Preliminary Results of Application of Oil and Dispersed Oil on Drag on Bowhead Whale Baleen

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Goal:

Assess the effects of Alaska North Slope crude oil and Corexit 9500A on baleen *via* drag

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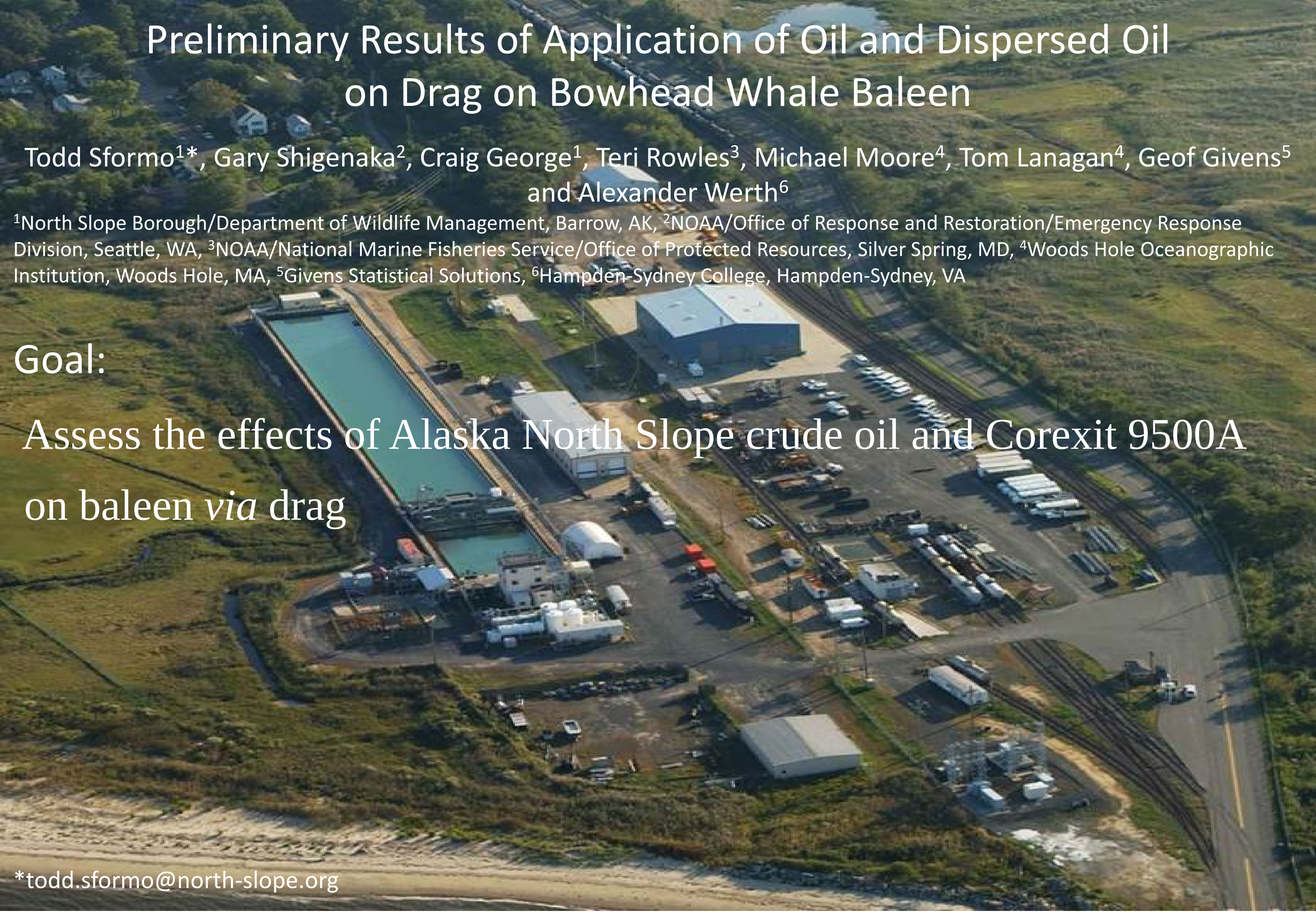


Oil and Hazardous Materials Simulated Environmental Test Tank, Leonardo, New Jersey

Photo: wikipedia.org/wiki/ Ohmsett#/media/File: Ohmsett_AerialOriginal_2-03.jpg

- *Balaena mysticetus* long-lived, large-bodied
- Inhabits arctic and sub-arctic waters—ice-associated cetacean
- Mainstay of food and cultural practices for the Inupiaq people of the North Slope
- Listed species
- Potential of fouling of baleen
    - Food Security
    - Oil contingency plans in the Arctic

- functional units of bowhead are the filter-feeding mechanisms are baleen

- 20 cm “hairs”
- Bristles create a high surface area
- Main Q: does crude oil cleave?

Braithwaite (1983)

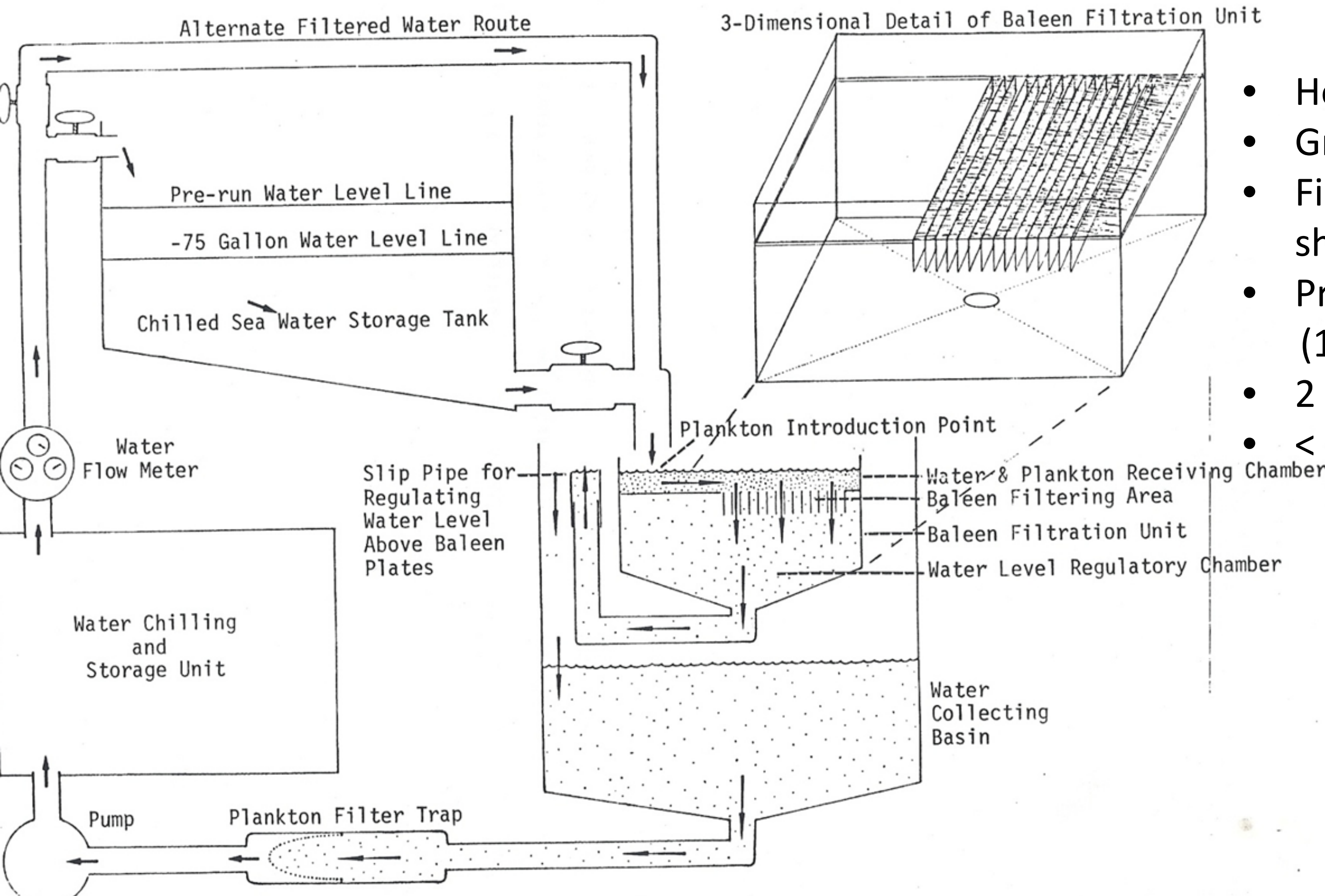


Figure 1. Experimental Baleen filtering apparatus showing the general system components and directional routes of water flow.

