Report of the Workshop on North Atlantic Right Whale Health Assessment: June 24-26, 2019 Silver Spring, MD

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Presented by Michael Moore, Woods Hole Oceanographic Institution, Workshop Moderator (mmoore@whoi.edu)

This Workshop was held under the auspices of the Working Group on Marine Mammal Unusual Mortality Events (Working Group) in response to the ongoing North Atlantic Right Whale (*Eubalaena glacialis)* Unusual Mortality Event and the endangered status of the species. The main goals of the workshop were: 1) to assess current health information data, including associated data gaps, and 2) identify appropriate available and needed tools and techniques for collecting standardized health data that can be used to understand health effects of environmental and human impacts (e.g. entanglement) and inform fecundity and survivorship models to ultimately guide population recovery of North Atlantic right whales.
Health is the result of interacting biologic, social, and environmental determinants that interact to affect the animal's or population's capacity to cope with change. Health cannot be measured solely by what is absent, but rather by characteristics of the animals and their ecosystem that affect their vulnerability and resilience. Wildlife health is not a biologic state but rather a dynamic social construct based on human expectations and knowledge. This includes the need to study interrelated conditions and factors that influence population health over time and apply the resulting knowledge to actions to improve health. Therefore, the determinants of health include those affiliated with animal biology and ecology and those associated with human actions influencing animals.

Over the course of three days, the workshop participants helped the National Marine Fisheries Service summarize North Atlantic right whale population status and existing health-assessment information; identified several ways to prioritize health data collection, tools, and methods; and prioritized ways to increase the use of this health data to aid in monitoring individual health, informing population health, and identifying the population consequences of multiple stressors, including the connection between human activities (e.g., entanglement) and health.
Some of the highest health priorities identified included new or continued support for the following activities:

1. Continue to support the photo-identification catalog that provides the ability to track health at the individual level.
2. Continue to support the development of the Population Evaluation Tool model and support development of a population-level state-space model with integrated health metrics.
3. Continue and expand vessel and aerial photo-identification efforts to acquire population-level seasonal distribution and demographic data. Revisit and optimize survey effort based on our current understanding of the changing seasonal distribution of whales.
4. Evaluate seasonal presence of whales in new or unknown habitats, by further development of acoustic surveys of potentially important areas, potentially informed by current habitat modelling.
5. Continue and expand collection of health assessment data (e.g., biopsy, photos, photogrammetric length and width measurements, blow, feces) and continue longitudinal studies. Specifically, visual health assessment and scarring assessments should continue; photogrammetry should be expanded, standardized, and inter-calibrated with the visual health assessment data and other measures of health.
6. Necropsy response efforts should be continued and enhanced, including continued support for training of large whale necropsy techniques. Several trans-boundary activities should be established including a necropsy case review committee; a necropsy sampling workshop; and development of a comprehensive plan for North Atlantic right whale sample collection and management.

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June 24-26, 2019
Silver Spring, Maryland

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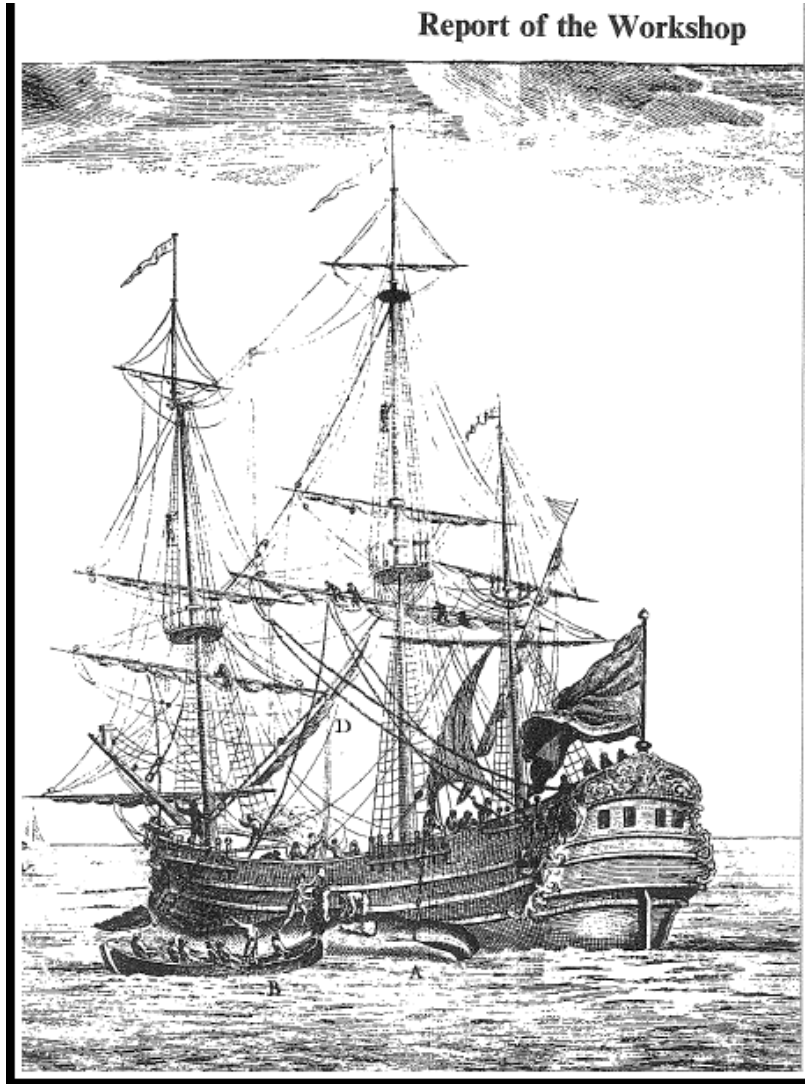


