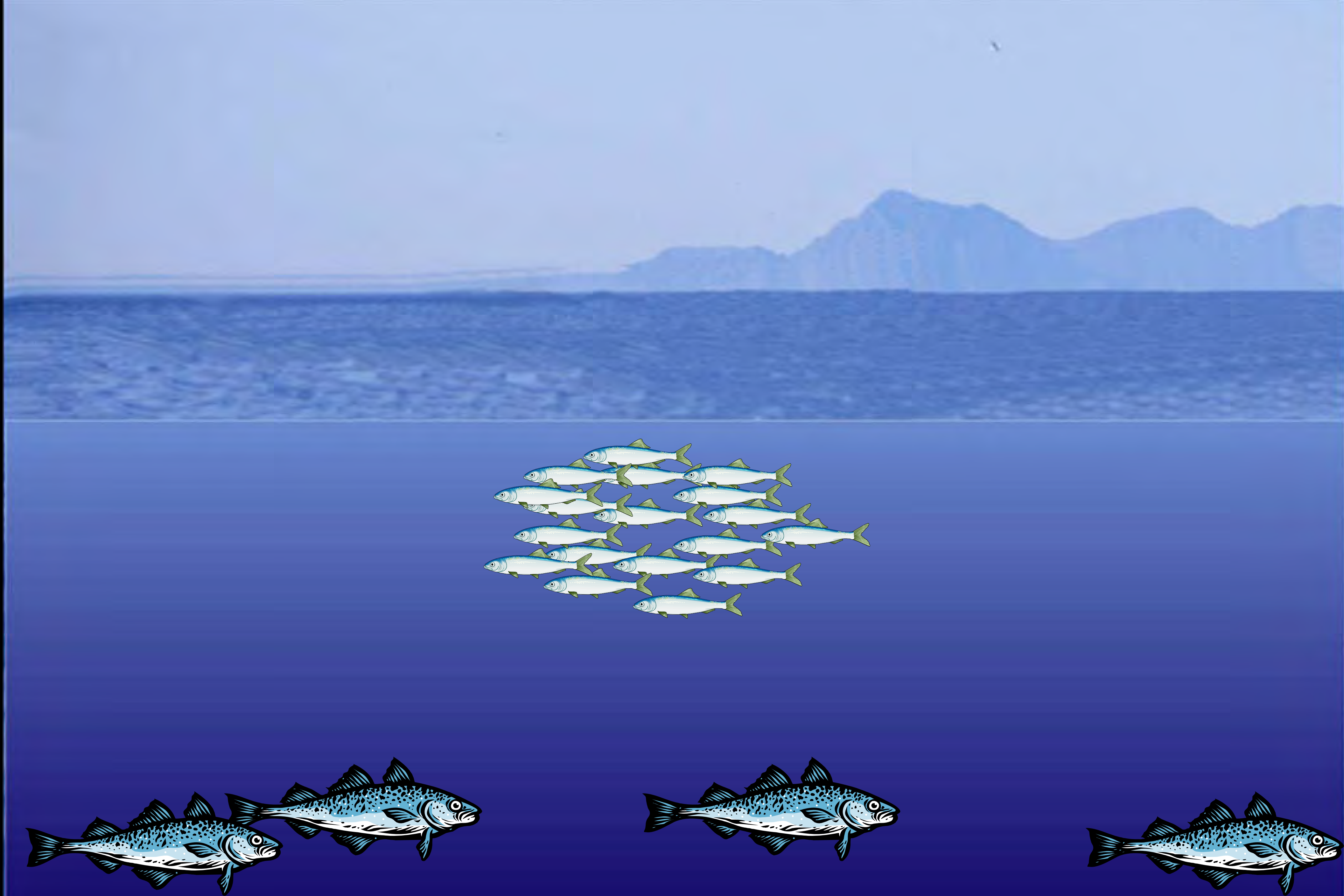
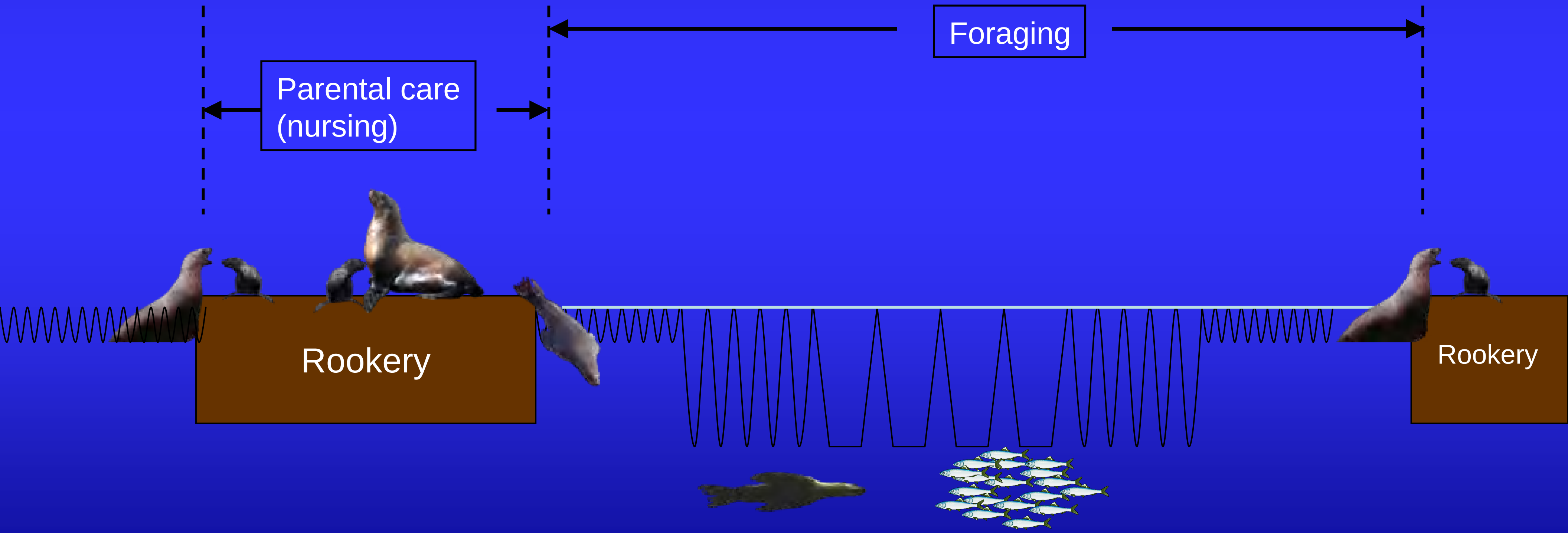
Overall Goals:

- Determine how Steller sea lions are affected by changes in prey type, quantity, quality, or availability.
  - Focus: Foraging ecology of instrumented adult females
- Gain insight into the demographic consequences of differences in diet and behavior.
  - (e.g. , exploit differences between populations with varying population trends or within populations over time)

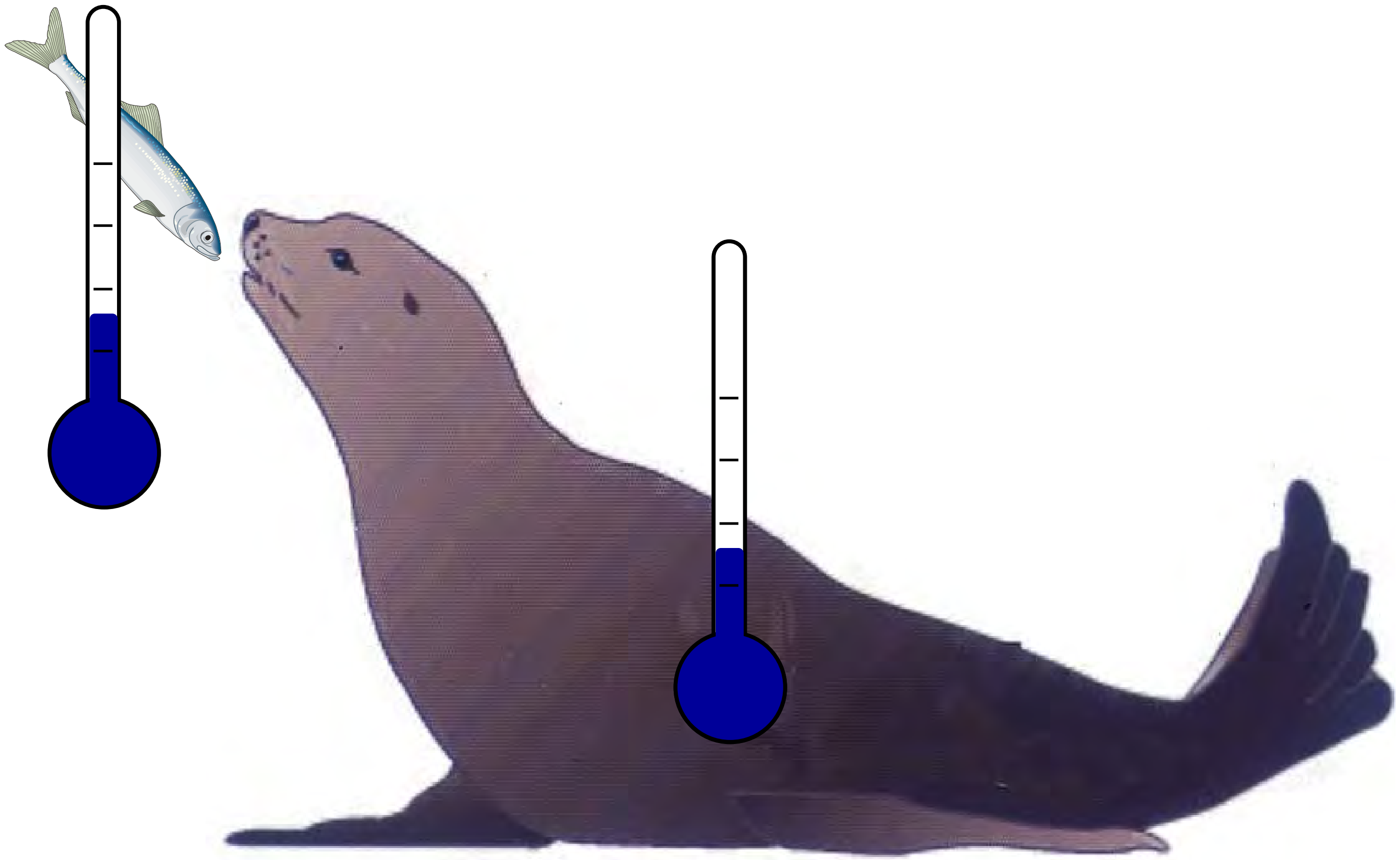


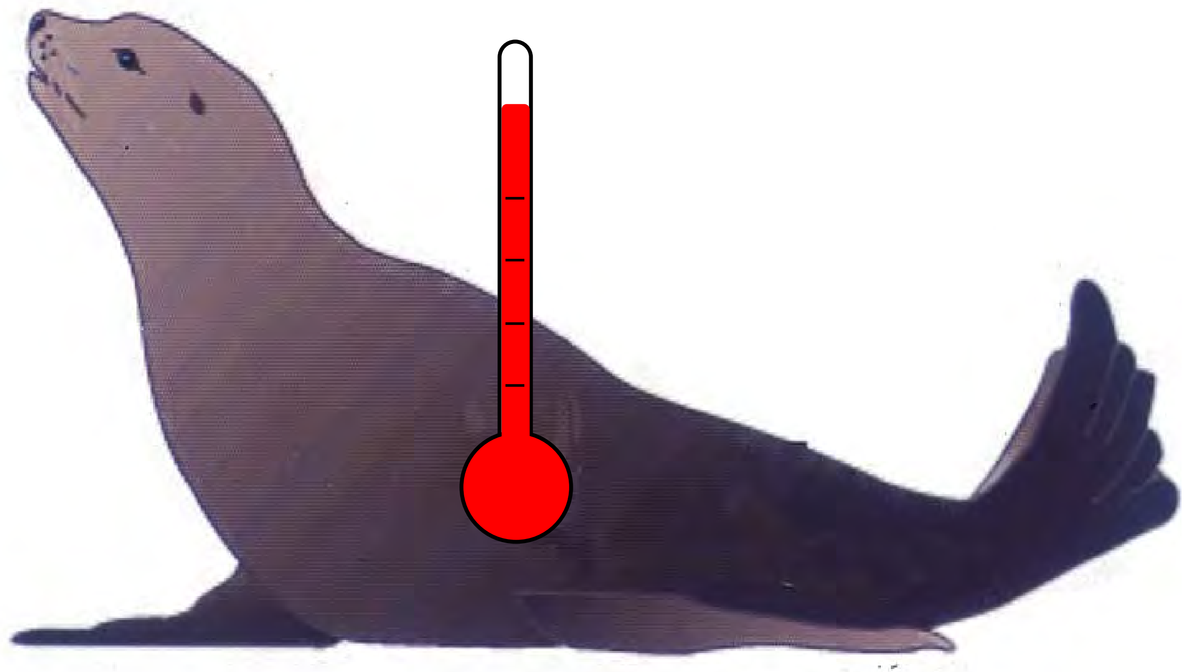
Monitoring the foraging behavior of adult females and relating it to reproductive success



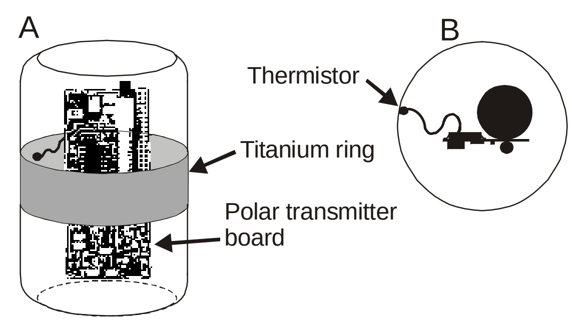
Methods for remotely detecting prey ingestion

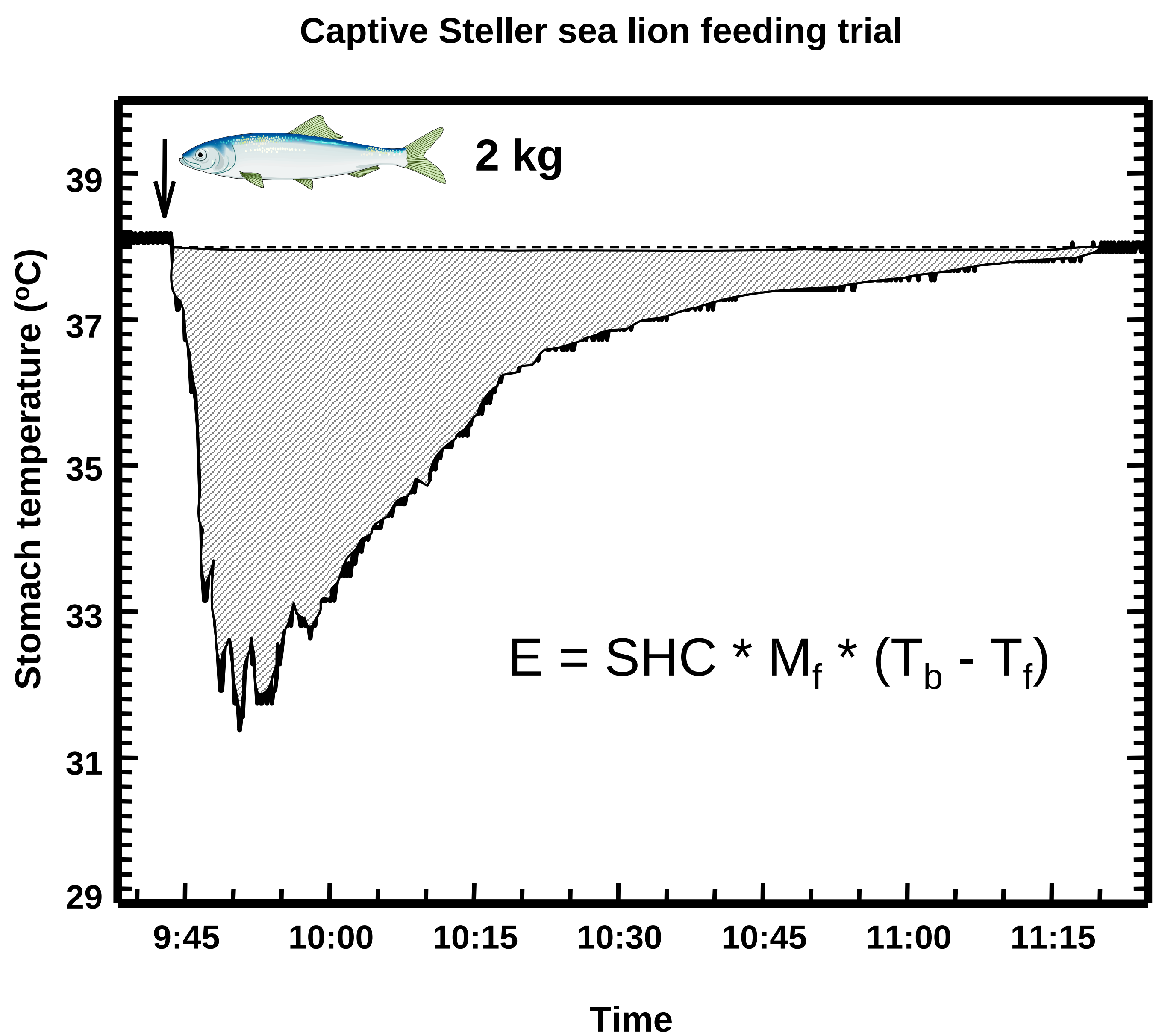
- Stomach temperature telemetry
- Imaging: head-mounted digital camera
- New sensors:
  - thoracic electrical impedance
  - intra-gastric pressure
  - jaw opening (Hall Effect and mandible/upper jaw differential acceleration)
  - head striking (differential acceleration of head and abdomen)
  - sonomicrometry of throat dimensions