- Horizontally plates
- Gravity fed water
- Filtered brine shrimp
- Prudhoe Bay, 9527 (1-10mm fouling)
- 2 and 12 °C
- < 6-12%

Geraci and St Aubin 1990

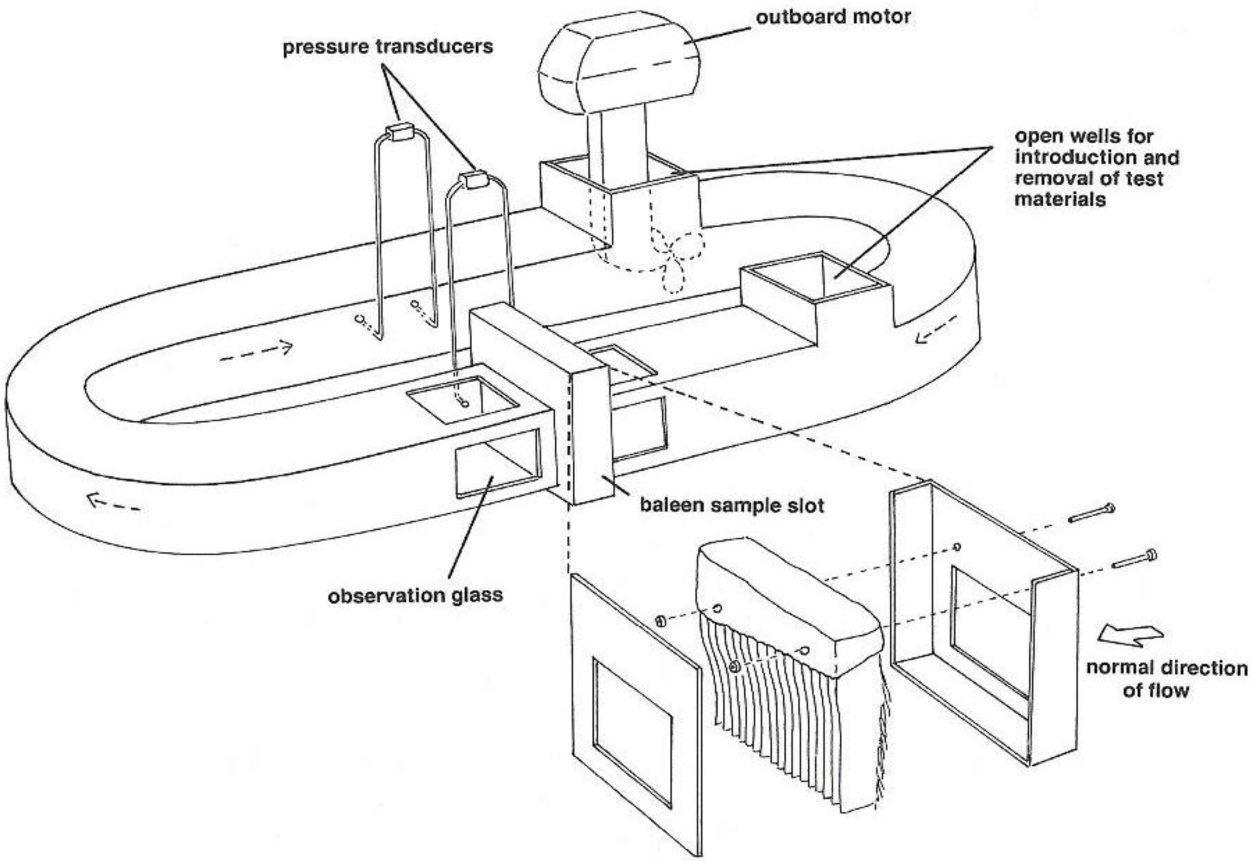


Figure 6-5
Tests were conducted in an elliptical tunnel with an outboard motor to circulate the water. Pressure transducers were positioned upstream and downstream from the baleen sample. Baleen specimens were mounted in a wooden frame for testing.

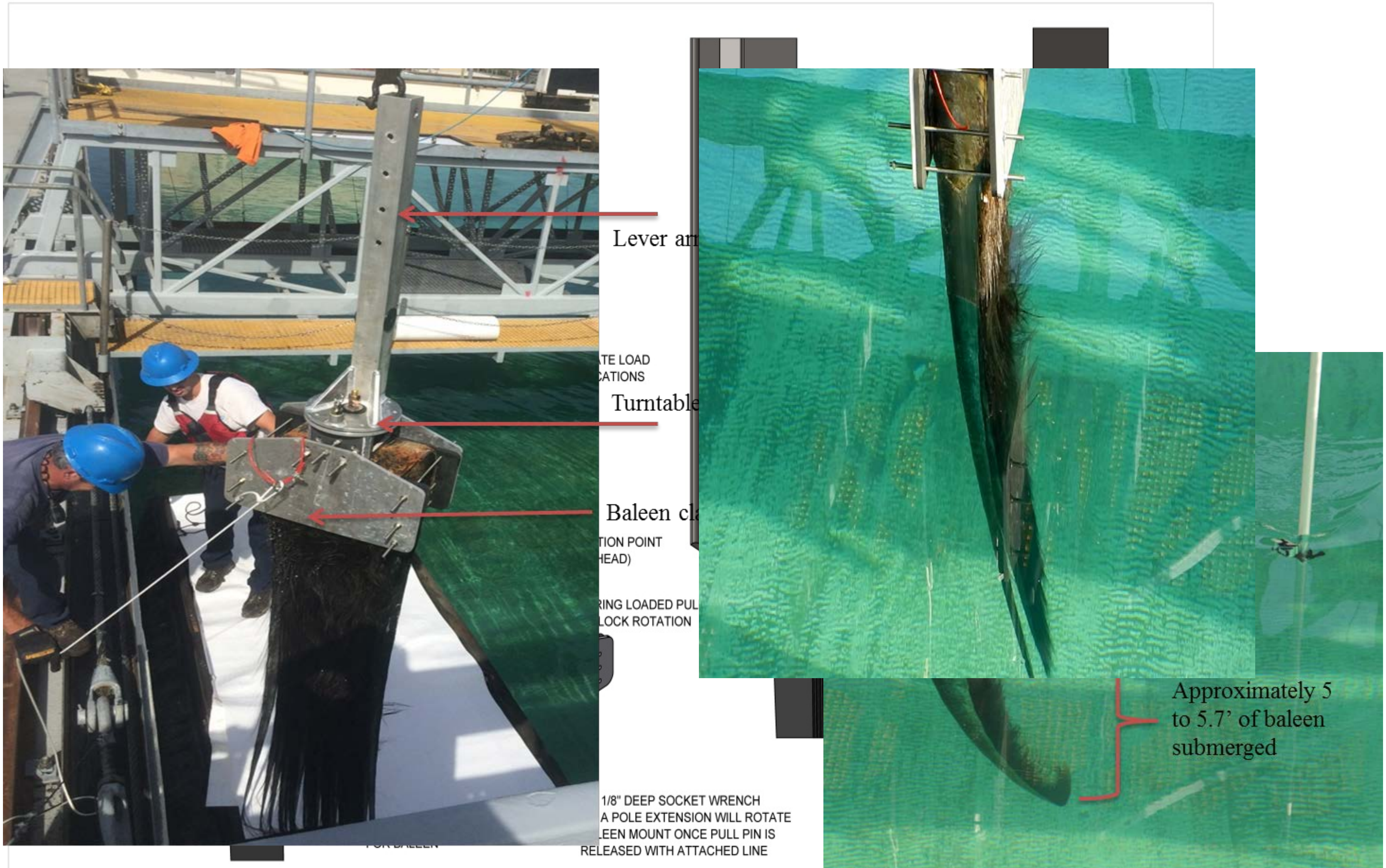
- Baleen from fin, gray, and humpback whale
- Bunker C oil
- resistance to flow [was] less than 75 % in fin and sei whale preparations. Gray whale samples were relatively unaffected