Image from: Brownell et al *Right Whales: Past and Present Status…, Boston, MA. IWC* Vol. 10. 1986 Page 1

Flensing whales in open waters, probably in the 18th century [Reproduced from Sañez Reguart, A. (1791) *Diccionario Histórico de los Artes de la Pesca Nacional* (Madrid): 330–453]

GOALS

1) Assess current health information data, including associated data gaps and tools/techniques needs

2) Identify appropriate available and needed tools and techniques for collecting standardized health data that can be used to:
    1) Understand health effects of environmental and human impacts (e.g. entanglement), and
    2) Inform fecundity and survivorship models to ultimately guide population recovery of North Atlantic right whales (NARW).

Health

- Biologic, social, and environmental determinants of animal's or population's capacity to cope with change.
- Not only what is absent, but rather by characteristics of the animals and their ecosystem that affect their vulnerability and resilience.
- Not a biologic state but rather a dynamic social construct based on human expectations and knowledge.
  - Study interrelated conditions and factors to improve health.
  - Determinants of health include animal biology and ecology and human actions influencing animals

Stephen, C. 2014. Toward a modernized definition of wildlife health. Journal of Wildlife Diseases 50:427-430.

BACKGROUND

- Previous right whale workshops (Michael Moore)
- Bottlenose dolphins: captive and wild – lessons learned (Cynthia Smith).
- NARW and other health literature (Ingrid Biedron)
- NARW distribution shift and its impacts on data we have and in the future (Phil Hamilton)

INJURY

- NARW overt mortality trend summary (Sarah Sharp)
- NEAq Injury Database and Visual Health Assessments (Heather Pettis)
- NOAA Fisheries Serious Injury Assessments (Allison Henry)
- Entanglements & vessel strikes: NARW reproduction (Amy Knowlton)

CONDITION

- Growth & body condition from photogrammetry (John Durban)
- Energetic cost of entanglement (Michael Moore & Julie van der Hoop)

REPRODUCTION

- NARW Female Reproduction- Catalog Perspective (Phil Hamilton)
- Reproductive & stress hormones - pregnancy loss? (Rosalind Rolland)

BIOTA

- Microbiomes, lipidome: NARW, bowhead, humpback (Carolyn Miller)
- Fecal Parasites & Harmful Algal Blooms (Rosalind Rolland)

MODELING

- Survival assessments & trends: reproductive females (Rob Schick)
- Population models and assessment tool (Richard Pace)
- Modeling with *Tursiops* health assessment data (Len Thomas)

Tool Discussion

- Visual Health Assessments
- Photogrammetry
- Non-invasive sampling (fecal collection, breath collection, sloughed skin, etc.)
- Invasive sampling (biopsy collection, tagging, etc.)
- Necropsy collection and data
- Sample archiving
- Sampling protocols and prioritized sampling guidelines