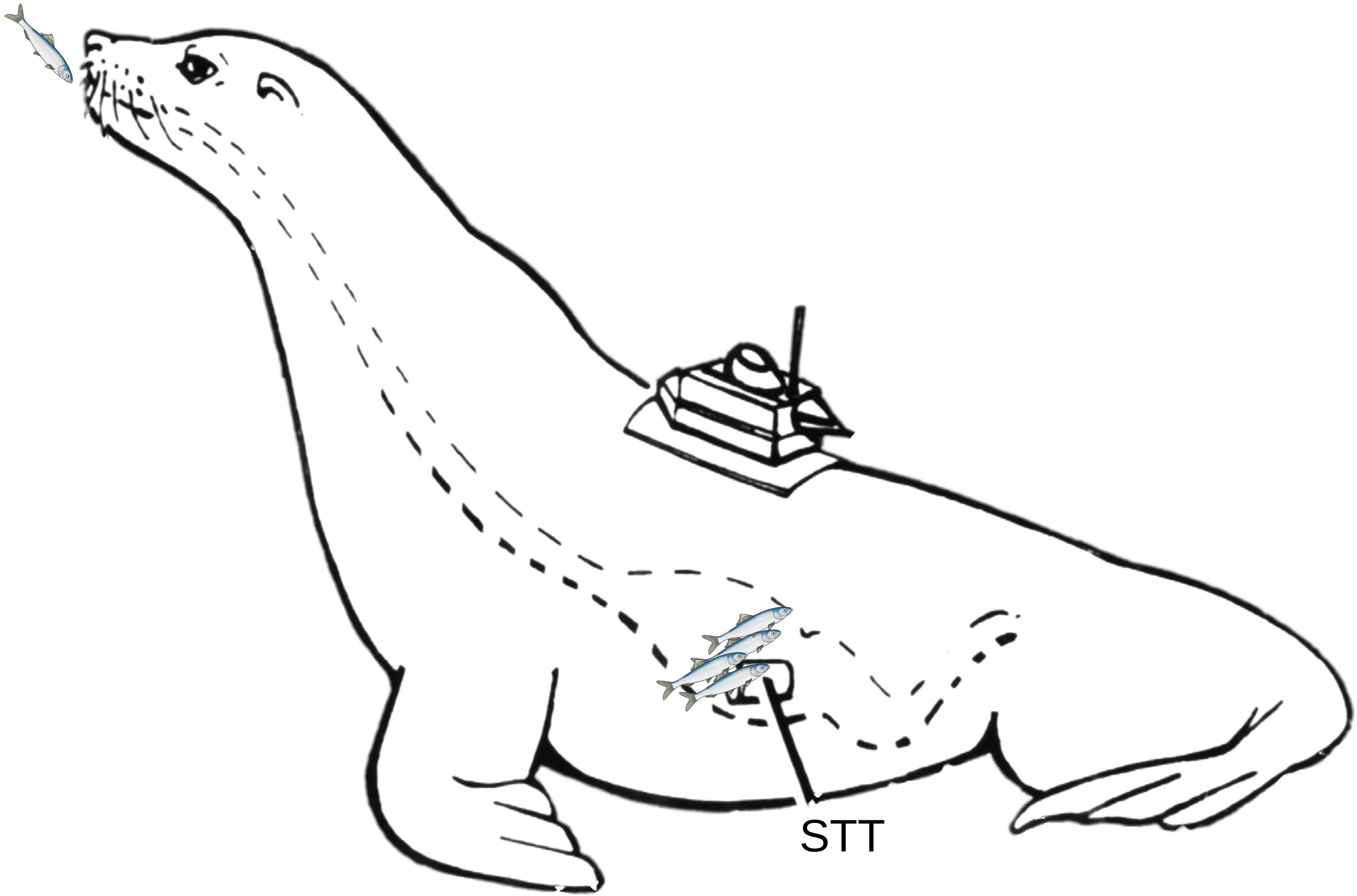


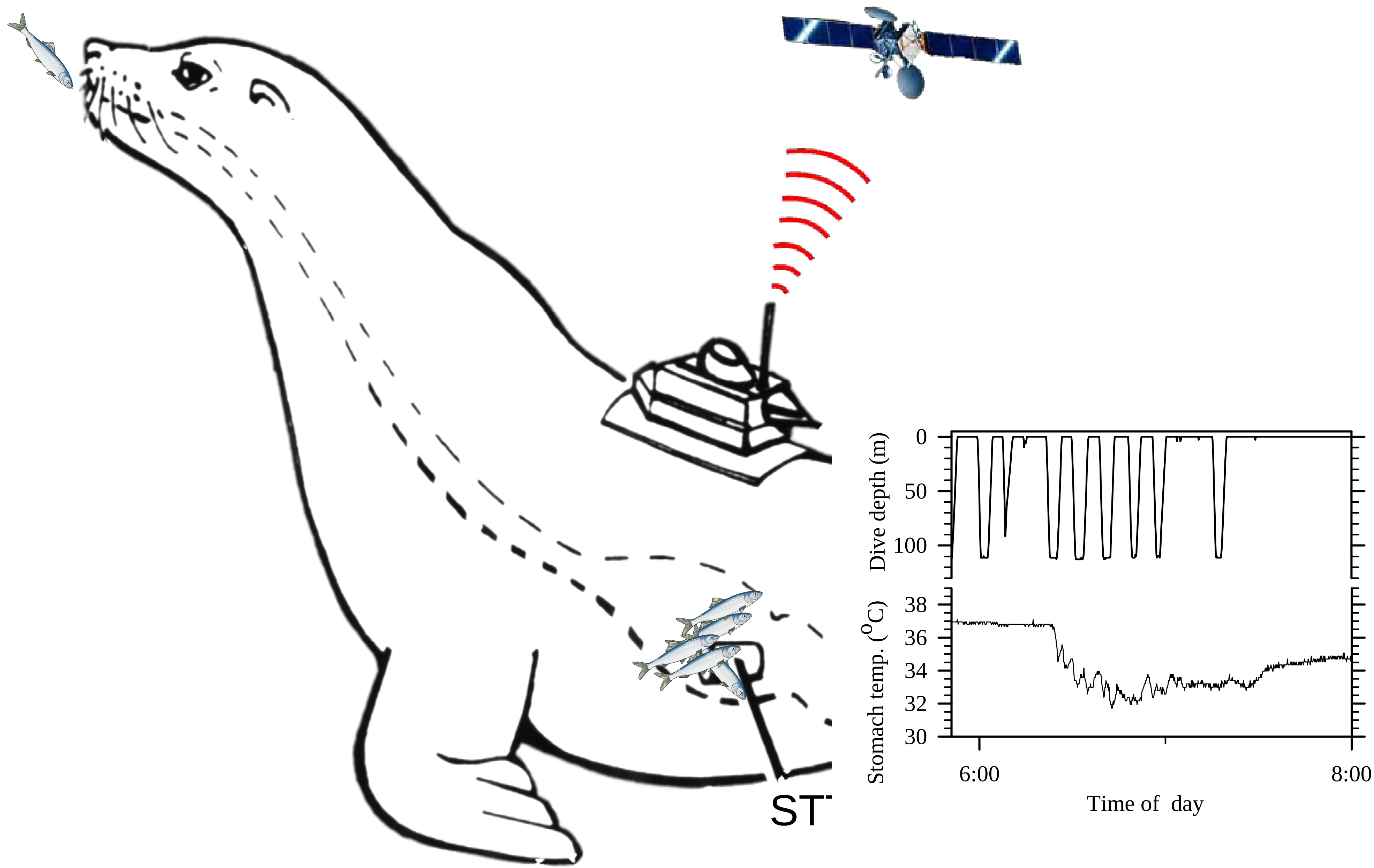


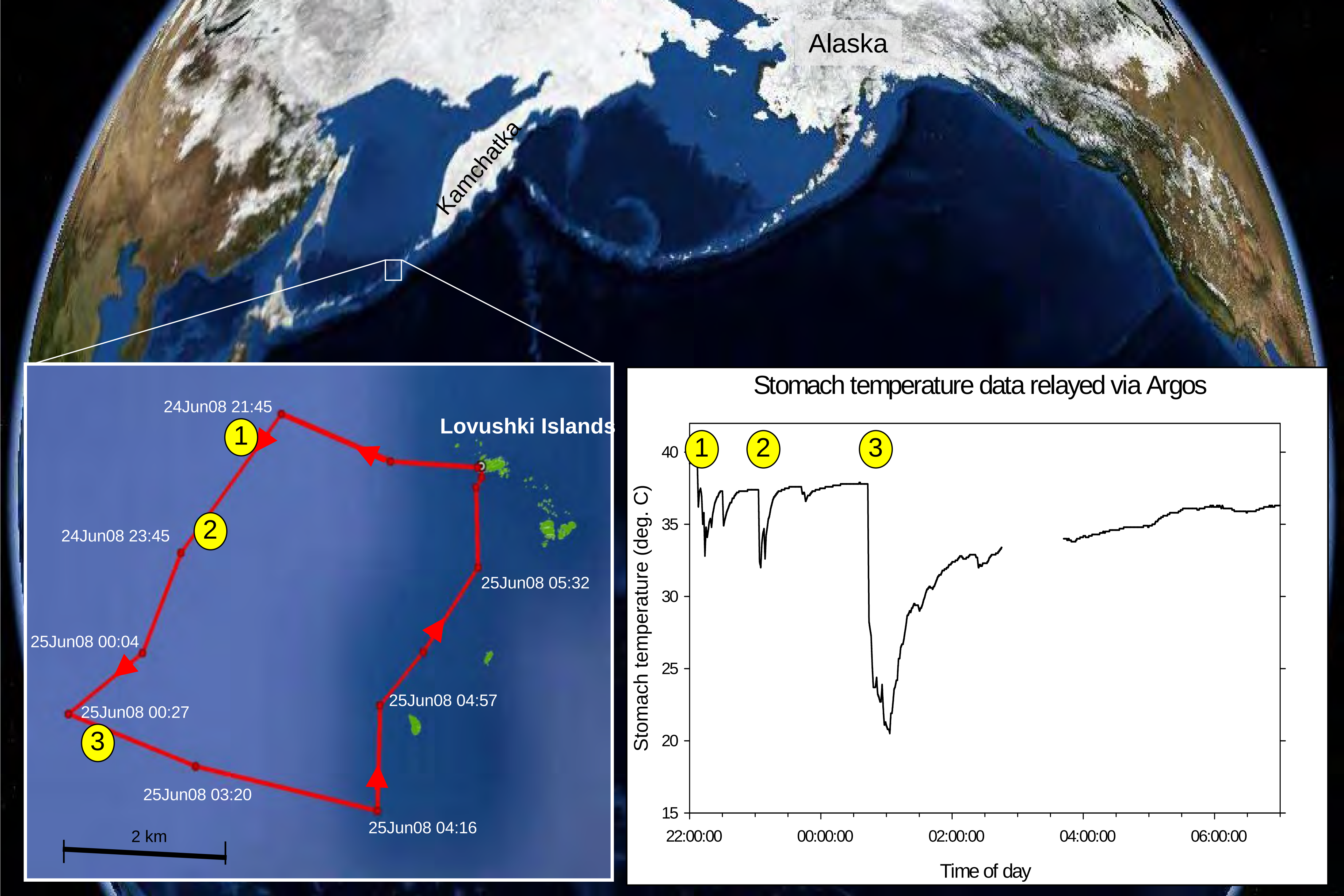
Stomach temperature transmitter (STT)

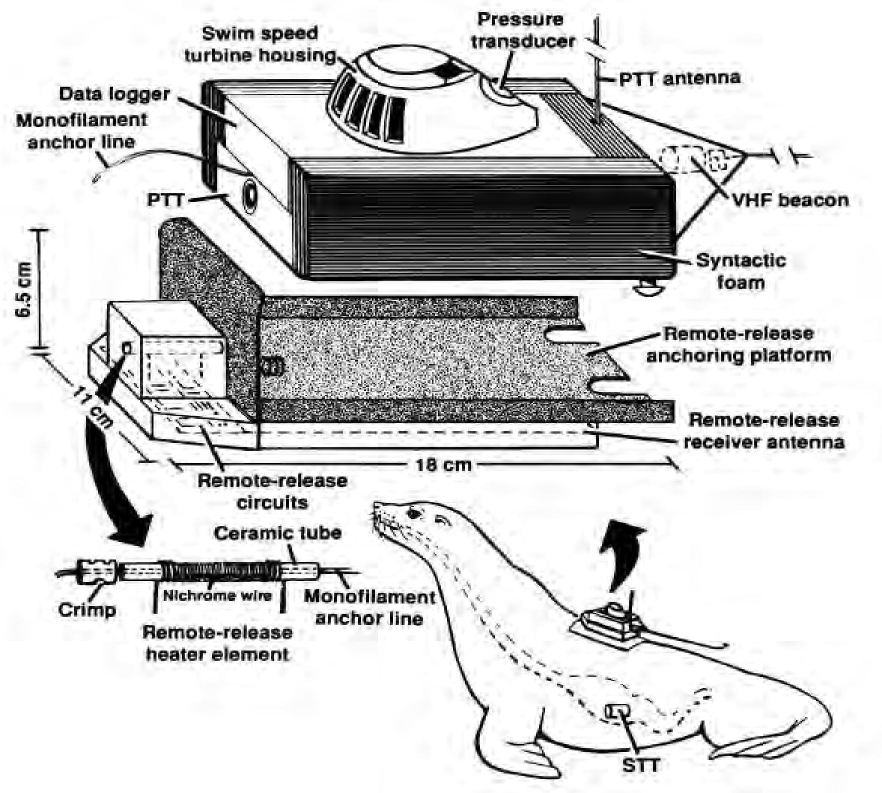



Captive Steller sea lion feeding trial
2 kg
Stomach temperature (ºC)
39
37
35
33
31
29
9:45
10:00
10:15
10:30
10:45
11:00
11:15
Time
E = SHC * M_f * (T_b - T_f)

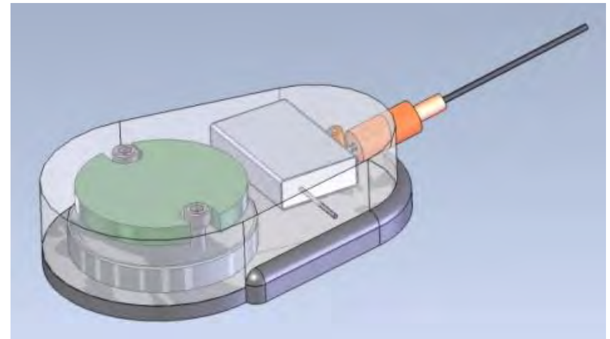

STT


ST
Dive depth (m)
0
50
100
Stomach temp. (°C)
38
36
34
32
30
6:00
8:00
Time of day


Alaska
Kamchatka
Lovushki Islands
24Jun08 21:45
24Jun08 23:45
25Jun08 00:04
25Jun08 00:27
25Jun08 03:20
25Jun08 04:16
25Jun08 04:57
25Jun08 05:32
2 km
1
2
3
Stomach temperature data relayed via Argos
Stomach temperature (deg. C)
40
35
30
25
20
15
22:00:00
00:00:00
02:00:00
04:00:00
06:00:00
Time of day