Methods & Materials

Oil and Hazardous Materials Simulated Environmental Test Tank, Leonardo, New Jersey

Methods & Materials

9 feet, 85 lbs., 15 plates



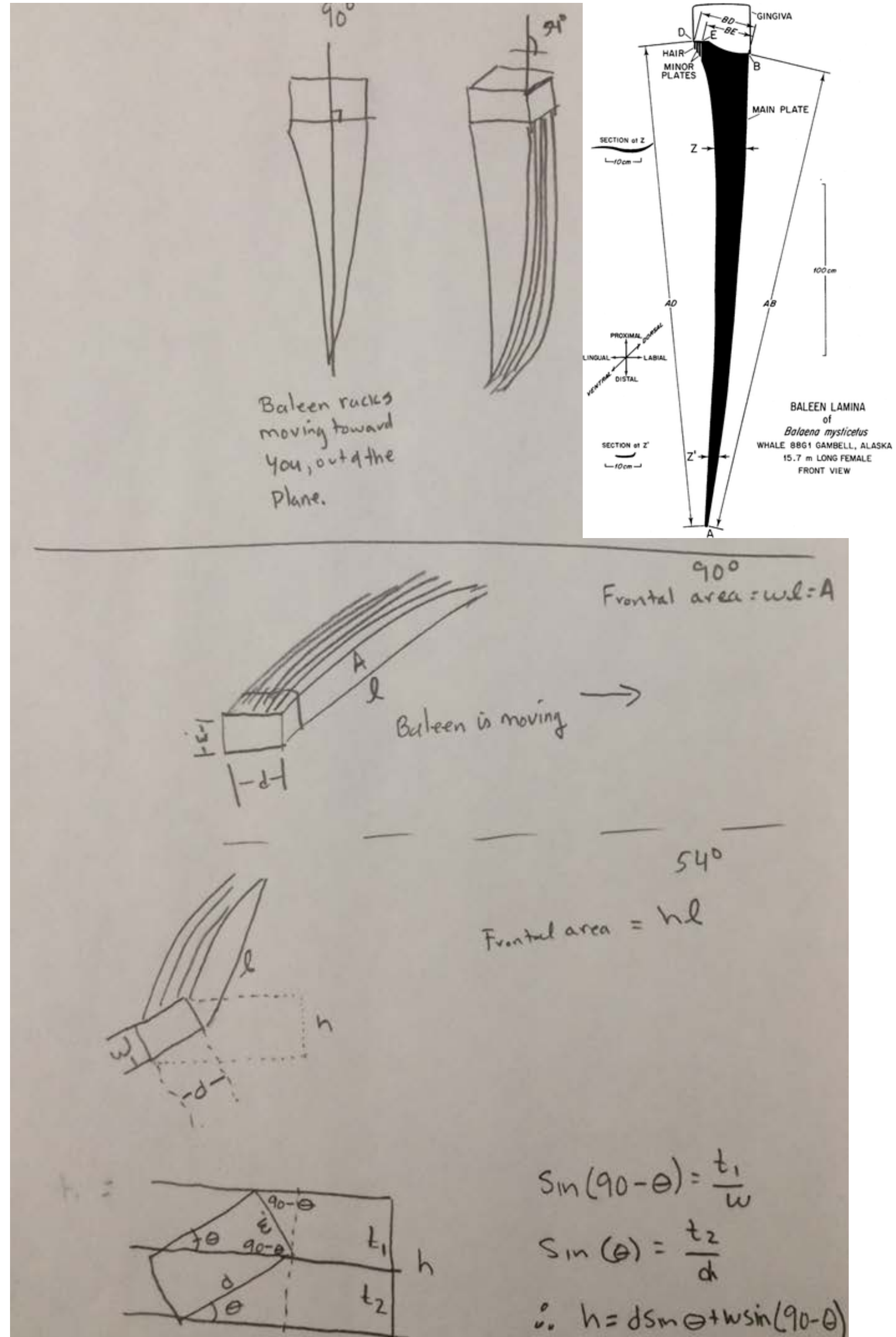
Baleen Mount (WHOI)

Recording Data

- LabView 10 Hz
- Load Cell: 100
- Bridges speed: 0.2 to 1.6 knots

Frontal Area calculation and sketch

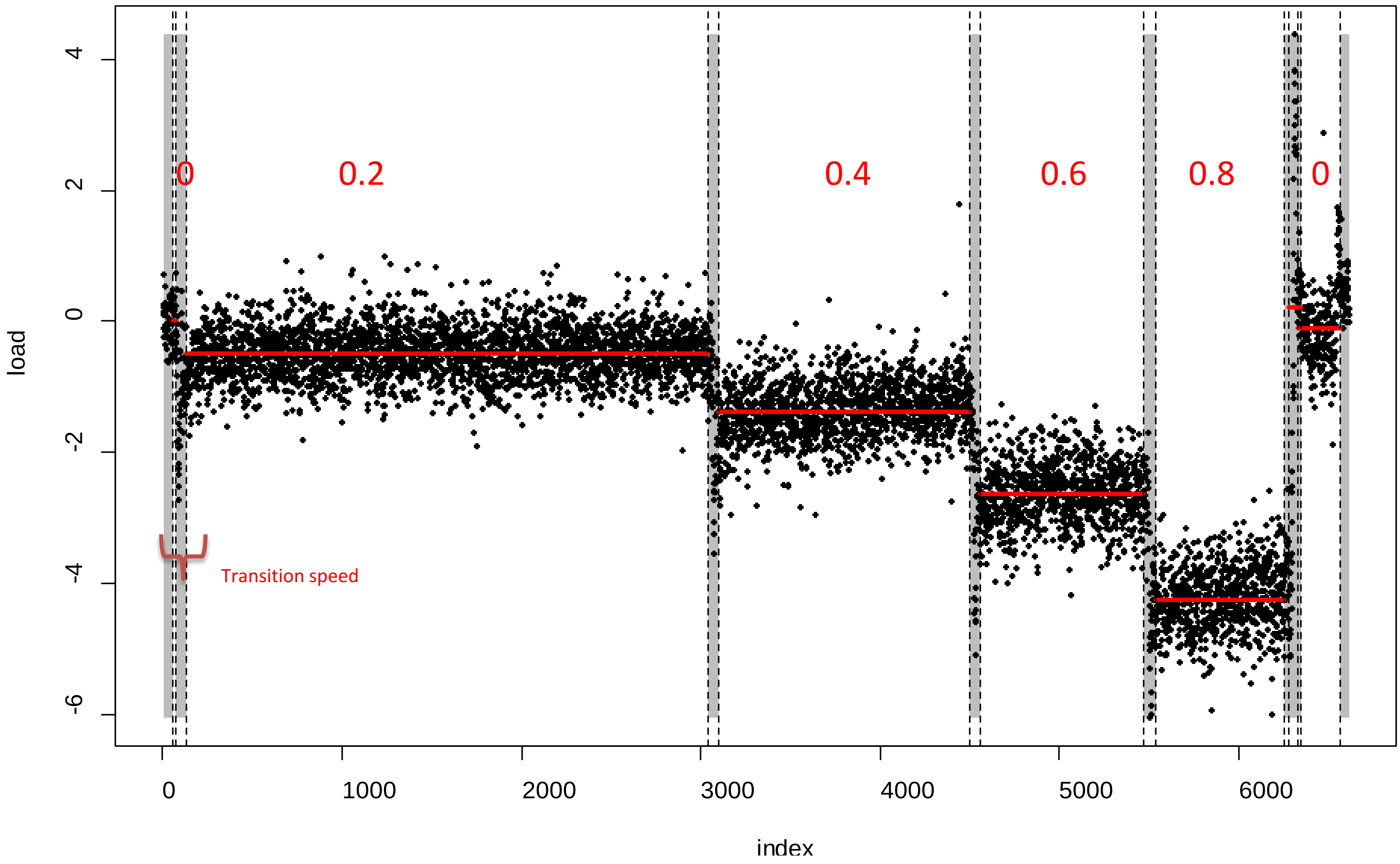
- bowhead racks that vary in plate number, length, and orientation