DISCUSSIONS

- Modelling
- Health Score
- Biopsy Priorities

Draft outline for a longer-term science plan and/or strategic plan

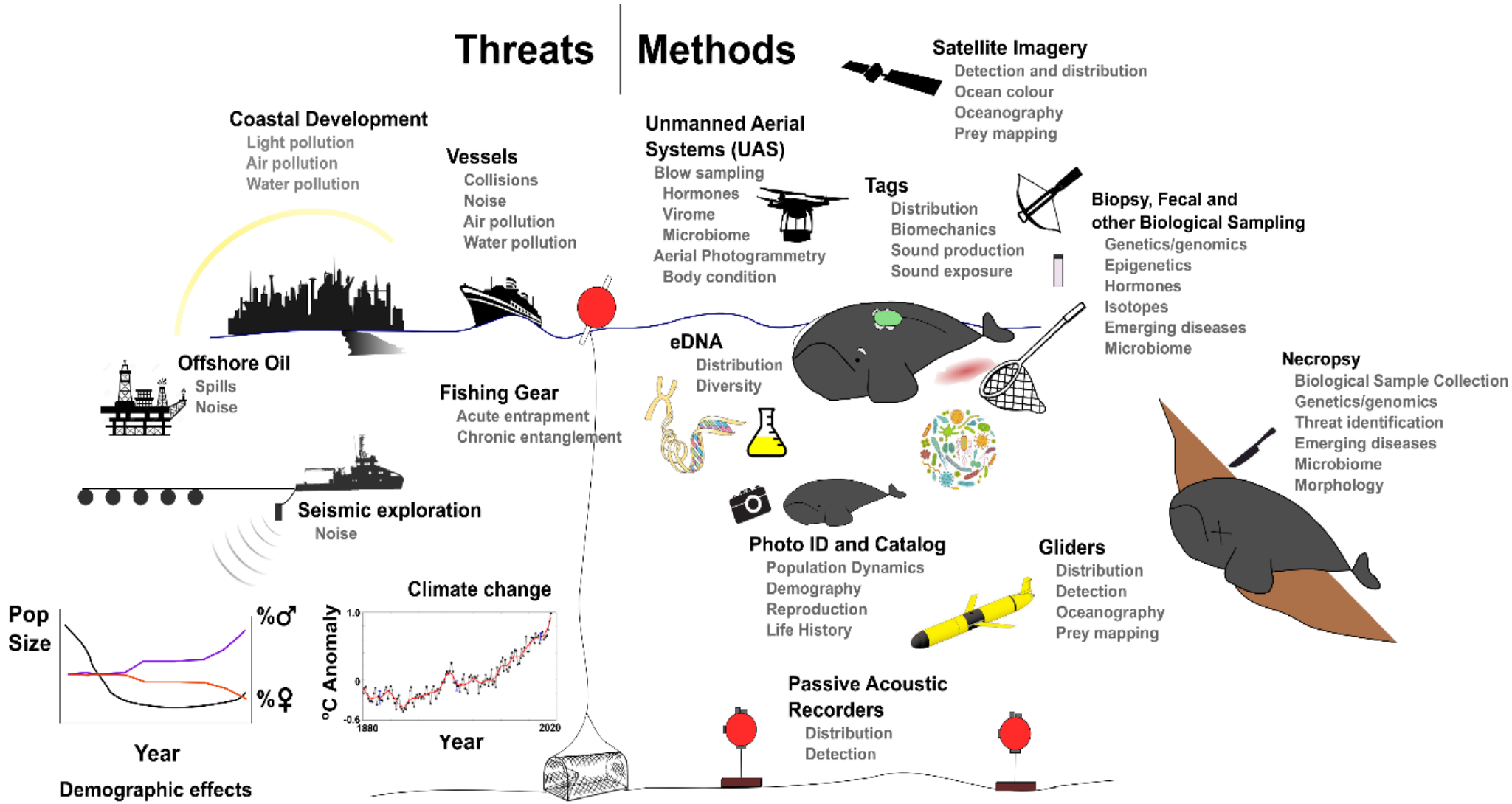
Details in report annexes

Distilled Tool Matrix - Excerpt

Purpose/Health indicator for...	Data/tissue collected	Method/Tool	Platform	Operational?
Abundance, distribution	Photographs	Photograph	Vessel, aerial (plane or UAS)	Yes
Abundance, distribution	Images	Satellite imagery	Remote	No
Behavior (Biomechanics, body condition, foraging rate and depth, risk exposure, habitat use, bioenergetics, costs of entanglement)	Movement, depth, biomechanics (thrust/power), diving behavior, speed, foraging, sound production, acoustic exposure, relative body density, ventilation, blubber, prey, position through time; Skin (opportunistic)	Tagging	Vessel	Yes, short attachment times
"Visual Health Assessment" (qualitative body condition, skin condition, rake marks, cyamid loads, lesions, life history), survival, fecundity, photo-id	Photographs	Photograph	Vessel, aerial (plane or UAS), necropsy	Yes
"Visual Health Assessment" (quantitative body condition, skin condition, rake marks, cyamid loads, lesions, life history), survival, fecundity, photo-id	Orthogonal planar photographs, altitude	UAS	Vessel	Yes
Bioenergetics model (body condition)	Blubber	Biopsy	Vessel, necropsy	Yes
Bioenergetics, wound healing, lesion characterization; open blowhole core temperature; detection of whale blow for ship avoidance (near field)	Photographs (Skin surface temperature)	Thermal IR camera	Vessel/aerial (plane or UAS)	Experimental
Contaminants, POPs, plasticizers-microplastics, macroplastics	Blubber (Lipidome, lipid content) (quality/quantity)	Biopsy	Vessel, necropsy	Yes

Model Parameter and Data Source Table - Excerpt

Model Parameter Category	Sub-Category	Sub-Category 2	Rank 1 Data Source	Rank 2 Data Source	Rank 3 Data Source	Rank 4 Data Source	Rank 5 Data Source	Rank 6 Data Source