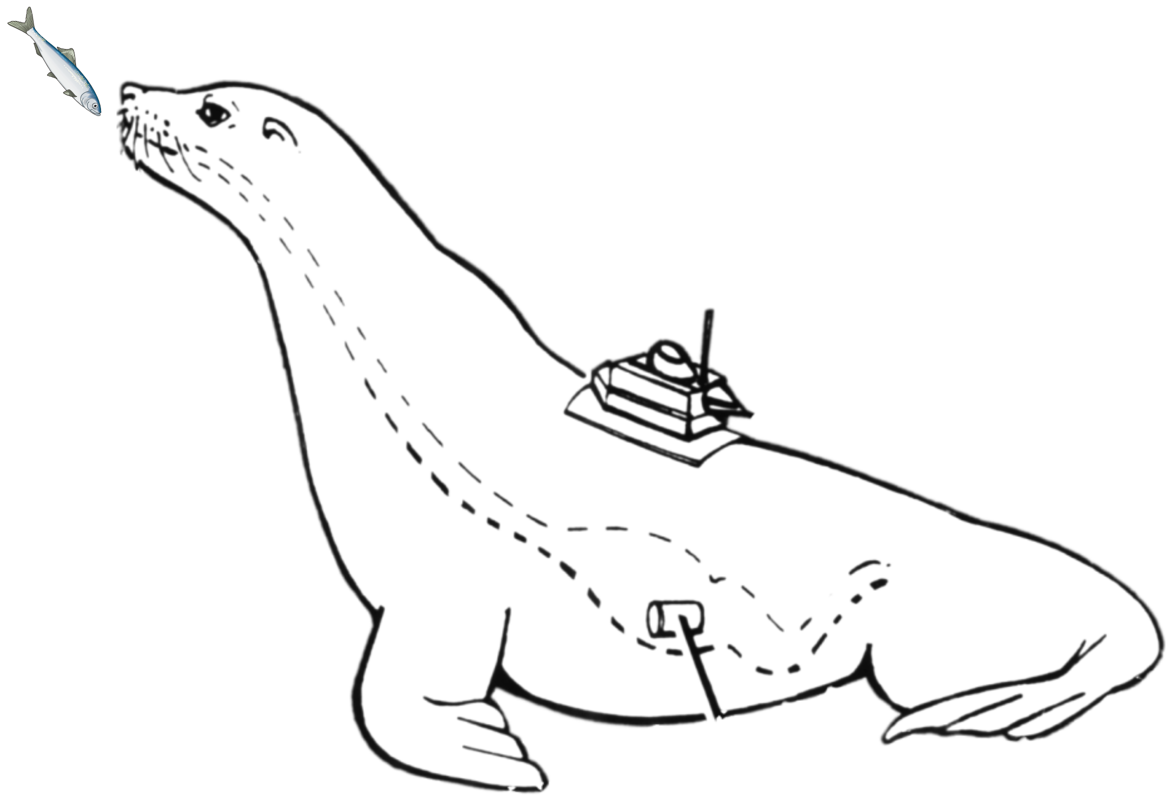
Andrews, R.D. 1998. Remotely releasable instruments for monitoring the foraging behaviour of pinnipeds. Mar. Ecol. Prog. Ser. 175:289-294



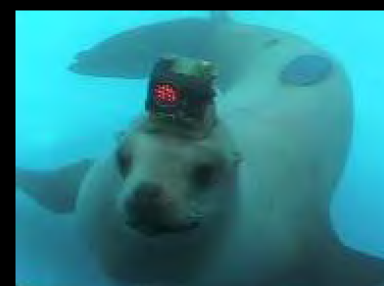
New Wildlife Computers remote-release design

Other Methods?

- Animal-borne cameras
- Jaw opening (e.g. IMASEN or mandibular accelerometer)
- Head striking






5012


VDAP_ASLC Clip12008

Disadvantages to animal-borne imaging:

- Large size, high drag -> increased work required
  - Steller sea lion with Venus camera = 4% added drag
  - Necessity for small, streamlined package limits battery capacity » length of recording time
  - Solution: still images instead of video
  - Prey items in view for 0.167 seconds, requiring a frame rate of ~ 2 Hz
- Can't always positively identify successful ingestion

Jaw opening

sensed via Hall Effect sensor and magnet or two accelerometers (head and mandible)

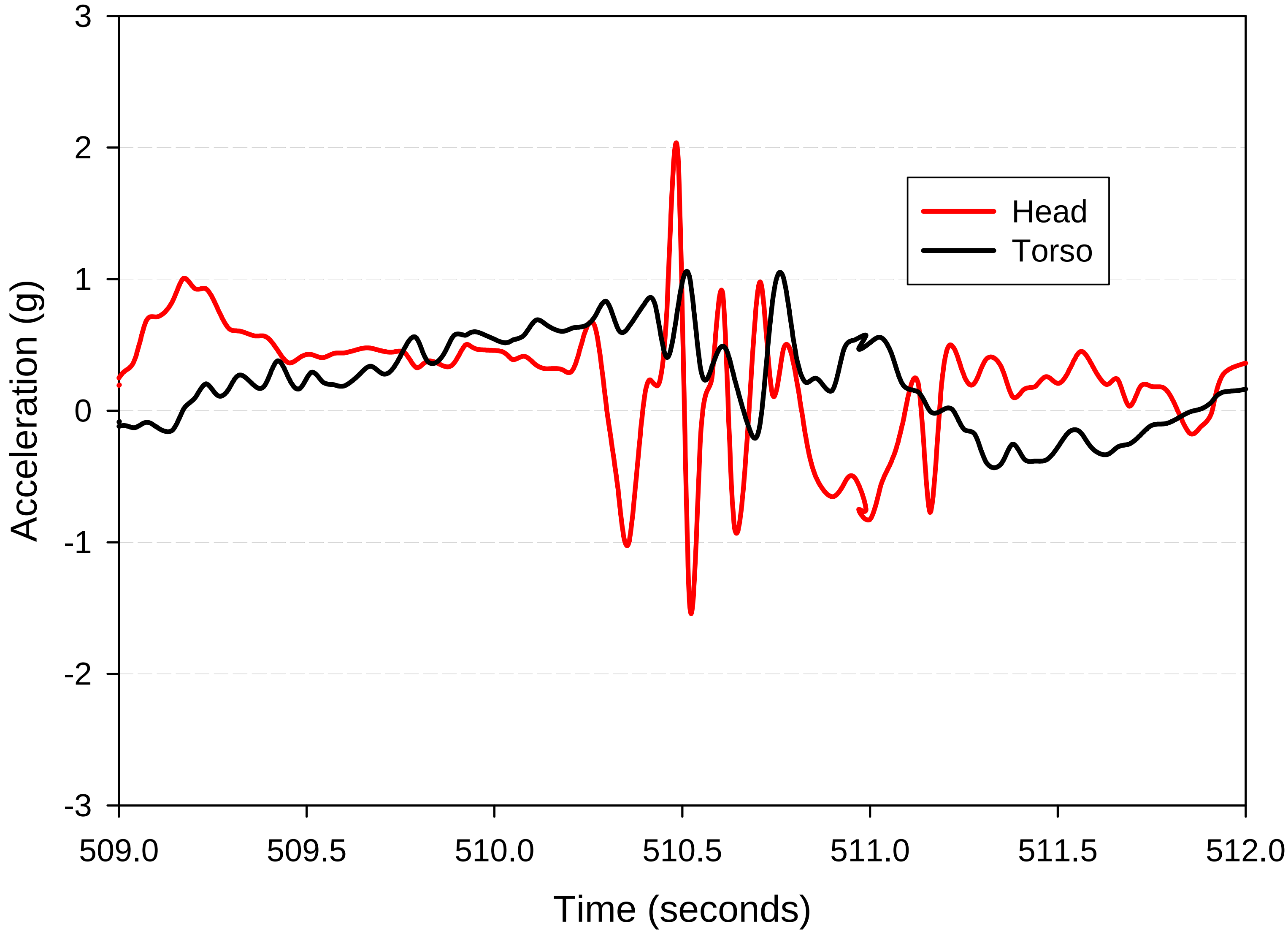
Head Strike Full Speed Closeup.wmv

Best Manipulation.wmv

Catch and Chase.wmv

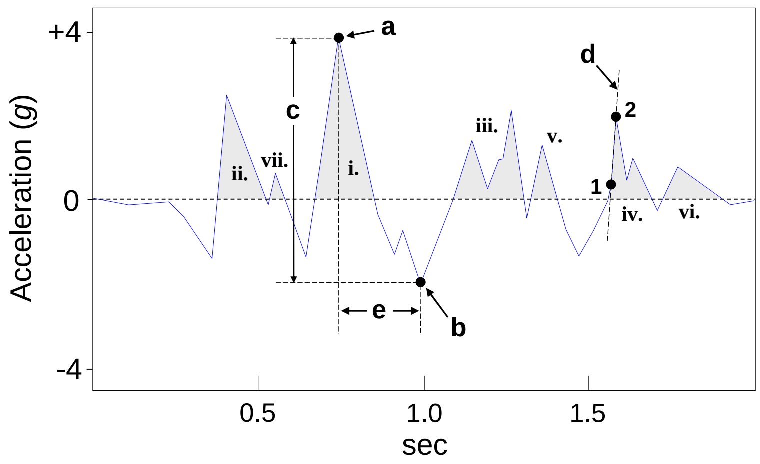
Head striking
Differential acceleration of head and back

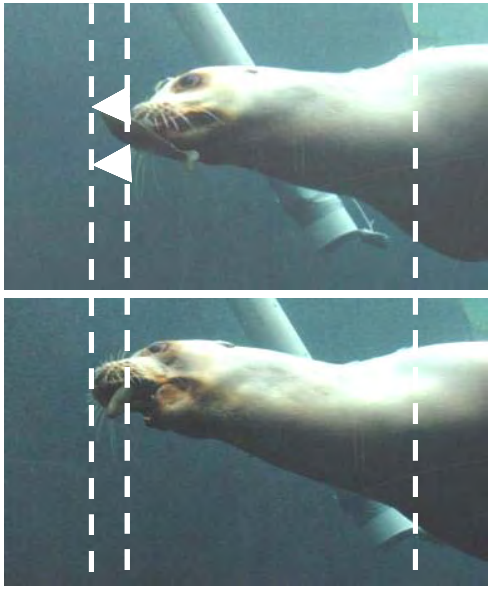
Head Strike Full Speed.wmv



Head
Torso
Acceleration (g)
3
2
1
0
-1
-2
-3
509.0
509.5
510.0
510.5
511.0
511.5
512.0
Time (seconds)

Overlay 4.wmv





		Dynamic Model		Differential Model	
		Predicted FCA		Predicted FCA	
		No	**Yes**	**No**	**Yes**
Actual FCA	**No** *(n=11953)*	11867	86[a]	11858	95[b]
	Yes *(n=92)*	17	75	19	73
	Total	11884	161	11877	168
		Accuracy	99.1%	Accuracy	99.1%
		Precision	46.6%	Precision	43.5%
		Sensitivity	81.5%	Sensitivity	79.3%
		Specificity	99.3%	Specificity	99.2%

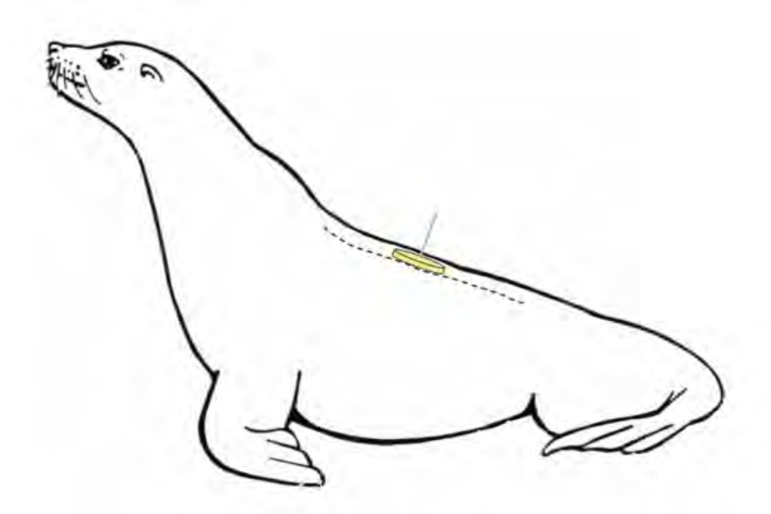
[a] Of 86 false positives, 85 occurred during fish chases
[b] Of 95 false positives, 86 occurred during fish chases

Skinner, J.P., Norberg, S.E. and Andrews, R.D. (2010, in press). Head striking during prey capture attempts by Steller sea lions and the potential for using head surge acceleration to predict feeding behavior. Endang. Spec. Res. doi: 10.3354/esr00236

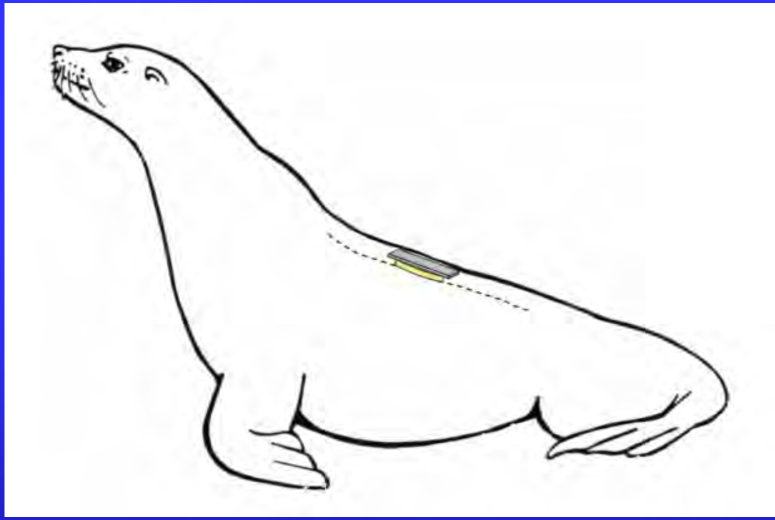
Developing a better long-term attachment method

Objective

Develop a better long-term attachment method

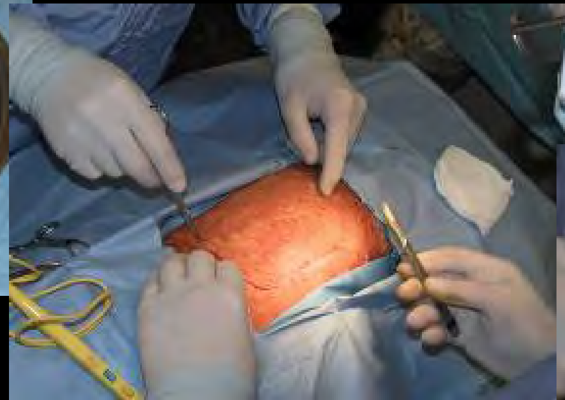
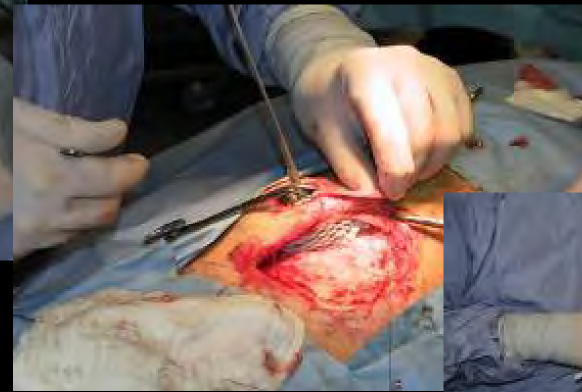