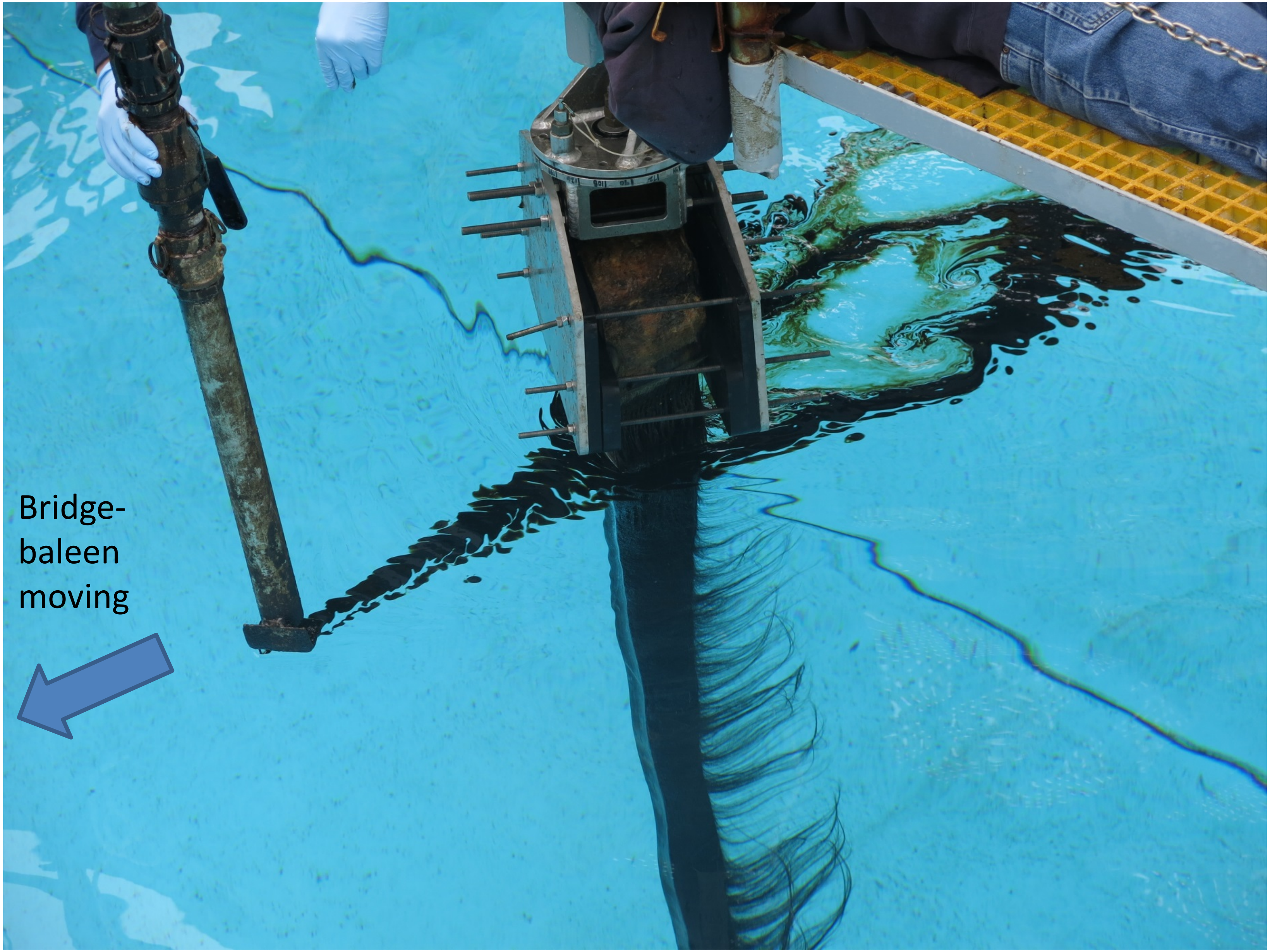
Baleen samples and calculation of frontal area
and ratio (exponientiated) between 54°/90° within a rack

Baleen Sample	Length (cm)	Depth (cm)	Width (cm)	Log Frontal Area (90°)	Log Frontal Area (54°)	Ratio of 54 to 90° by baleen rack
B30Long	200	41	26	8.556	9.17	1.86
B30short	110	29.2	12	7.185	8.12	2.55
B15	270	26	31	9.032	9.26	1.26
B10	270	15	31	9.032	9.01	0.97
B5	270	9	31	9.032	8.83	0.82
B22	190	37	19.8	8.233	8.97	2.09
B20	193	26	22.3	8.367	8.79	1.53

Run 28, recorded at 10 Hz. Data points with red lines are used to calculate median drag and mad.



Surface oil (fresh). Boom not touching water. Run 61



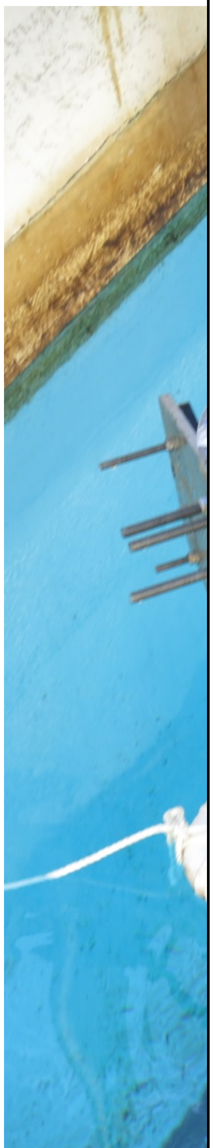
Boom dip. Done in this ord

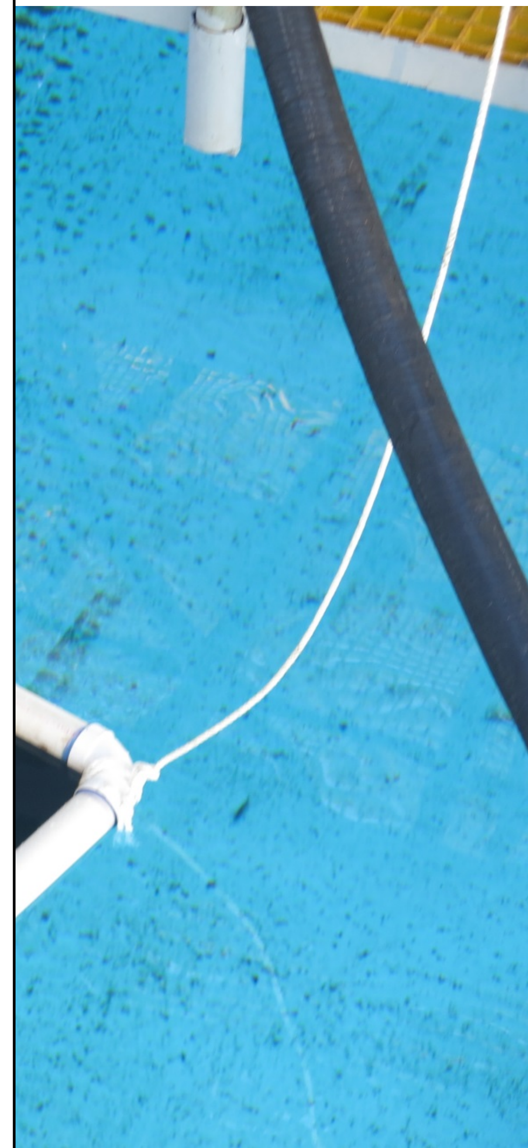
1. Lowered baleen in water in
2. Filled white hoop with oil (p
3. Withdrew baleen
4. Conduct run