Population-level demographic variables	Abundance		Photo ID_Mark recapture	New habitat discovery vs now scattered				
	Survival, fecundity		Photo ID_Mark recapture					
Stressors	Vessel trauma		Photo ID_Mark recapture & Photogrammetry	Mortalities (necropsy and SI&M determination)	Vessel collision risk by area	Self-reporting		
	Entanglement		Photo ID_Mark recapture & Photogrammetry	Scar assessment	Mortalities (necropsy and SI&M determination)	Recovered gear	Entanglement risk by area	Stress hormone assessment
	Reproduction	Pregnant	Breath/ blubber/fecal/baleen analysis for sex steroids	Photo ID & Photogrammetry (incl. outcome)	Necropsy			
		Lactating	Photo ID_Mark recapture & Photogrammetry (incl. outcome)	Fecal sex steroid	Necropsy			


Threats
Methods
Coastal Development
Light pollution
Air pollution
Water pollution
Vessels
Collisions
Noise
Air pollution
Water pollution
Unmanned Aerial Systems (UAS)
Blow sampling
Hormones
Virome
Microbiome
Aerial Photogrammetry
Body condition
Satellite Imagery
Detection and distribution
Ocean colour
Oceanography
Prey mapping
Tags
Distribution
Biomechanics
Sound production
Sound exposure
Biopsy, Fecal and other Biological Sampling
Genetics/genomics
Epigenetics
Hormones
Isotopes
Emerging diseases
Microbiome
Offshore Oil
Spills
Noise
Fishing Gear
Acute entrapment
Chronic entanglement
eDNA
Distribution
Diversity
Necropsy
Biological Sample Collection
Genetics/genomics
Threat identification
Emerging diseases
Microbiome
Morphology
Seismic exploration
Noise
Photo ID and Catalog
Population Dynamics
Demography
Reproduction
Life History
Gliders
Distribution
Detection
Oceanography
Prey mapping
Climate change
Pop Size
%♂
%♀
Year
Demographic effects
°C Anomaly
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0
-0.6
1880
2020
Year
Passive Acoustic Recorders
Distribution
Detection