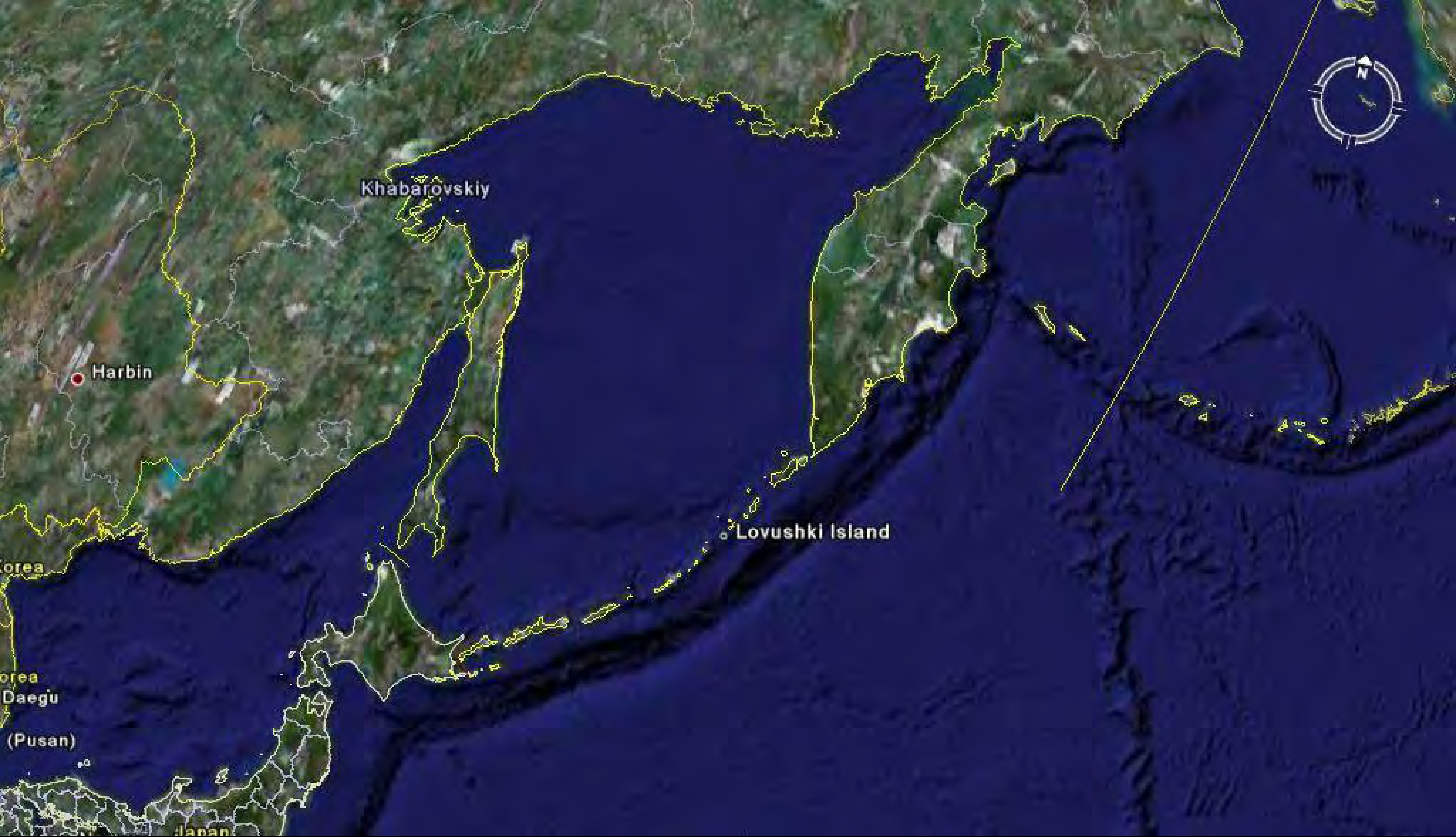
Approach 1: subcutaneous PTT implant & percutaneous antenna



Approach 2: subcutaneous PTT implant with flat antenna

Epithelialized-pouch with percutaneous antenna



Khabarovskiy
Harbin
Lovushki Island
Daegu
(Pusan)

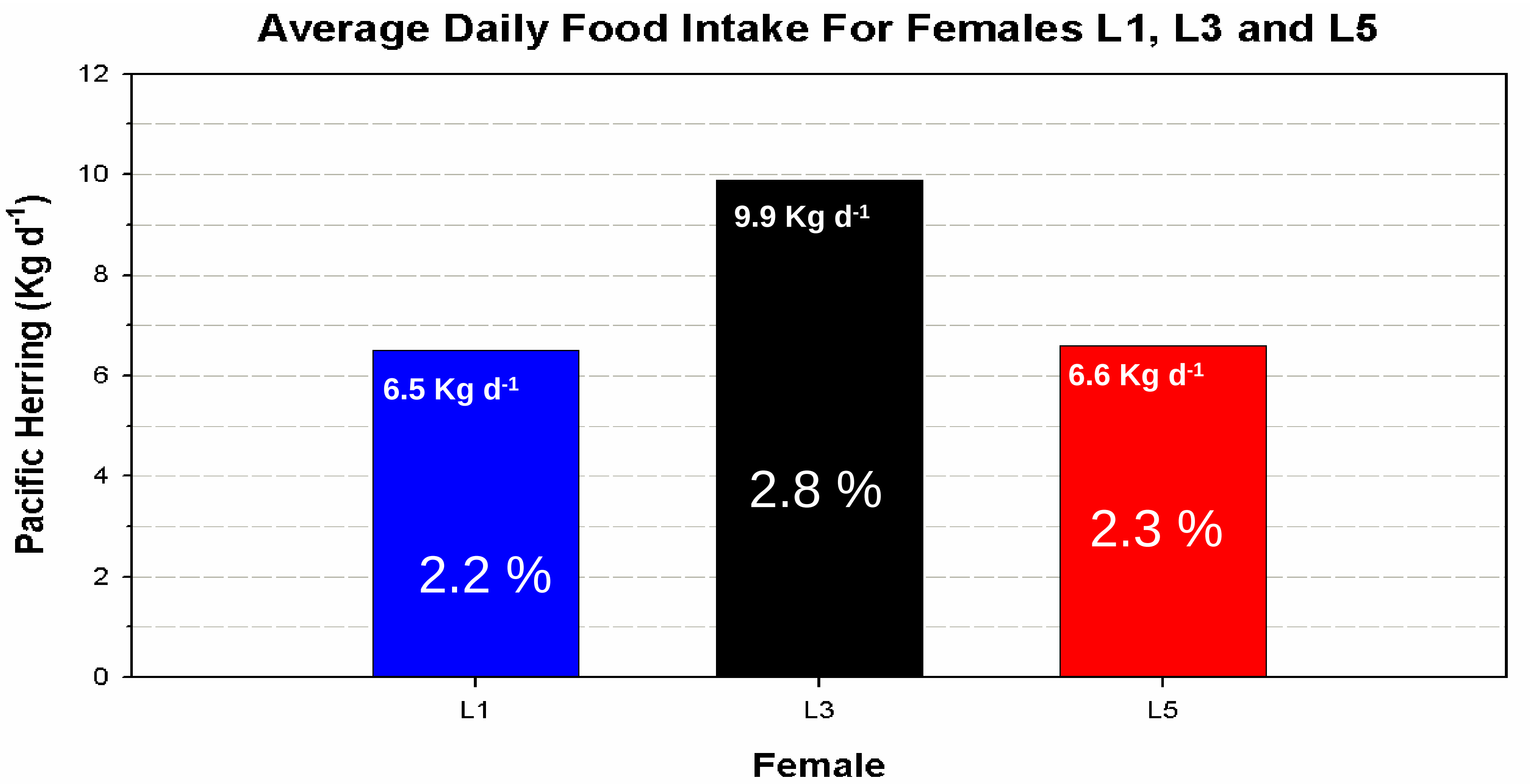

Paramushir Island
Lovushki Island


50

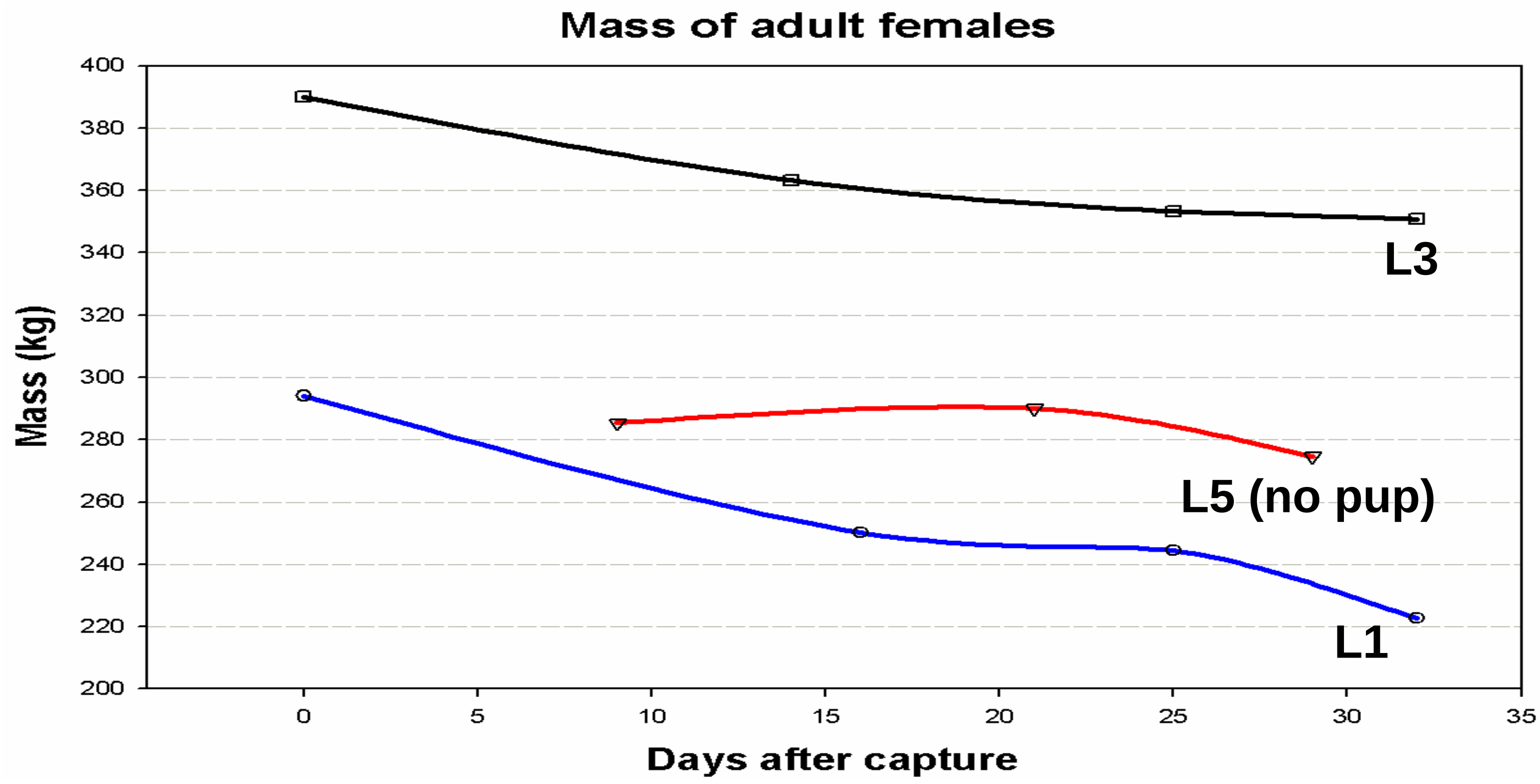

КЖ-354


2005-JUL-18 02:13:55
L18H
BLUD2
SAMSUNG

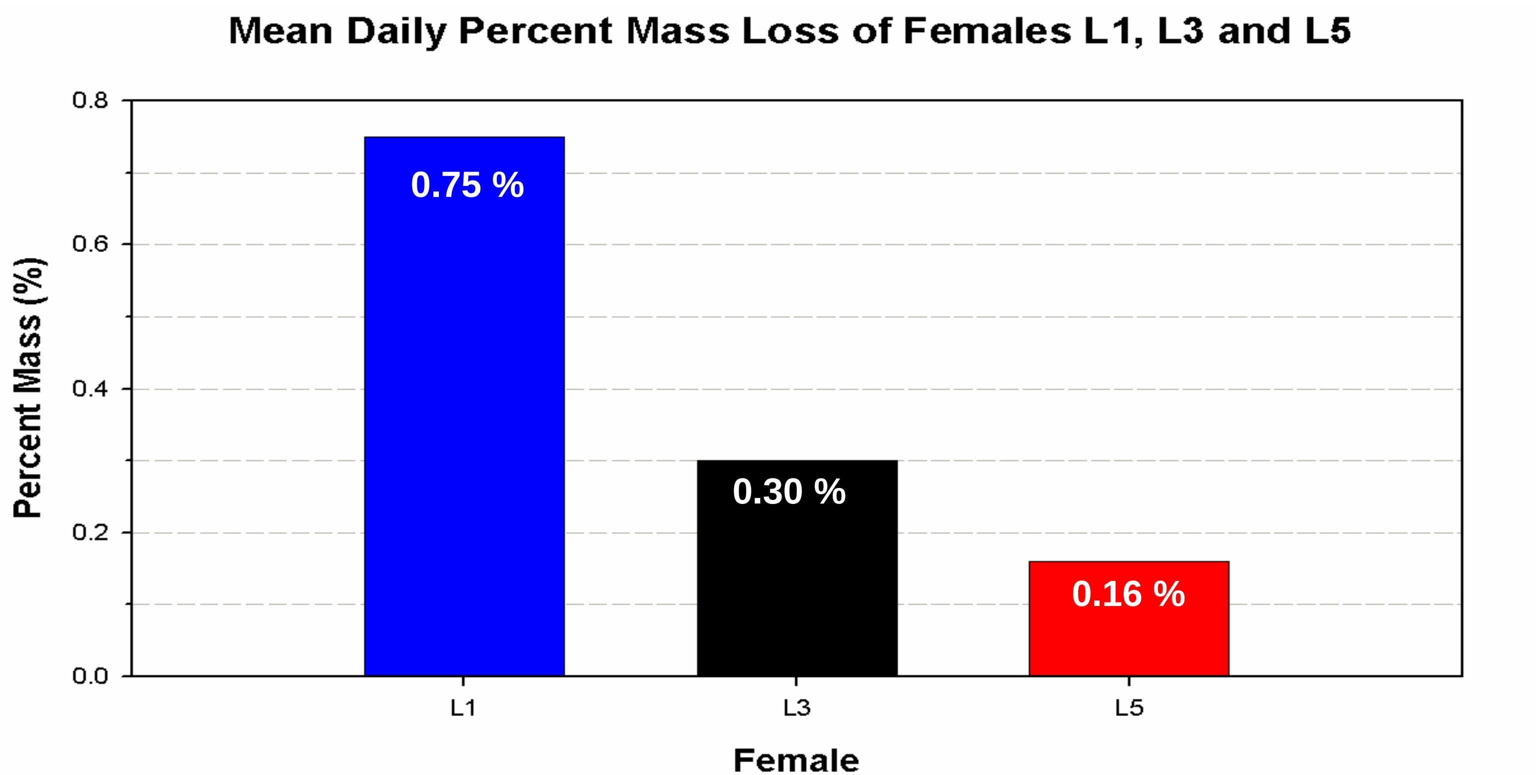

КАМЧАТСКИЕ АВИА
МИ-8

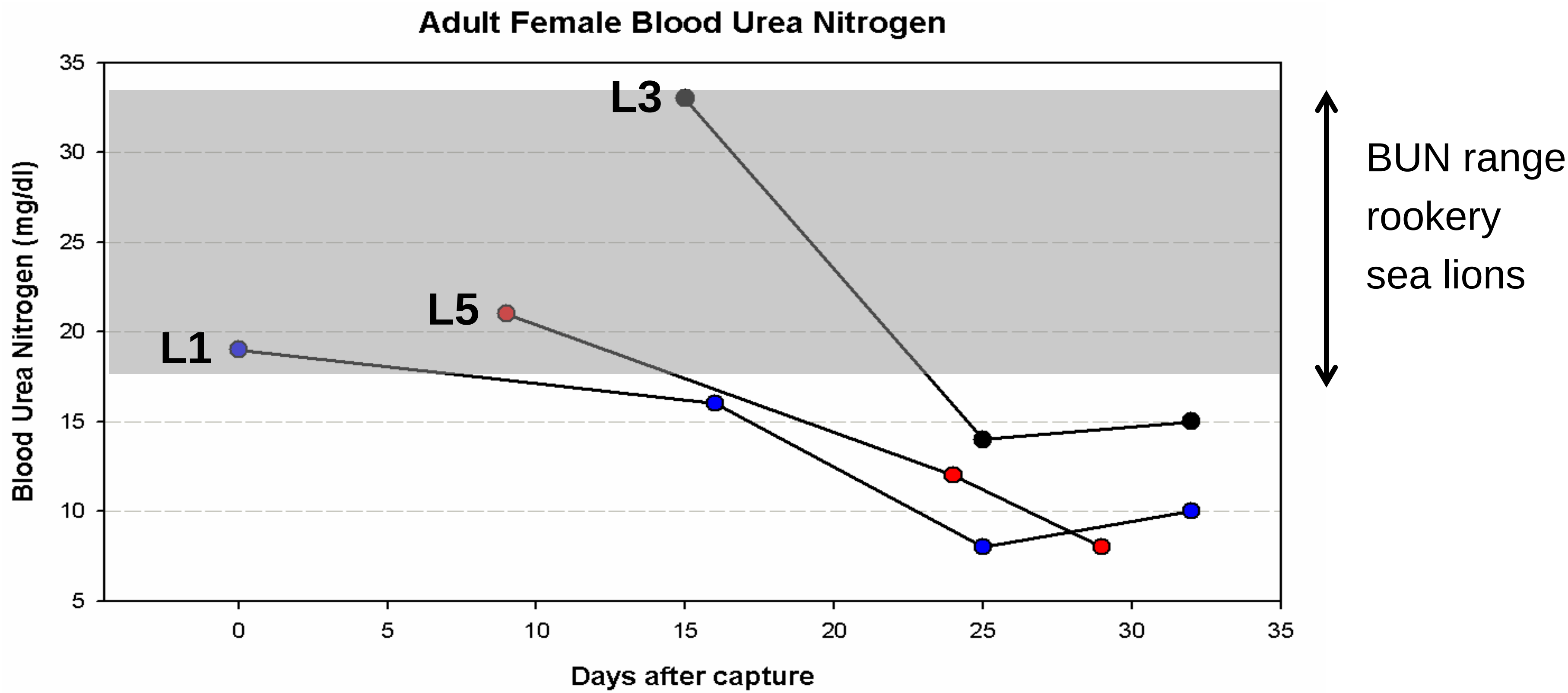


Bioenergetic models predict >10% per day is necessary (Winship et al. 2002)