Photo of Run 69

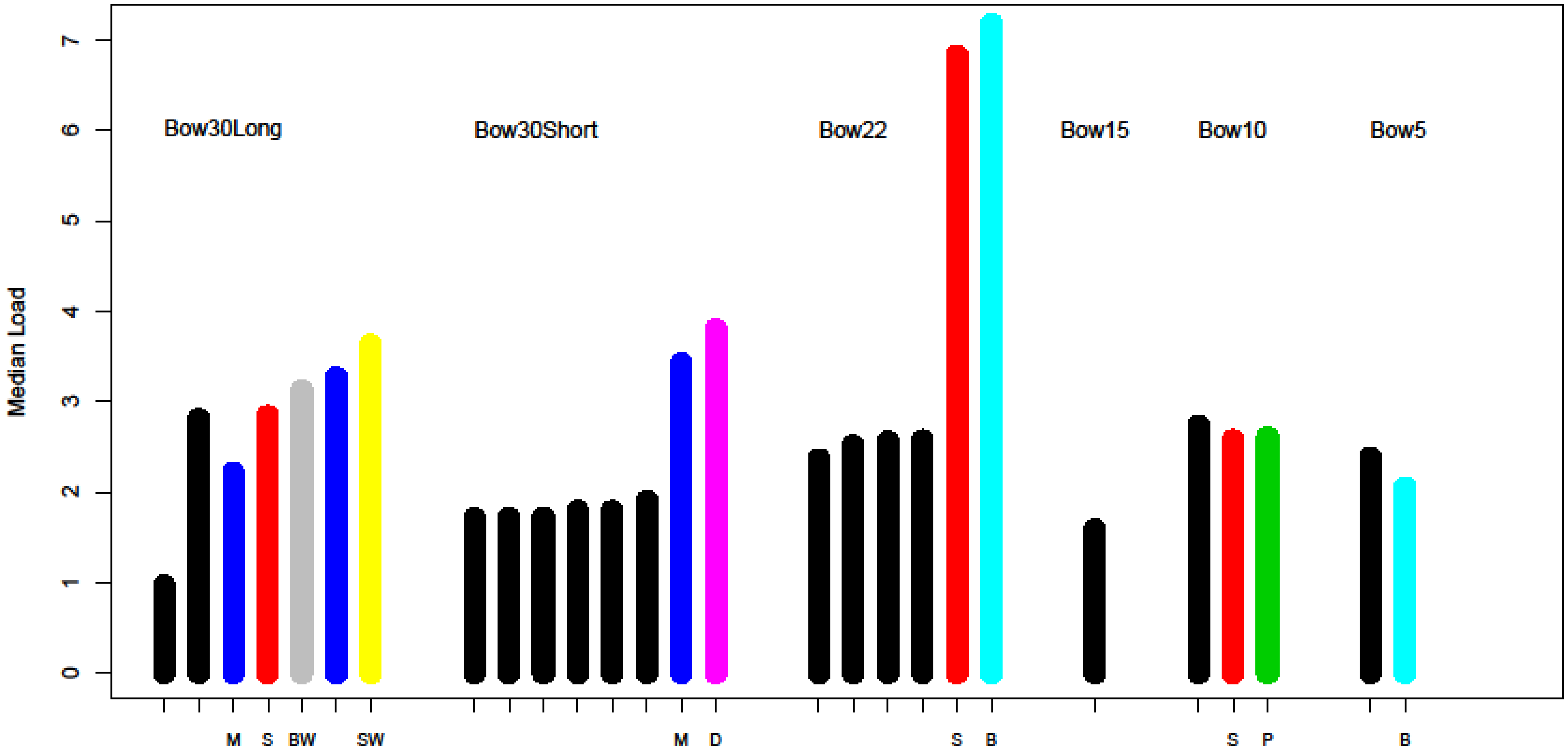
Apply dispersed oil

Video clip



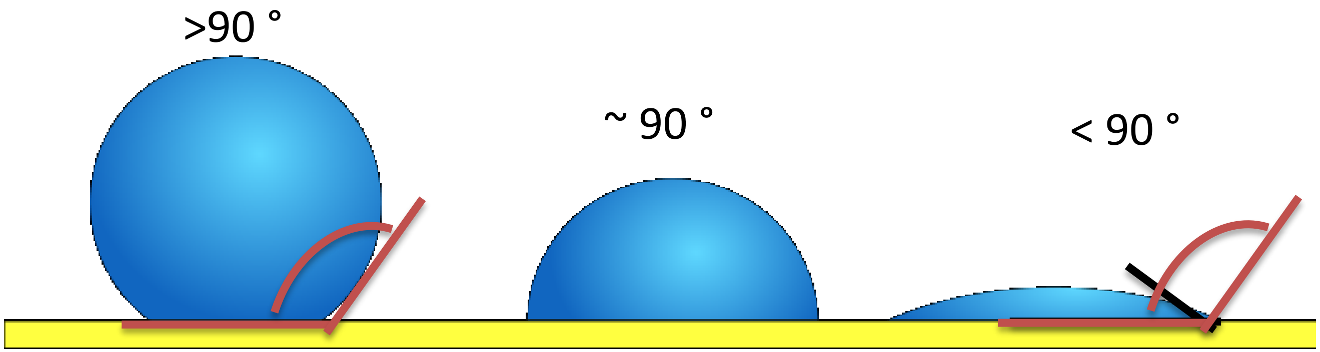


Results: (54 degrees and 0.6 knots)



- Control runs (n=15, black), 7 trt over 5 racks.
- Treatments: **S** (surface oil); P (painted oil); **M** (oil and dispersant via manifold); **B** (boom dip); D (dispersant); SW (weathered, surface); and BW (weathered, boom dip)
- Destructive sampling:
- Results indicate that under various treatments of oil and/or oil-dispersant drag does not appear to increase

A side study: ability of oil to wet baleen



From left to right, decreasing surface tension and contact angle *(source: White, Harvey E. (1948). Modern College Physics p 164).*

Contact Angle Measurements (conducted at Future Digital Scientific)

	Mean angle	STD	N
Crude oil (fresh)	144.5	22.0	6
Crude + dispersant	54.4	17.8	6
Crude oil 5°C	144.5	22.0	6
Crude oil -1.5°C	145.5	10.0	2