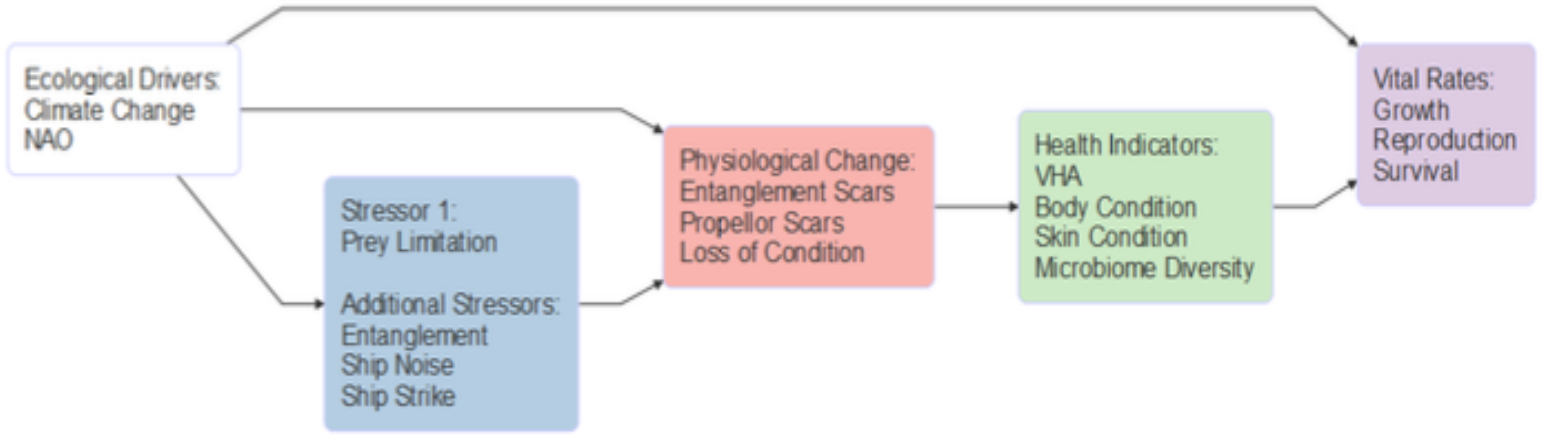

Figure 5. PCoMS model for NARW that links multiple stressors (blue box) to changes in physiology (red box) that are detected from retrospective work and drone-based studies (green box). All of these, as well as background environmental signals of climate change and the North Atlantic Oscillation, link to changes in growth (measured by the drone), reproduction and survival (purple box).

North Atlantic Right Whale Population Consequences of Disturbance (PCOD)

STRATEGIC PLAN

Action	Information gained	Focus	Data Collected and Associated Methodology
Acquire Population-Level Seasonal Distribution and Demographic Variables	Abundance, survival, fecundity, location/distribution	Reproduction and survival	Vessel and aerial photo-ID, +/- tagging
Categorize and Quantify Stressors	Vessel trauma	Conflicts with vessels	Vessel and aerial photo-ID, photogrammetry, necropsy, serious injury and mortality determination, recovered gear analysis (for entanglement)
	Entanglement	Fixed gear trap and gillnet fisheries	
	Reproduction - resting, pregnancy, lactation	Fecundity failure	Breath, blubber, fecal, & baleen sex steroid analysis, photo-ID and Unmanned Aerial System (UAS) photogrammetry
	*Food abundance and quality**	Inadequate nutrition	*Plankton sampling (ID, lipid content, stable isotopes), physical oceanography, climate change, ocean color, biopsy and necropsy (hormones, stable isotopes, etc.)*
	*Noise**	Background and episodic noise pollution: shipping, energy exploration and production, defense	Passive acoustic monitoring and soundscape modelling
	Disease, microbiome and toxicants	Infectious and non-infectious disease states	Skin, blubber, breath, fecal sampling and analyses
Quantify Health and Welfare Status	Body condition/ nutritional state/ pain and suffering	Reproductive failure, Stress and Entanglement	Disentanglement, Visual Health Assessment and UAS photogrammetry, stress hormones and adrenal gland function
Acquire State Variables	Length (& growth), age, sex, reproductive stage	Poor population health	Photo-ID, UAS photogrammetry, necropsy, genetics (sex is first priority), breath, blubber, fecal, baleen sex steroids
Individual and Population Based Models	Projections of Individual and Population Status	Extinction risk, Threats assessment, Evaluation of Management tradeoffs	Population projection models, Mechanistic individual-based population dynamic models, and individual based bioenergetic models linked to multiple population consequences of disturbance models
Develop New Methodologies	Blood health screens, serology, hormones and other*	Poor health	*Remote blood sampler*
	*Infrared Thermography of skin lesions and core temperature**		*UAS FLIR imagery of skin and open blowholes*
Synthesis	Available data and sample aggregation	Collation of available data, samples and analysis thereof	TBD
Regular font: ongoing and critical to maintain; *Italics: need development and/or lower priority			

SHORT-TERM PRIORITIES

- Photo-identification catalog to track health at the individual level.
- Population Evaluation Tool model & a population-level state-space model with integrated health metrics.
- Vessel and aerial photo-identification for population-level seasonal distribution
- Whales in new or unknown habitats: acoustic surveys informed by current habitat modelling.
- Health assessment: longitudinal studies. Visual, scarring, photogrammetry
- Necropsy enhanced, training, transboundary case review & plan sample collection and management.

NEXT STEPS

- Report under review by UME Working Group – expect release January 2020
- Peer reviewed manuscript In Prep
- Long Term Strategic Plan or Investment Strategy