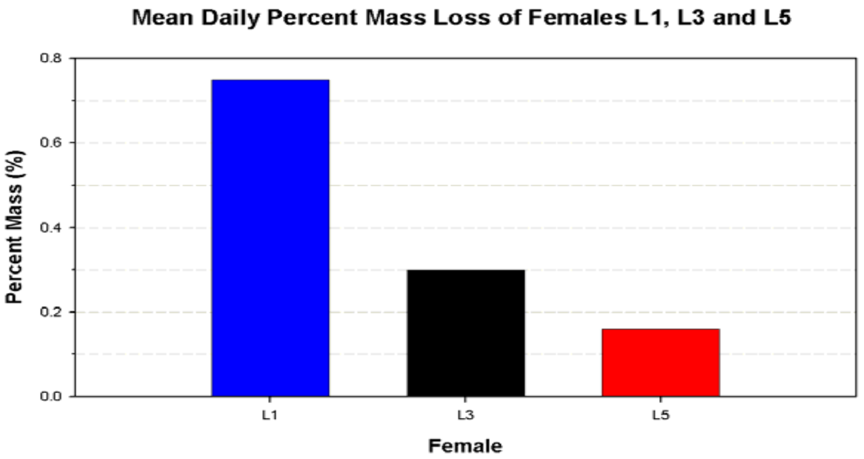


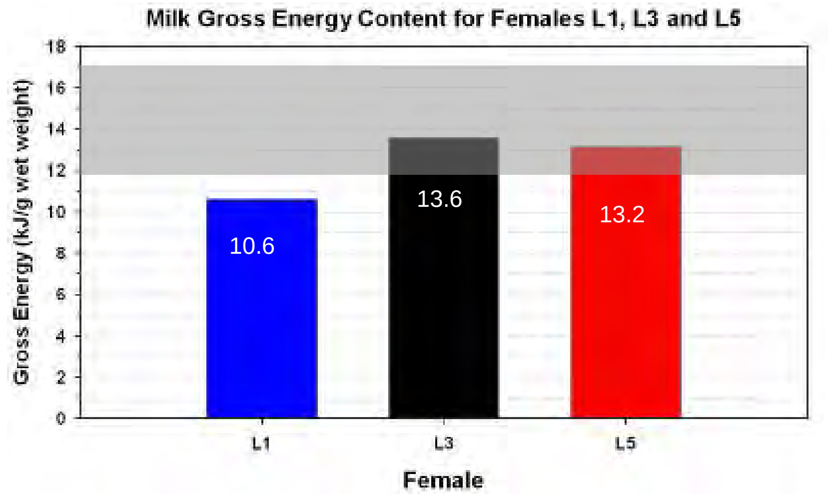
Mass of adult females
400
380
360
340
320
300
280
260
240
220
200
Mass (kg)
0
5
10
15
20
25
30
35
Days after capture
L3
L5 (no pup)
L1

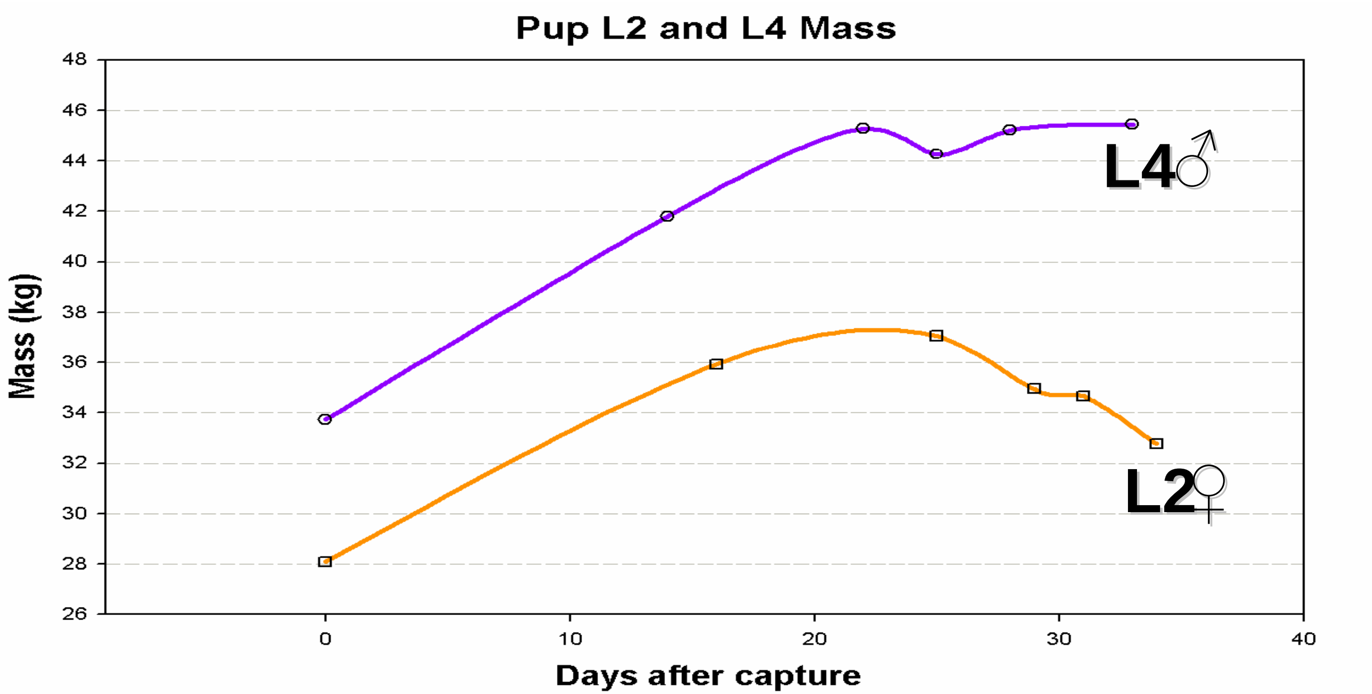

Mean Daily Percent Mass Loss of Females L1, L3 and L5
0.8
0.6
0.4
0.2
0.0
Percent Mass (%)
0.75 %
0.30 %
0.16 %
L1
L3
L5
Female

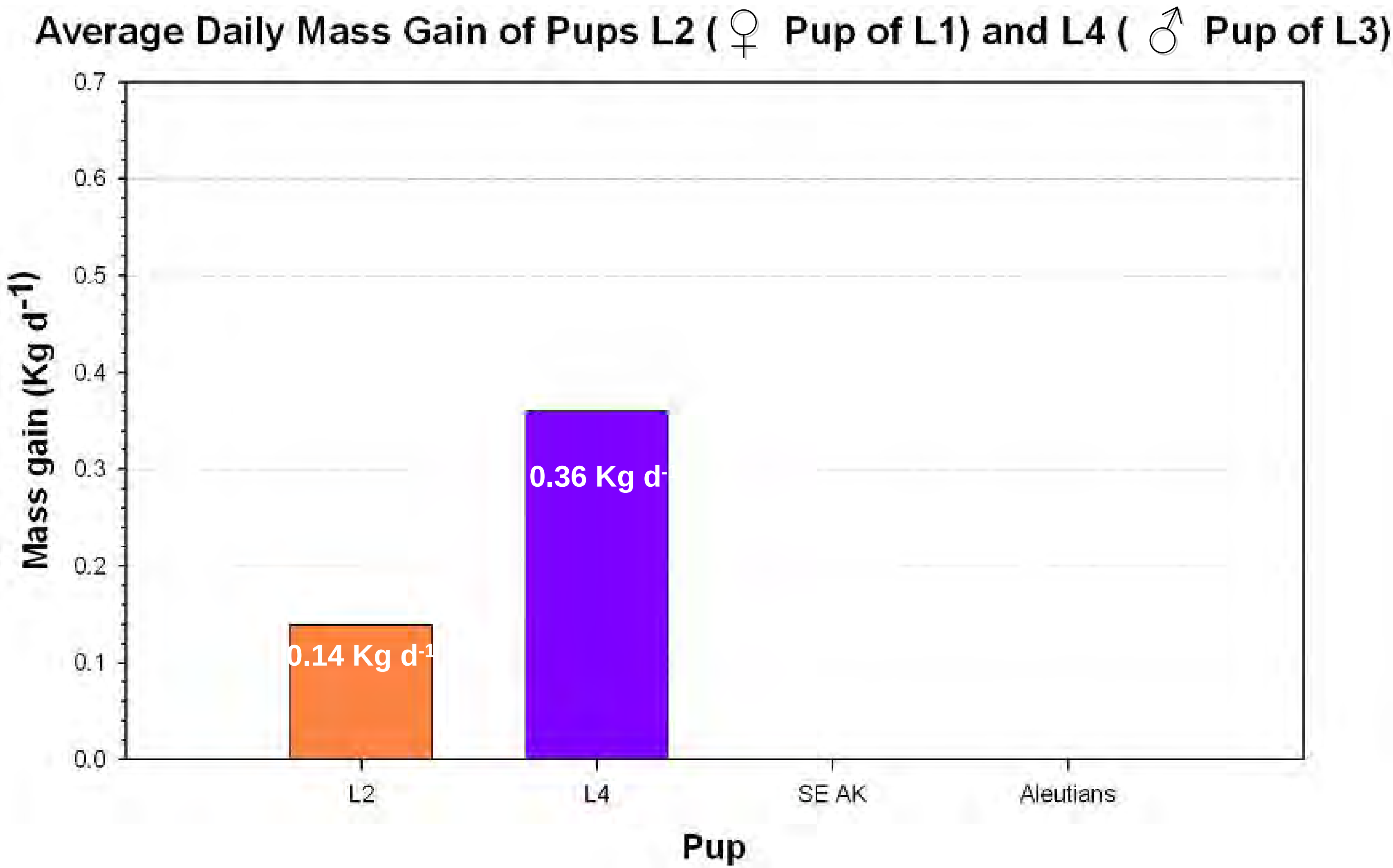


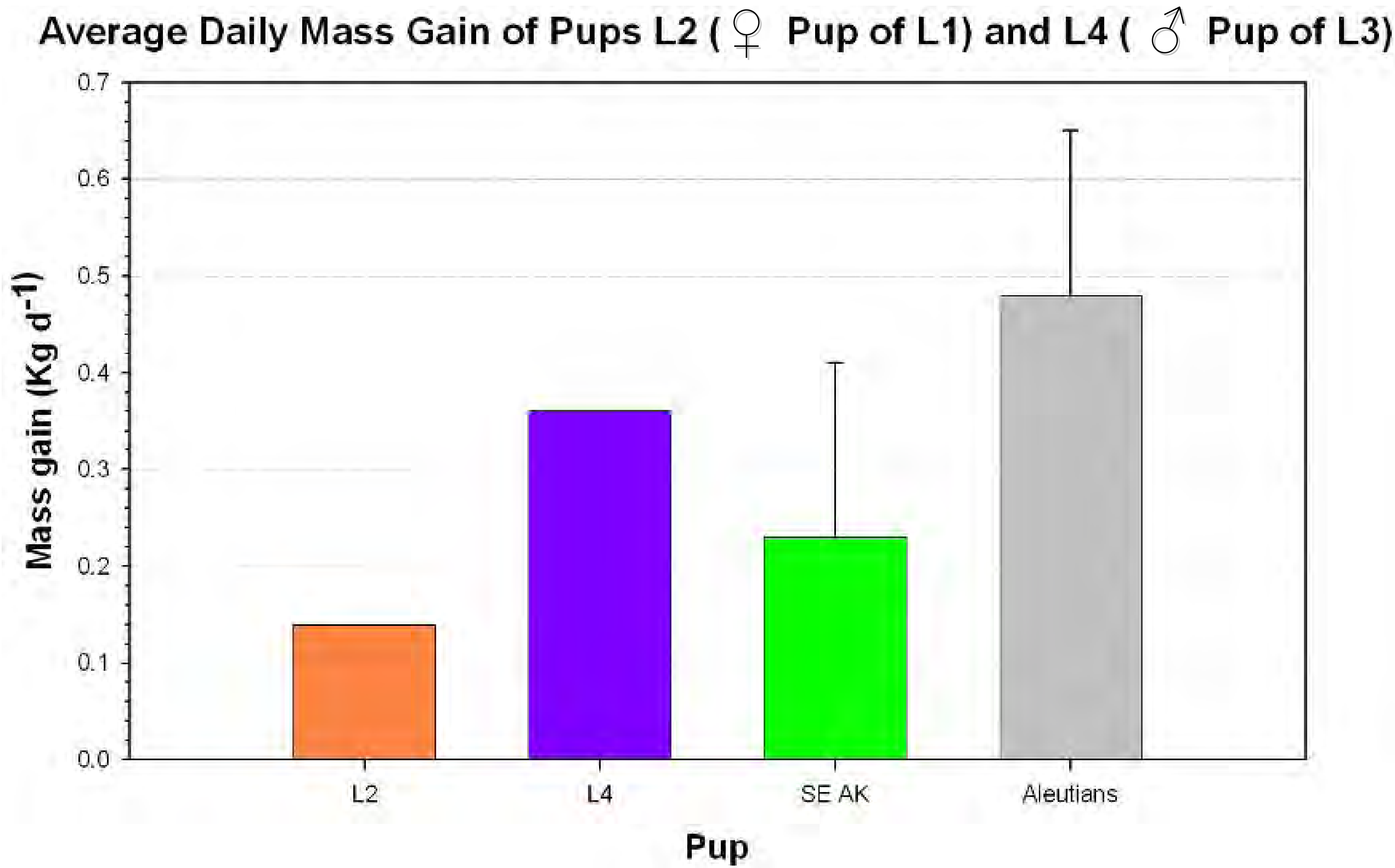
Adult Female Blood Urea Nitrogen
Blood Urea Nitrogen (mg/dl)
35
30
25
20
15
10
5
L3
L5
L1
0
5
10
15
20
25
30
35
Days after capture
BUN range
rookery
sea lions


Mean Daily Percent Mass Loss of Females L1, L3 and L5
Percent Mass (%)
0.0
0.2
0.4
0.6
0.8
L1
L3
L5
Female


Milk Gross Energy Content for Females L1, L3 and L5
Gross Energy (kJ/g wet weight)
0
2
4
6
8
10
12
14
16
18
10.6
13.6
13.2
L1
L3
L5
Female


Pup L2 and L4 Mass
Mass (kg)
26
28
30
32
34
36
38
40
42
44
46
48
0
10
20
30
40
Days after capture
L4♂
L2♀


Average Daily Mass Gain of Pups L2 (♀ Pup of L1) and L4 (♂ Pup of L3)
Mass gain (Kg d-1)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.14 Kg d-1
0.36 Kg d-
L2
L4
SE AK
Aleutians
Pup



Average Daily Mass Gain of Pups L2 (♀ Pup of L1) and L4 (♂ Pup of L3)
Mass gain (Kg d-1)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
L2
L4
SE AK
Aleutians
Pup