Does NOT necessarily mean biological significance

Acknowledgements

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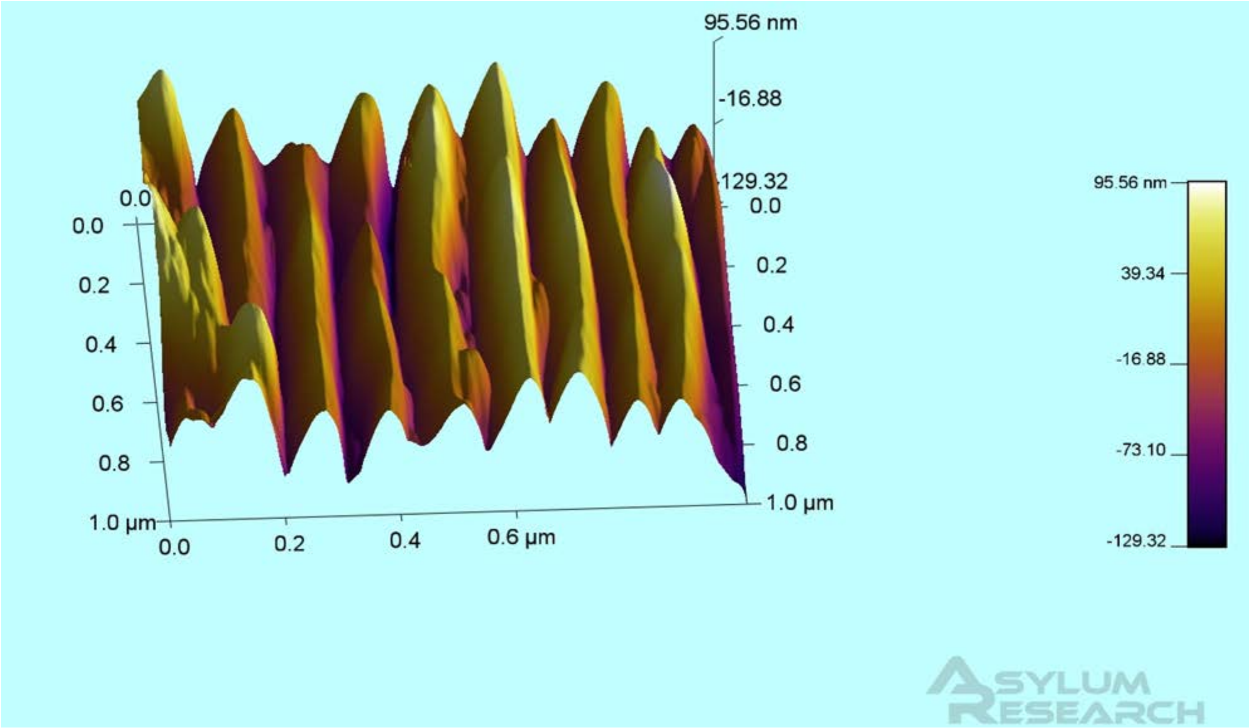
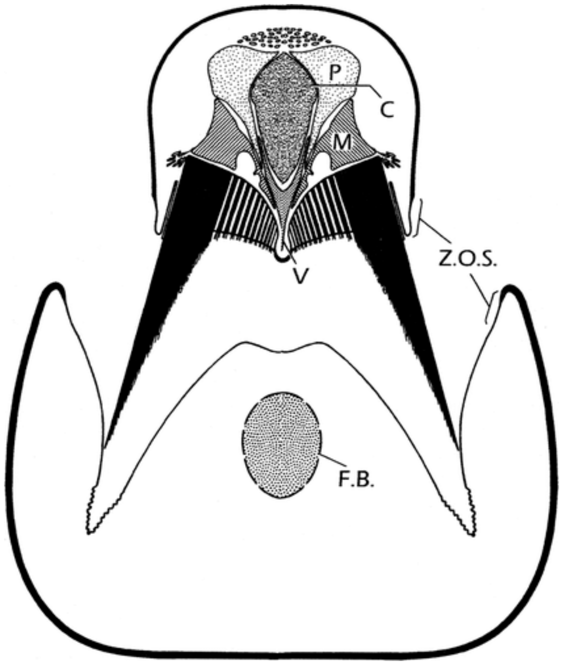
- OMSETT staff and engineers

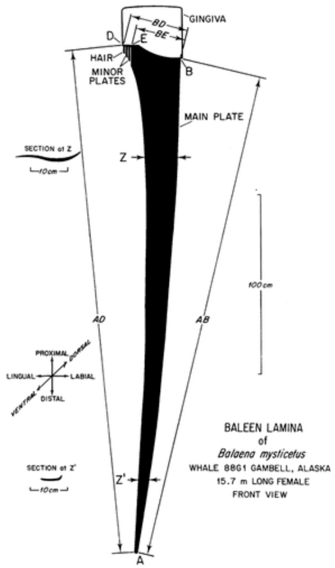
- Funding: NOAA and North Slope Borough Department of Wildlife Management

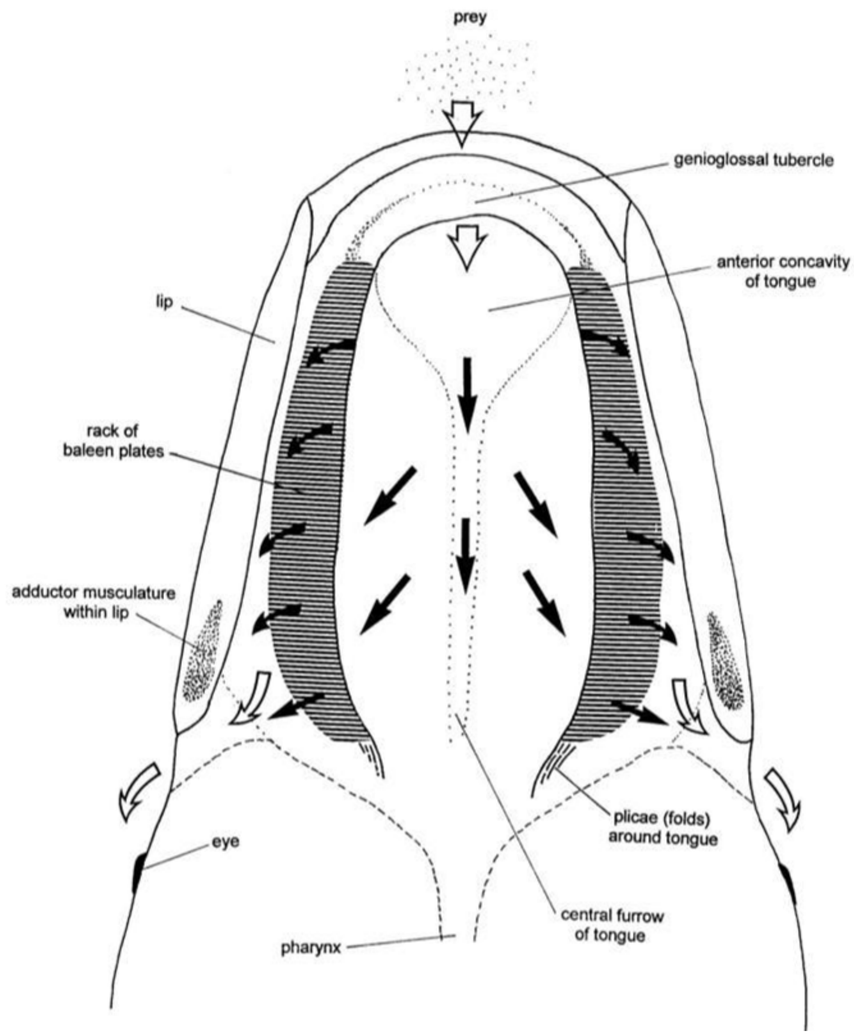
- Work was conducted under NMFS Permits 17350 and 18786



Baleen plate imaged on an atomic force microscope at Asylum Research (Santa Barbara, CA) by Todd Sformo and Sophia Hohlbauch.