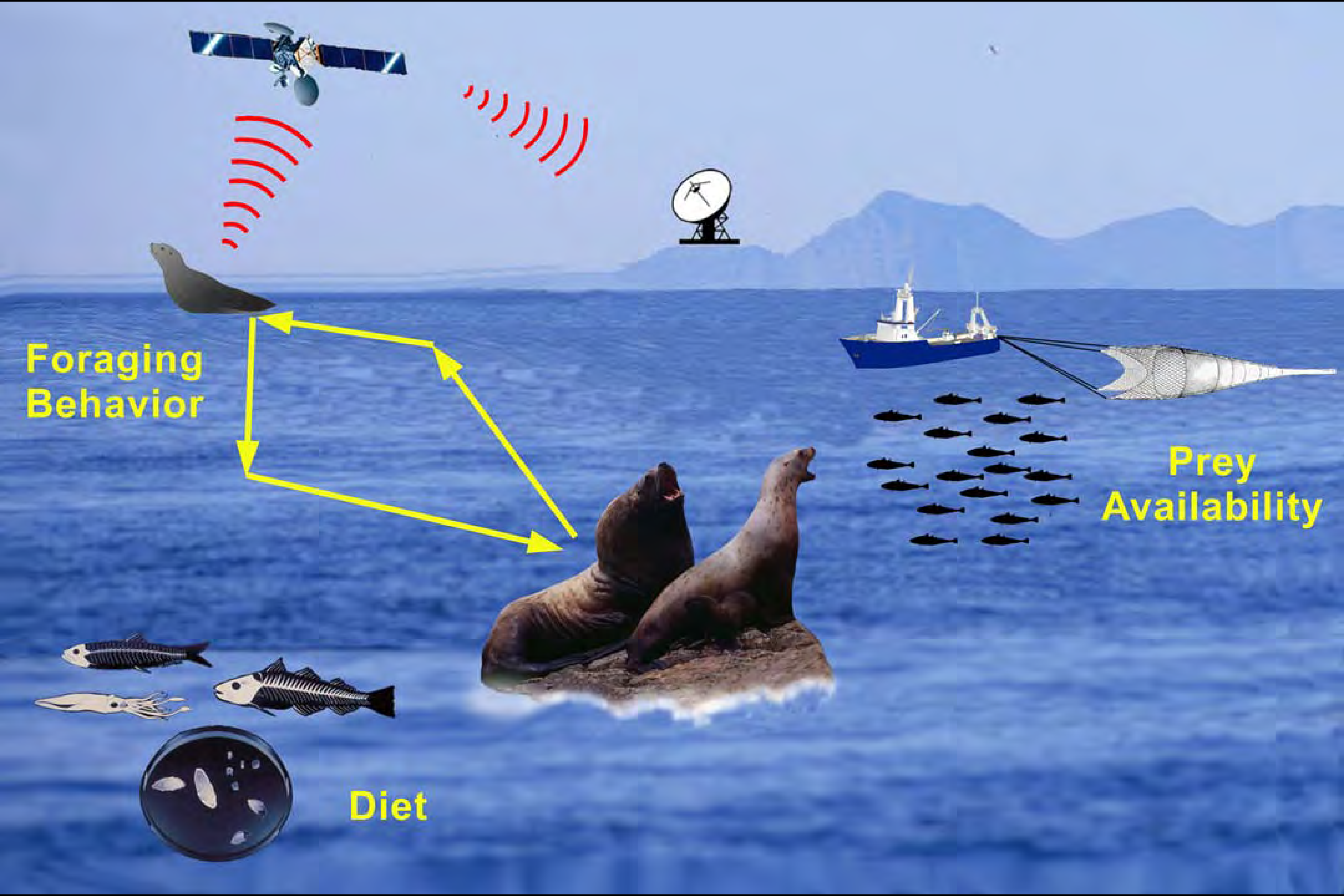


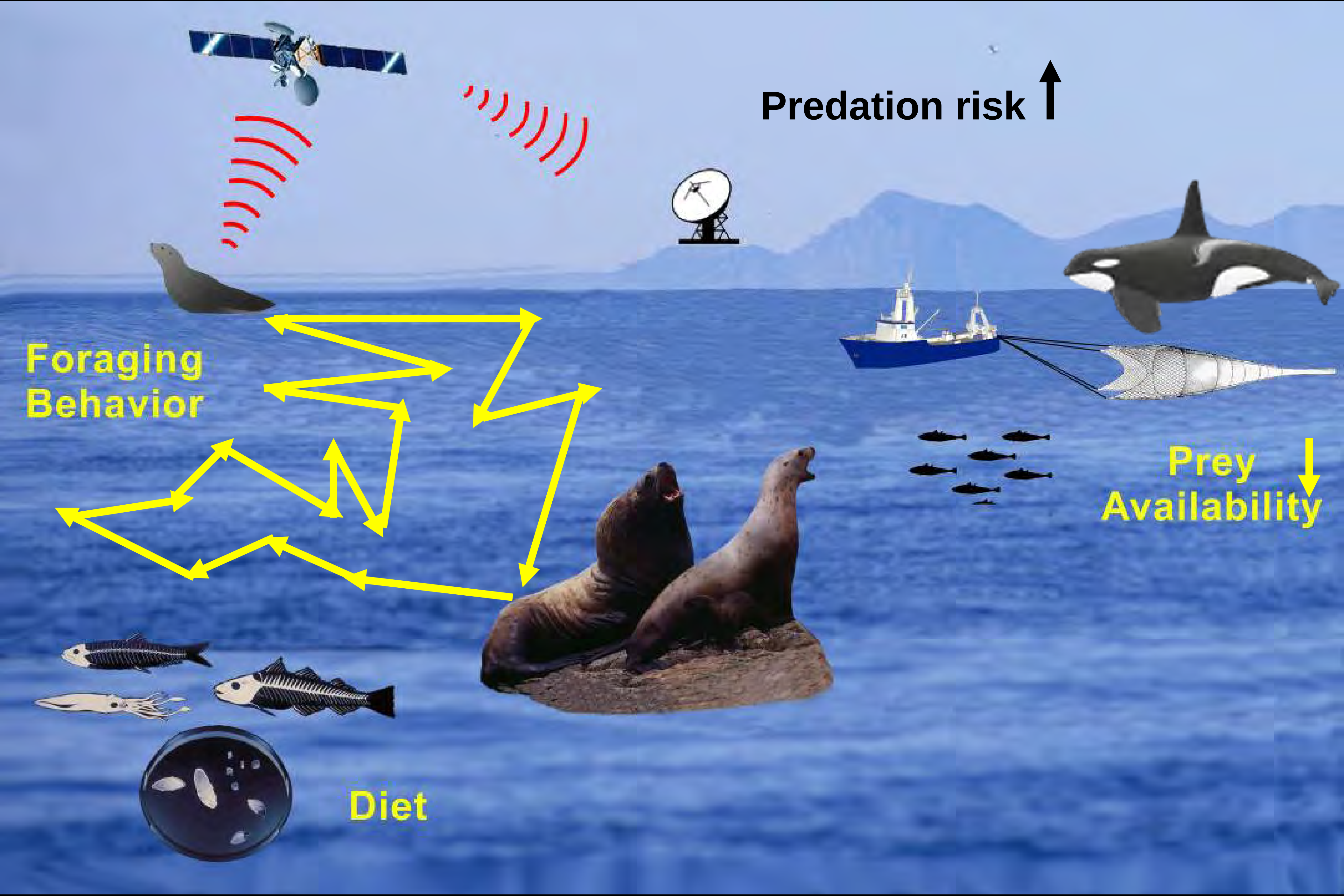
- Duration of transmissions:
  - L1: 4 months
  - L3: 11 months
  - L5: 2 weeks

June 2006

- Submersion sensor posts snapped off – seawater intruded and shorted out battery, leading to a continuing source of irritation. Otherwise pouch epithelialization was successful.
- Future tags would not need sensors posts – technique holds promise for multiple-year monitoring of individuals

June 21, 2007


Foraging
Behavior
Prey
Availability
Diet

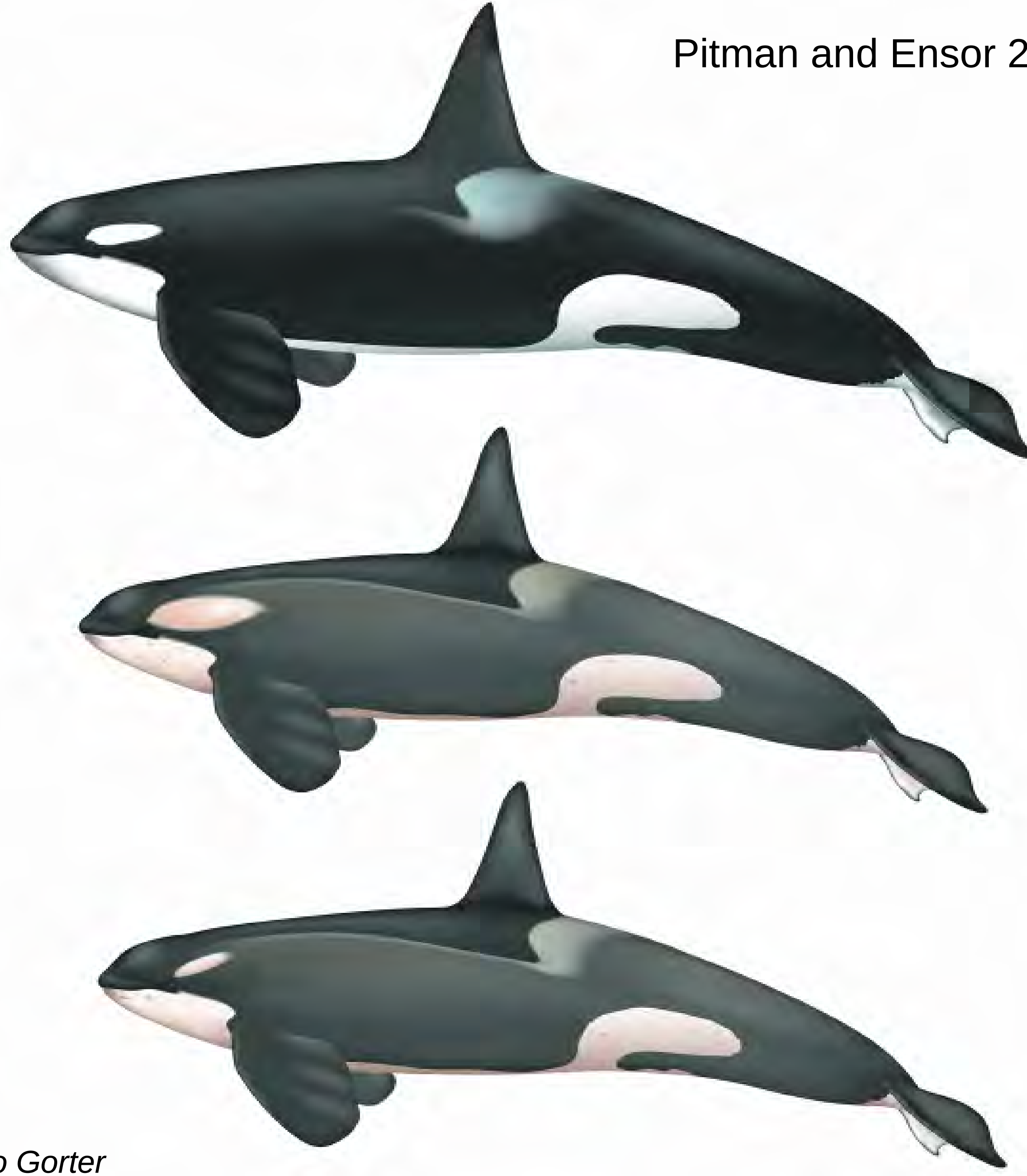

Predation risk
Foraging Behavior
Prey Availability
Diet

Pitman and Ensor 2003

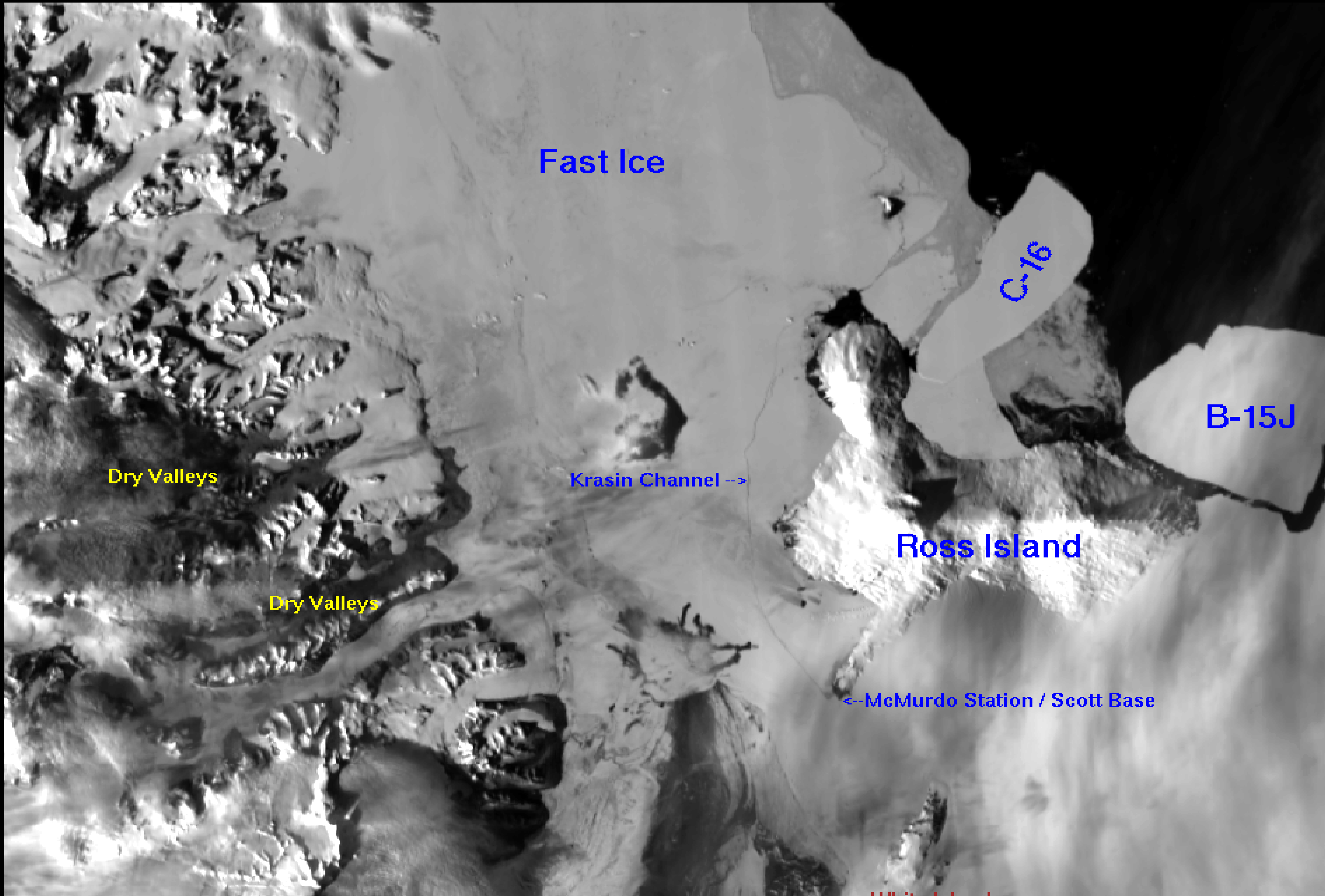
- Type A
  - black & white
  - open water
  - minke specialist

- Type B
  - gray, black, white
  - loose pack ice
  - seal specialist

- Type C
  - gray, black, white
  - dense pack ice
  - fish specialist



Illustrations Uko Gorter


Fast Ice
C-16
B-15J
Dry Valleys
Krasin Channel -->
Ross Island
Dry Valleys
<--McMurdo Station / Scott Base

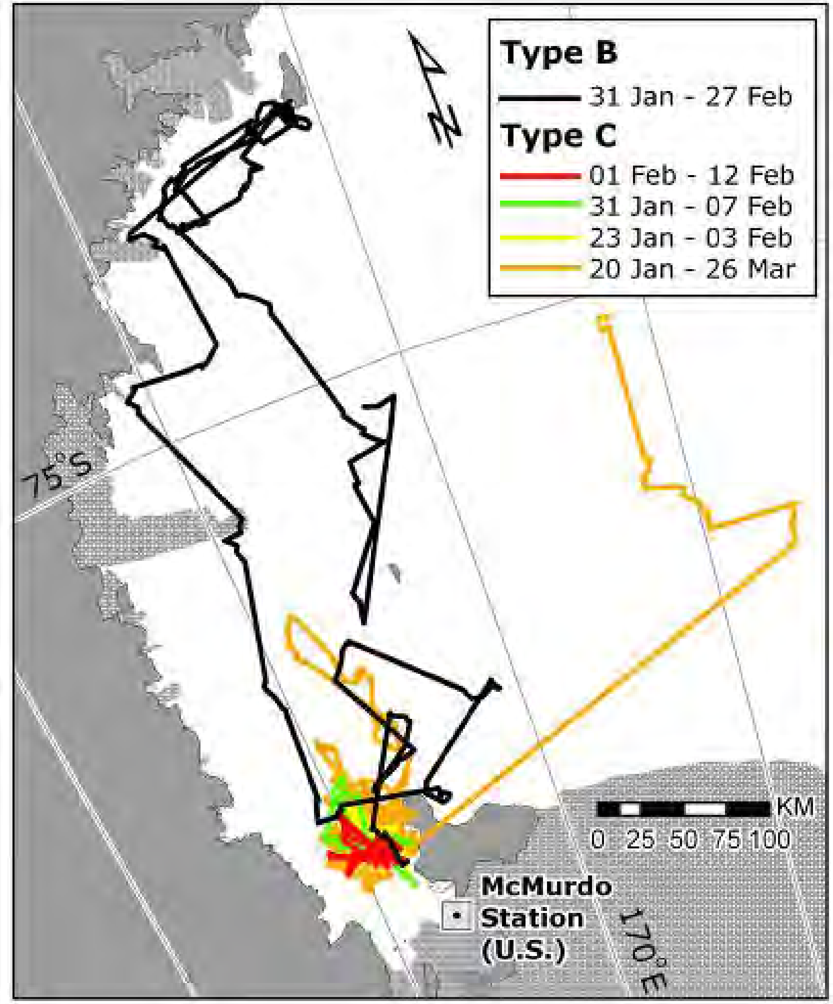
Type B adult female tagged in McMurdo Sound, Antarctica – duration of attachment: 27 days