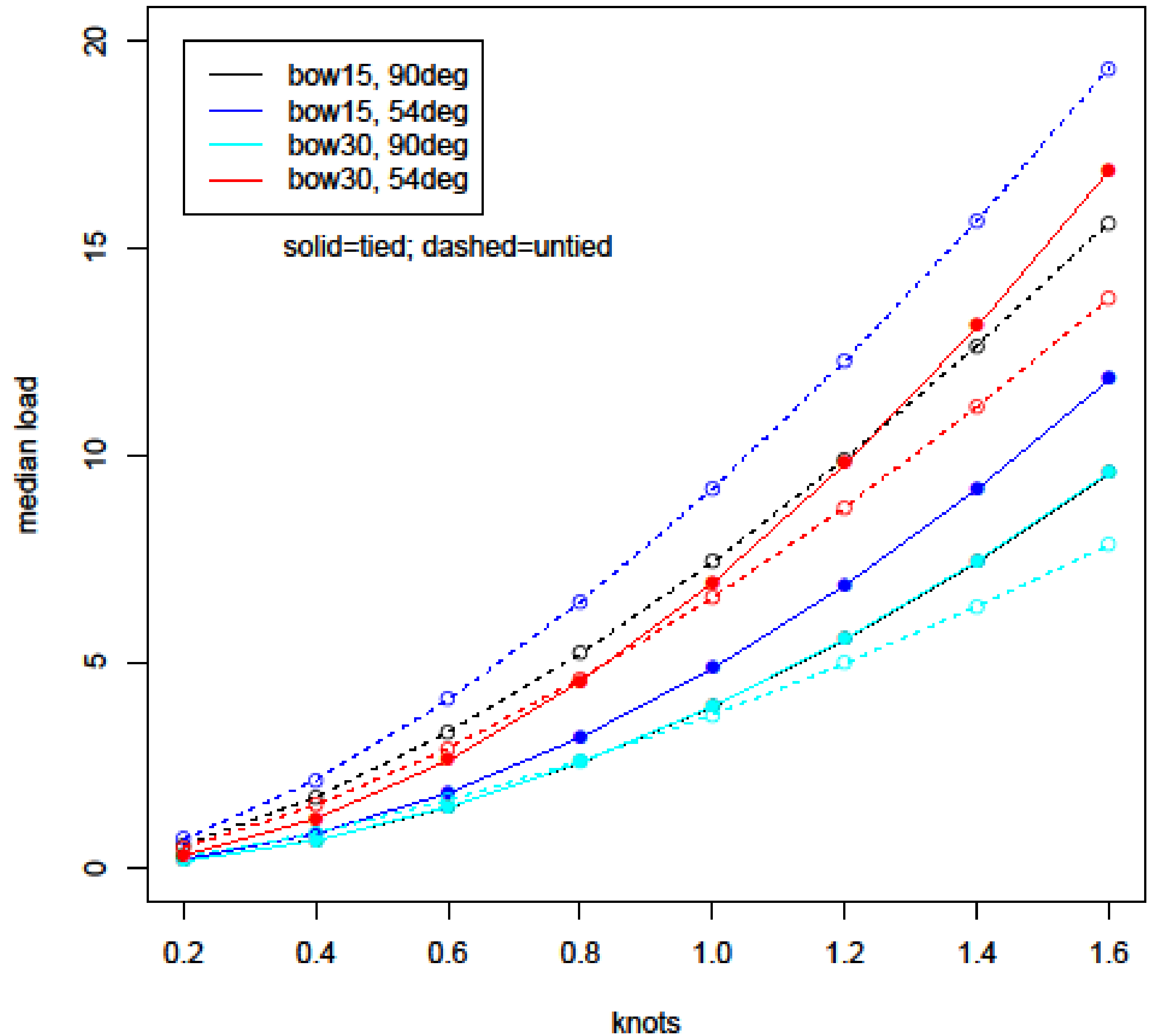


Lambertsen (2005)

Werth 2004 (Dorsal View)



Bow 15 on left shows the cleaving of plates into 3- or 4- plate groups at higher speeds. Photo on the right indicates the decreasing plate-group cleaving after tying plates together.

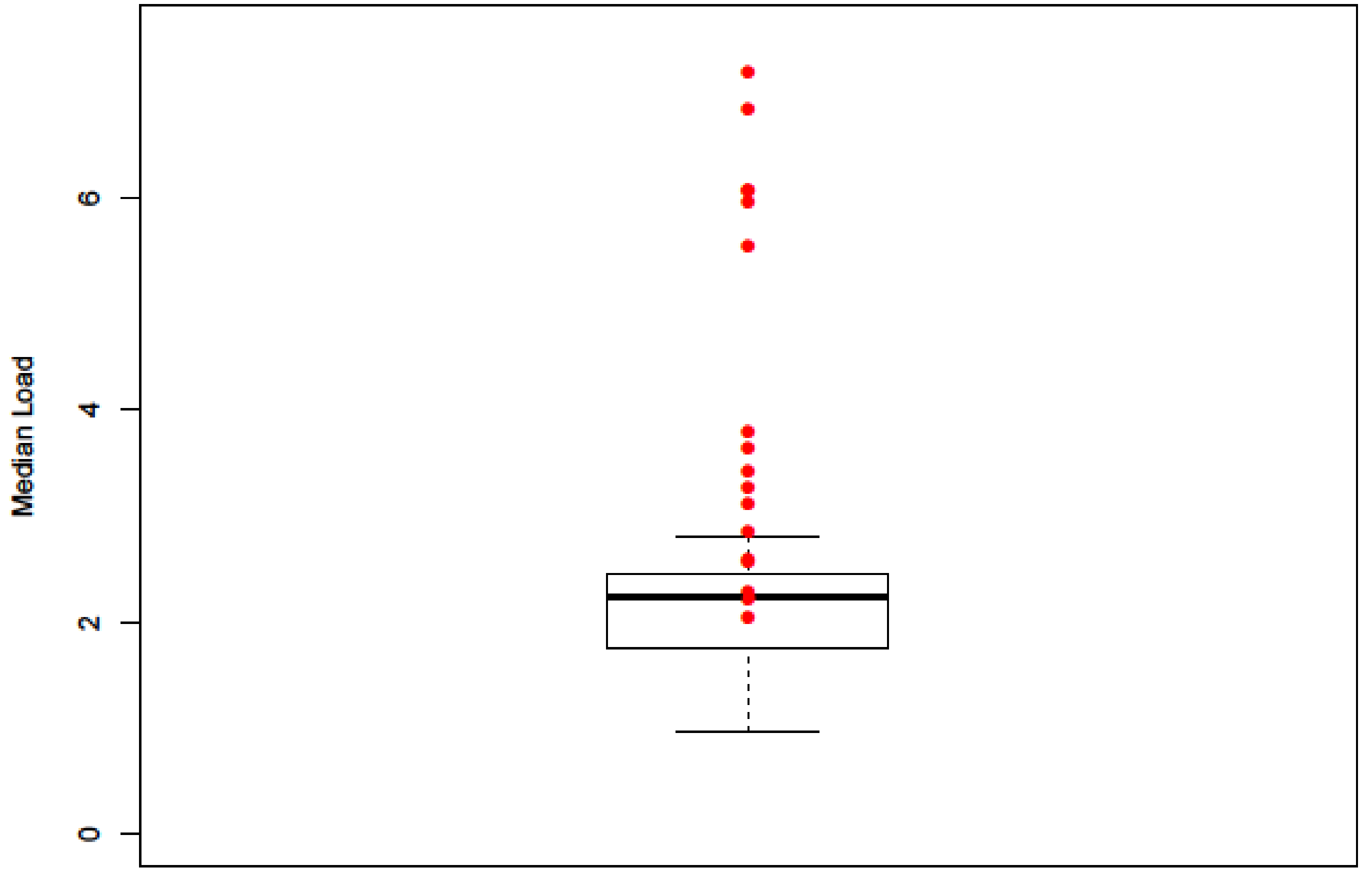

bow15, 90deg
bow15, 54deg
bow30, 90deg
bow30, 54deg
solid=tied; dashed=untied
median load
knots
0
5
10
15
20
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

The first analysis compared tied and untied baleen. The ANOVA table is as follows:

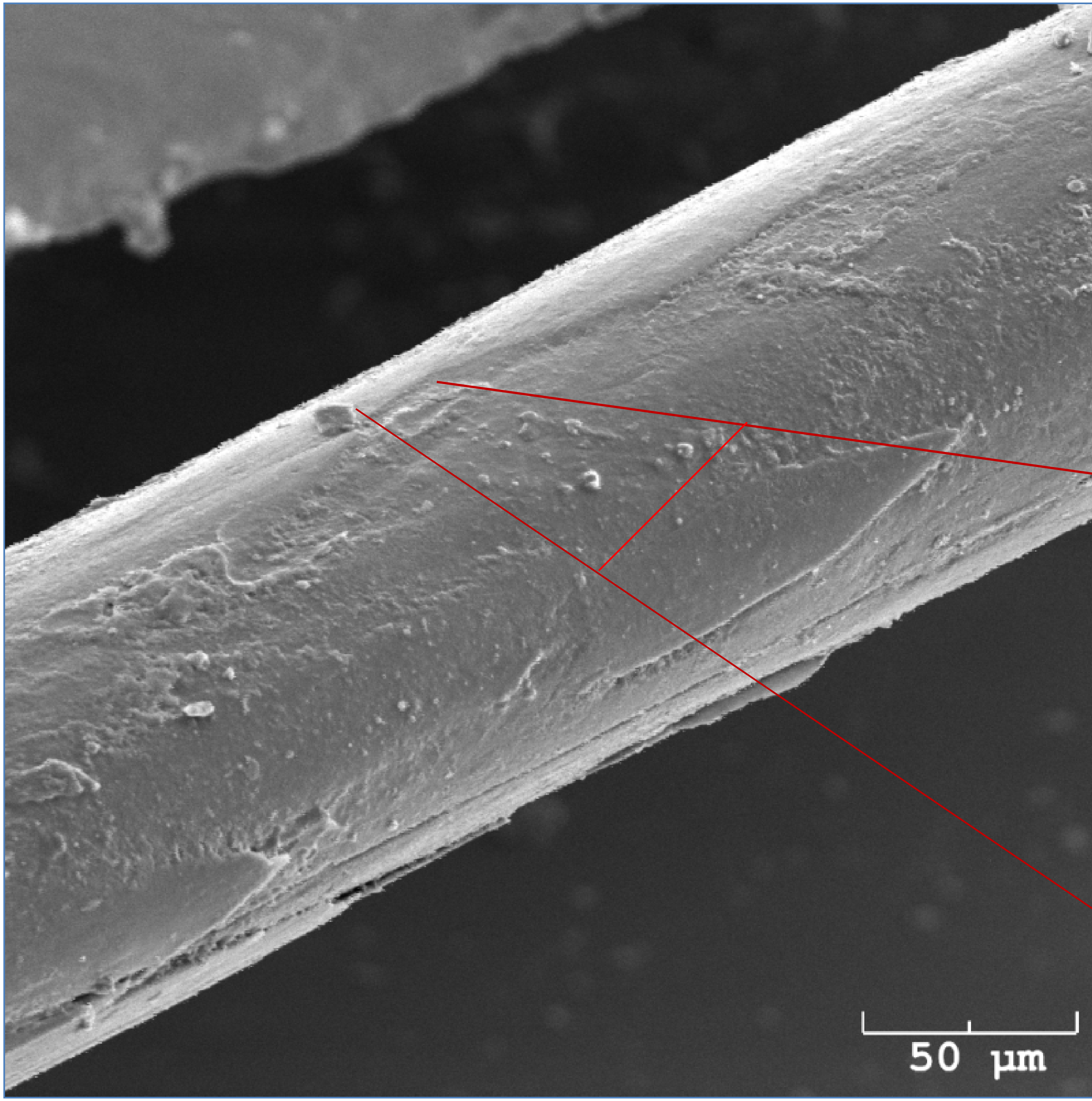
```
                     Estimate Std. Error t value Pr(>|t|)
(Intercept)          -5.75171    1.64945  -3.487 0.000693 ***
log.fa.meas           0.90793    0.17005   5.339 4.76e-07 ***
logknots              1.58614    0.13132  12.079  < 2e-16 ***
fac.tied1            -1.84111    0.40196  -4.580 1.18e-05 ***
depth.meas           -0.01719    0.01065  -1.615 0.109095
logknots:fac.tied1    0.31060    0.15889   1.955 0.053038 .
fac.tied1:depth.meas  0.04631    0.01219   3.800 0.000233 ***
```

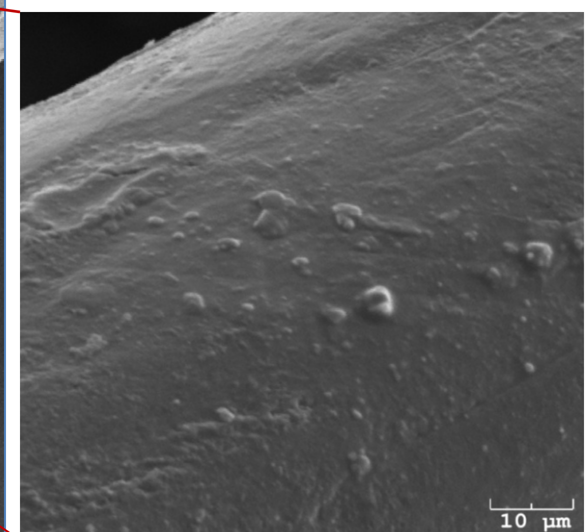
We see that tied=1 (that is, tied baleen) has significantly less drag than untied, after controlling for frontal area, velocity, the "depth" of the rack, and interactions.

the boxplot represents control runs for 19 observations of 7 racks, predominately bow30short, bow22 and bow20, 54 degrees, 0.6 knots



“Baleen bristles [or fringe] establish the basic functional unit of the whale’s filtration system” (Lamberstein *et al*. 1989, p. 38)





A close-up of a bowhead fringe hair

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Research

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Hydration affects the physical and mechanical properties of baleen tissue

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Baleen, an anisotropic oral filtering tissue found only in the mouth of mysticete whales and made solely of alpha-keratin, exhibits markedly differing physical and mechanical properties between dried or (as in life) hydrated states. On average baleen is 32.35% water by weight in North Atlantic right whales (*Eubalaena glacialis*) and 34.37% in bowhead whales (*Balaena mysticetus*). Baleen's wettability measured by water droplet contact angles shows that dried baleen is hydrophobic whereas hydrated baleen is highly hydrophilic. Three-point flexural bending tests of mechanical strength reveal that baleen is strong yet ductile. Dried baleen is brittle and shatters at about 20–30 $N\,mm^{-2}$ but hydrated baleen is less stiff; it bends with little force and absorbed water is squeezed out when force is applied. Maximum recorded stress was 4× higher in dried (mean 14.29 $N\,mm^{-2}$) versus hydrated (mean 3.69 $N\,mm^{-2}$) baleen, and the flexural stiffness was >10× higher in dried (mean 633 $N\,mm^{-2}$) versus hydrated (mean 58 $N\,mm^{-2}$) baleen. In addition to documenting hydration's powerful effects on baleen, this study indicates that baleen is far more pliant and malleable than commonly supposed, with implications for studies of baleen's structure and function as well as its susceptibility to oil or other hydrophobic pollutants.

1. Background

Baleen is a uniquely specialized oral tissue with no functional analogue or evolutionary homologue. It hangs in sheets (called plates or laminae) from the palate of whales, where it filters aggregations of small planktonic or nektonic prey from seawater. Baleen's origin approximately 30 Ma in the Oligocene Epoch was a key innovation that led to an adaptive radiation in the mammalian Suborder Mysticeti and the evolution of gigantic body size in whale species [1–3].

Water content of bowhead baleen ~ 34.7%

Oil & dispersant via manifold (M). Run 122

Baleen
X

Baleen (x) and
Bridge moving