(Andrews, Pitman, & Ballance 2008; Polar Biology)

- Type B
  - gray, black, white
  - loose pack ice
  - seal specialist

- Type C
  - gray, black, white
  - dense pack ice
  - fish specialist

Pitman and Ensor 2003

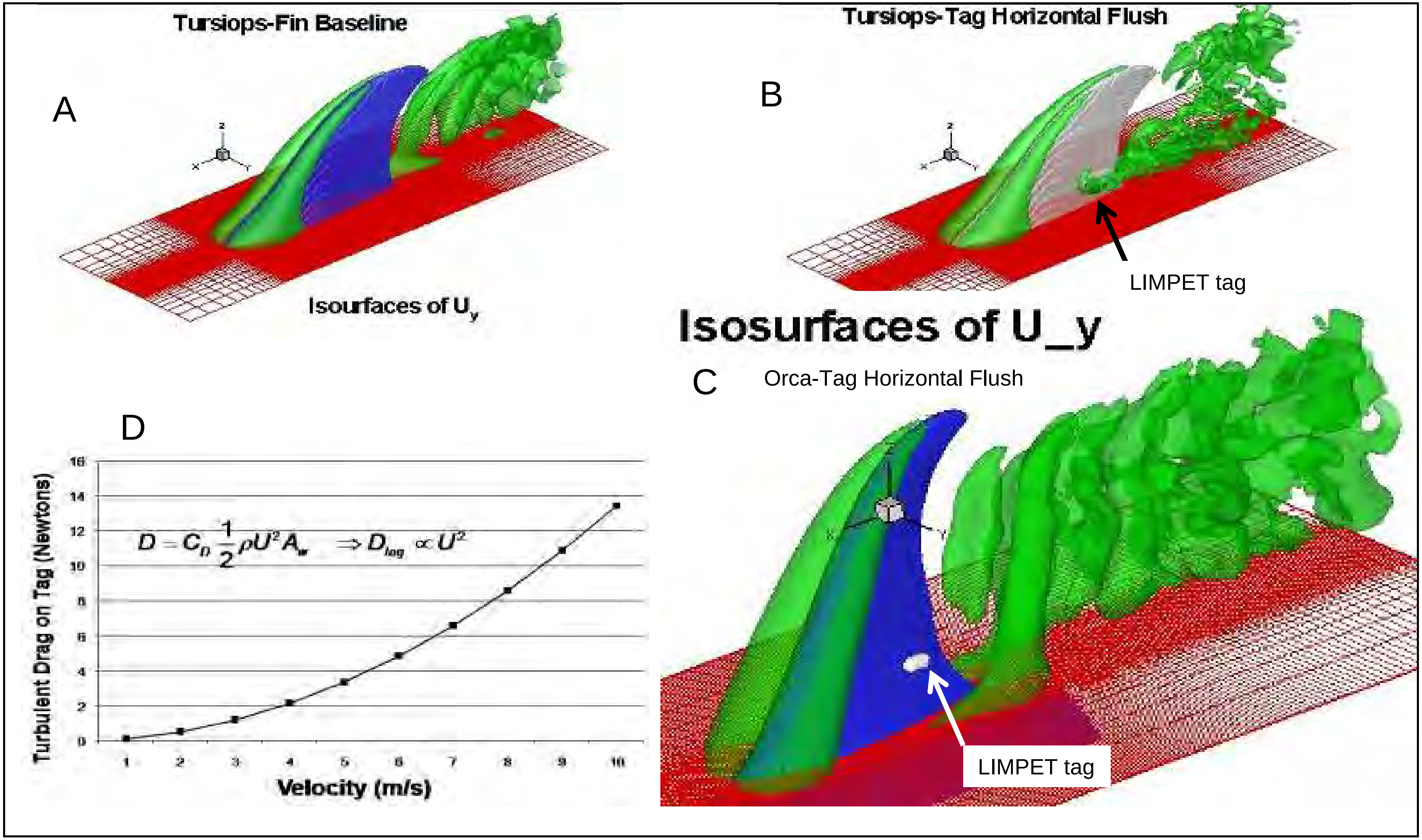


Andrews et al. (2008). Polar Biology

Illustrations Uko Gorter

LIMPET Tag
(Low Impact Minimally Percutaneous External-electronics Transmitter)

Andrews et al. 2008. Polar Biol. 31:1461-1468



Mittal, Najjar, Fish and Hanson, unpublished data


East Siberian Sea
CANADA
YUKON TERRITORY
S A K H A
A S I A
Yakutsk
Kovlyuneskin
Fairbanks
Yukon
A L A S K A
Arctic Circle
Mount McKinley 20,320 ft
RUSSIA
C H U K O T
KHABAROVSK
MAGADAN
Anadyr'
UNITED STATES
Anchorage
NORTH AMERICA
International Date Line
KORYAK
Magadan
Tigil'
Bering Sea
Gulf of Alaska
Sea of Okhotsk
Petropavlovsk-Kamchatskiy
PACIFIC OCEAN
120°
125°
130°
135°
140°
145°
155°
160°
165°
170°
175°
180°
130°
60°
140°
55°
145°
50°
©2005 Microsoft Corp.

Bering Sea
Moffet Point
Izembek Lagoon
Cape Glazenap
Cold Bay
Cold Bay
ALASKA
PENINSULA
Thin Point
Cape Krenitzin
Otter Point
Bechevin Bay
Cape Lapin
Cape Mordvinof
ALASKA
FOX ISLANDS
Morzhovoi
False Pass
Black Hill
ALEUTIANS EAST
Isanotski Peaks
Sentinal Peak
Ikatan Bay
Shishaldin Volcano 9414 ft
Eickelberg Peak
UNIMAK ISLAND
Dora Peak
Cape Pankof
Conical Red Hill
Brown Peak
Lazaref Peak
Pogromni Volcano
Faris Peak
Westdahl Peak
Cape Lutke
Promontory Hill
Seal Cape
Sanak
Sanak Peak
ALEUTIAN ISLANDS
Akun Bay
AKUN
PACIFIC OCEAN
55
54° 30


© John Durban

Photographic documentation of killer whale AK1 dorsal fin response to tagging

AK1 tagged 09 August 2006

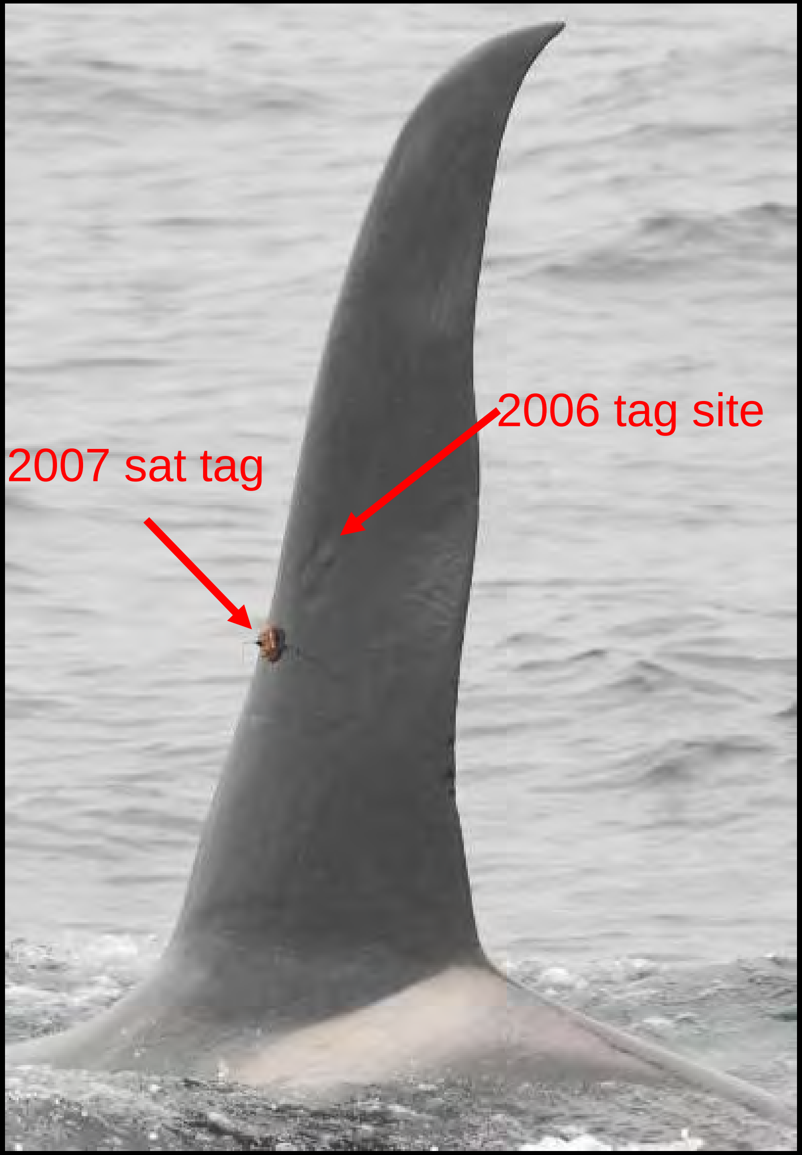
24 days after deployment.

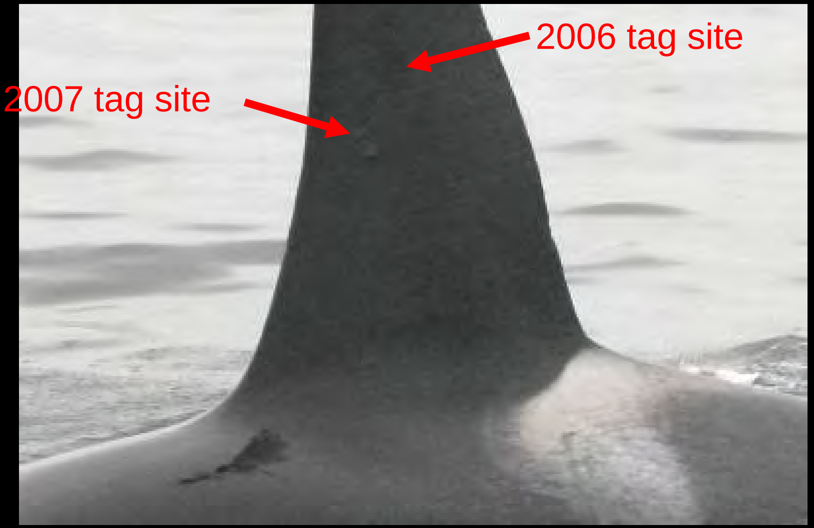
35 days after deployment

262 days after tag deployment and 217 days after tag fell out (attachment duration: 45 d).

Note: dart penetration holes have completely healed over, but there is a small swelling at the site of each dart penetration point.

AK1 was tagged a 2nd time on 12 June 2007
307 days after first tag deployment:





361 days after first tag deployment
(54 days after the 2nd satellite tag attachment; dur. 24 d)
Swelling at the 2006 satellite tag site no longer visible, two similar points of swelling apparent at dart penetration points for 2007 tag.

405 days after first tag deployment
(98 days after the 2nd satellite tag attachment)
All wounds repigmented and healed, no more swelling or scars visible at either tag site.

2006 thru 2008: 47 Alaskan killer whales tagged in the dorsal fin:
Mean duration: 28 days (median = 26 d)[1]

18 out of 47 displayed no immediate visible response to tagging

For '06 & '07 whales, 20 of 29 have been resighted from 1 day to 3 years after tagging; none of them had anything worse than a small (2- 3 cm diameter) scar that appeared to have healed well.

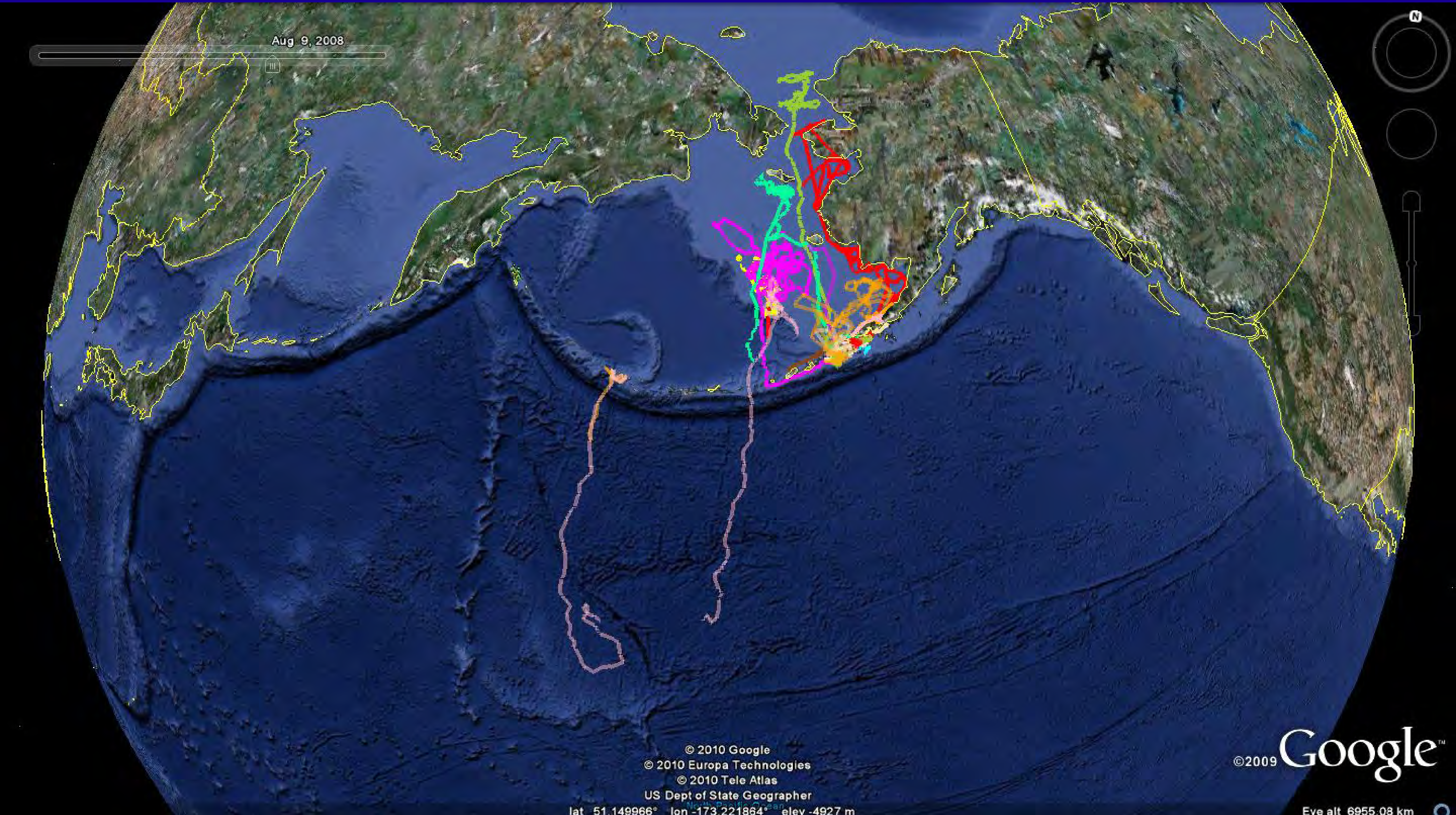
No evidence of increased mortality

Tags last longer when attached to the dorsal fin (blubber n=9, mean 14 d, median 6 d) , but one whale tagged in the flank transmitted for 86 days:

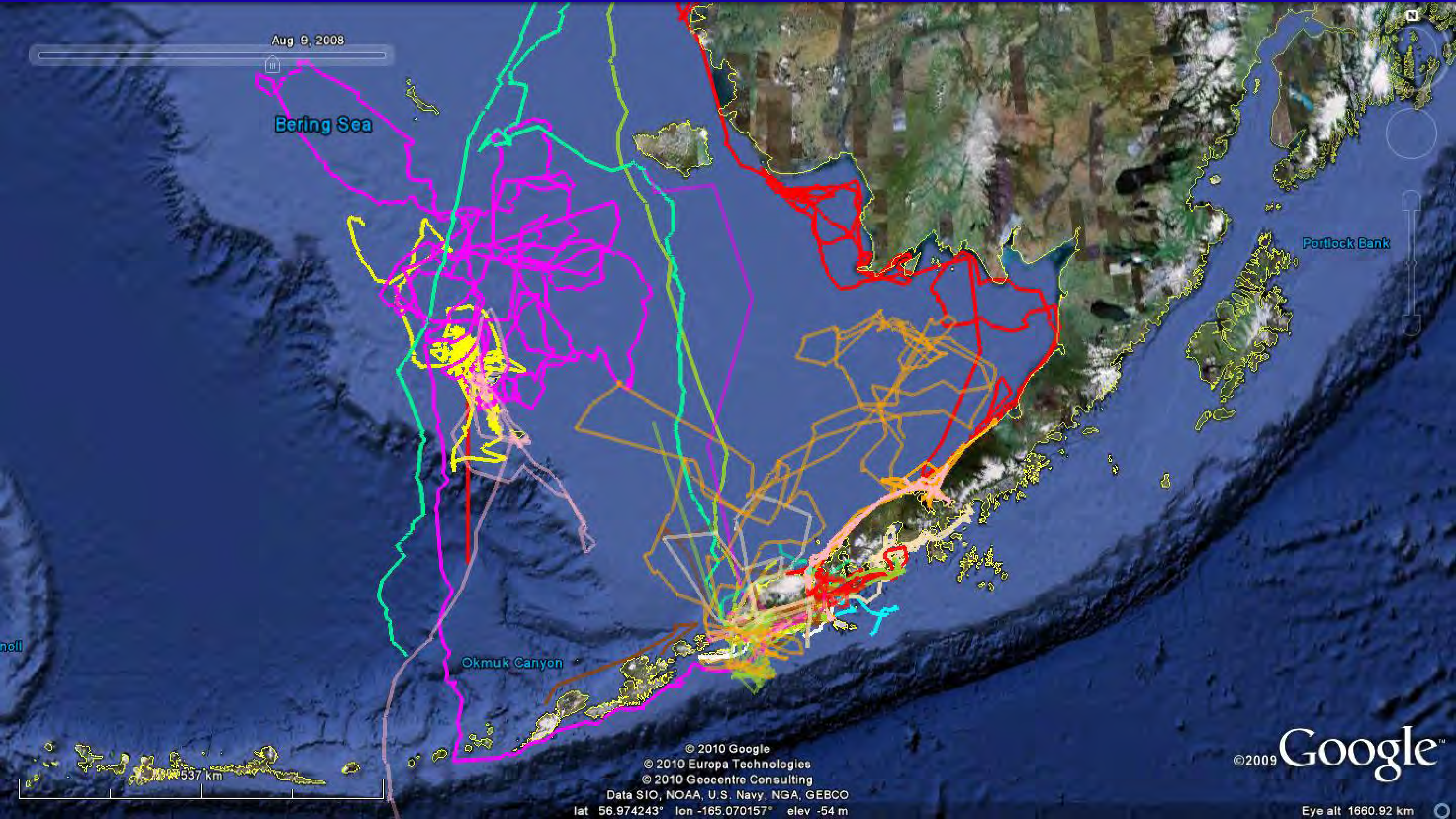
WT364 tagged in AK by J. Durban on 15May08.
(left photo: 17May08, L. Barrett-Lennard; right: D. Ellifrit, 21May08)

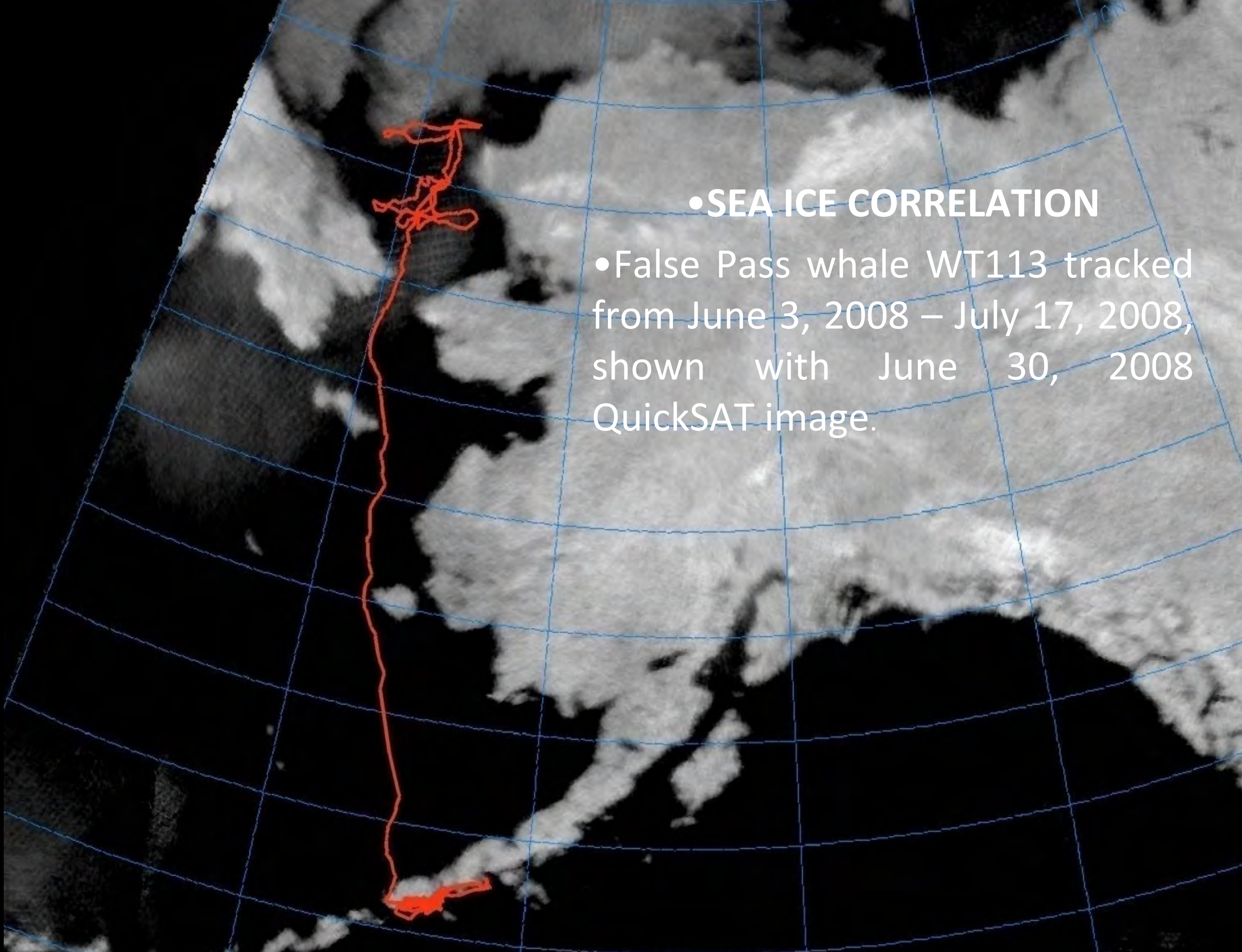
1: Andrews, R., J. Durban & C. Matkin, unpublished data

LIMPET tag (w/ 6.5 cm Ti darts) on mammal-eating killer whales 2006-2009:



LIMPET tag (w/ 6.5 cm Ti darts) on mammal-eating killer whales 2006-2009:

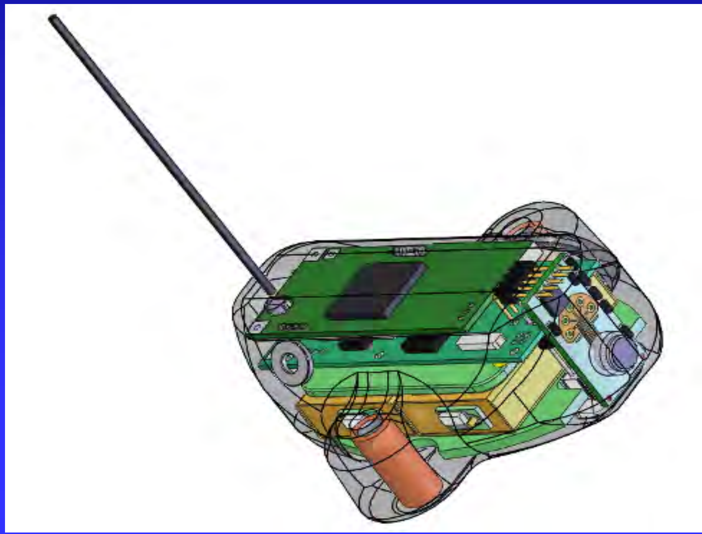




•SEA ICE CORRELATION

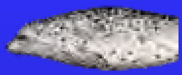
•False Pass whale WT113 tracked from June 3, 2008 – July 17, 2008, shown with June 30, 2008 QuickSAT image.

- Impact of killer whale predation on marine mammal populations?



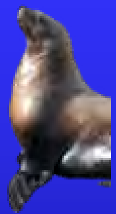
6 sea otters

or



2/3 of harbor seal

or

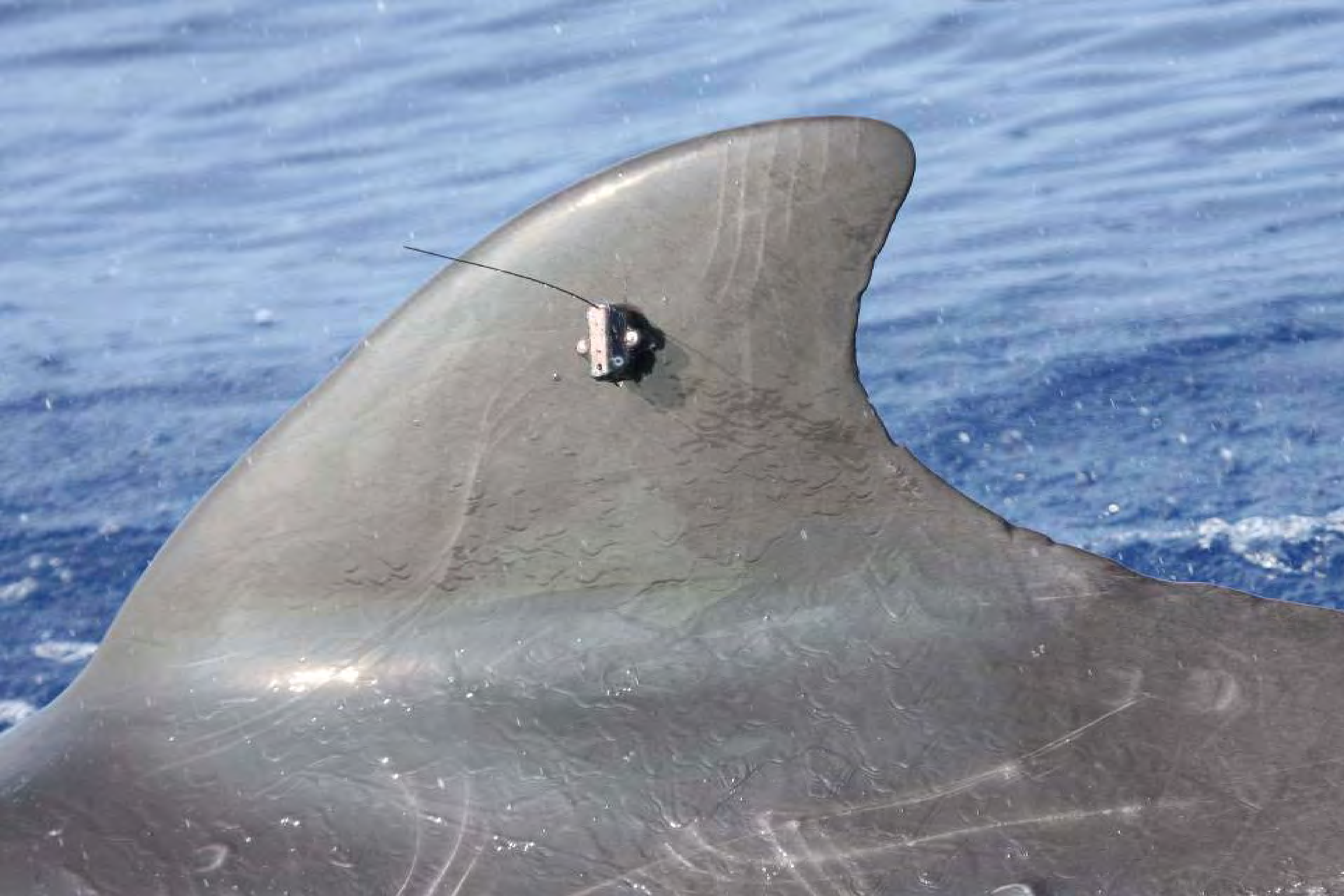


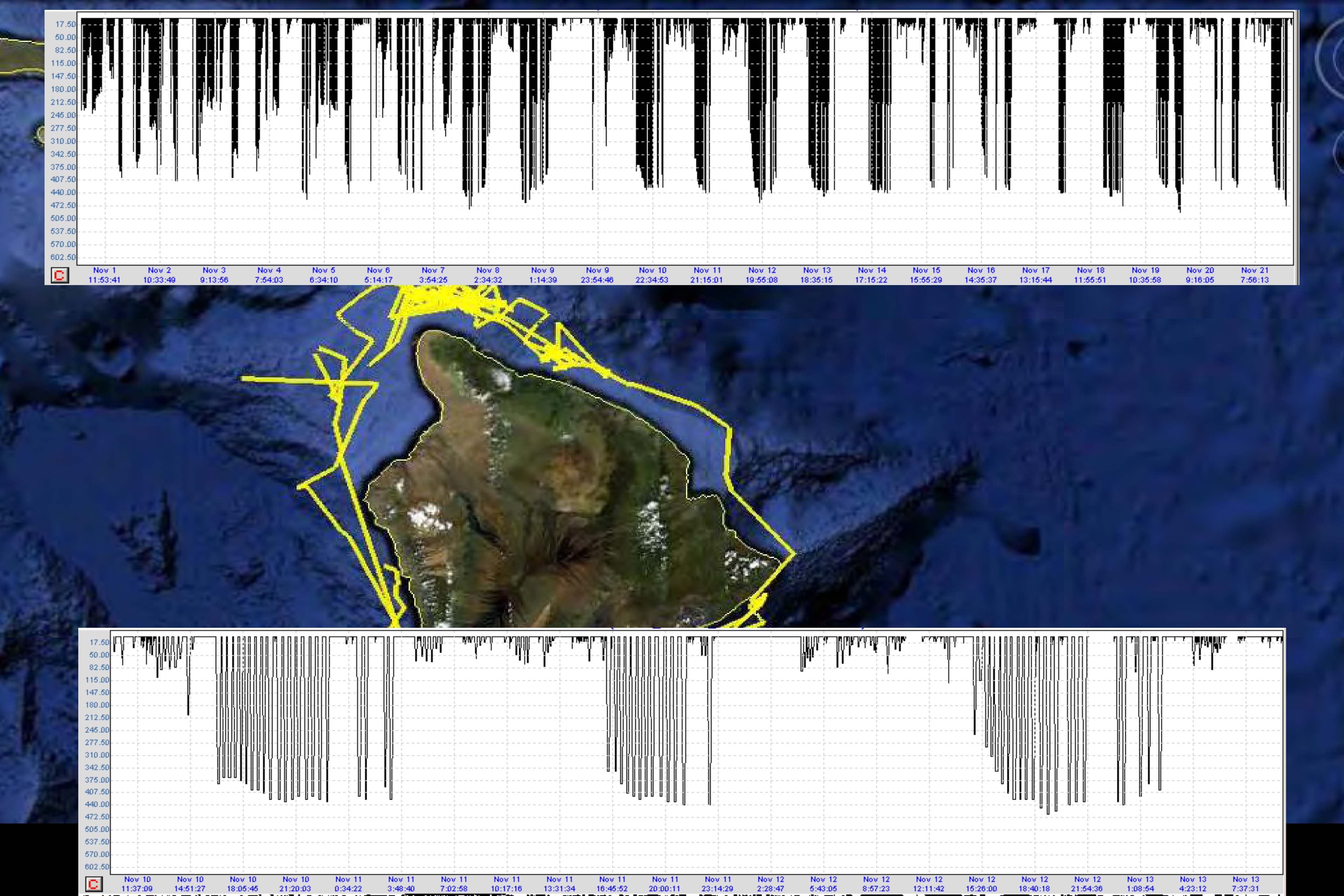
1/2 of Steller sea lion

or

6 Steller sea lion pups

Caloric requirements: female: 193,210 kcal day^{-1} Williams et al. (2004)

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115.00
147.50
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Nov 1 11:53:41
Nov 2 10:33:49
Nov 3 9:13:56
Nov 4 7:54:03
Nov 5 6:34:10
Nov 6 5:14:17
Nov 7 3:54:25
Nov 8 2:34:32
Nov 9 1:14:39
Nov 9 23:54:46
Nov 10 22:34:53
Nov 11 21:15:01
Nov 12 19:55:08
Nov 13 18:35:15
Nov 14 17:15:22
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Nov 12 18:40:18
Nov 12 21:54:36
Nov 13 1:08:54
Nov 13 4:23:12
Nov 13 7:37:31

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