

# Getting to the bottom of things

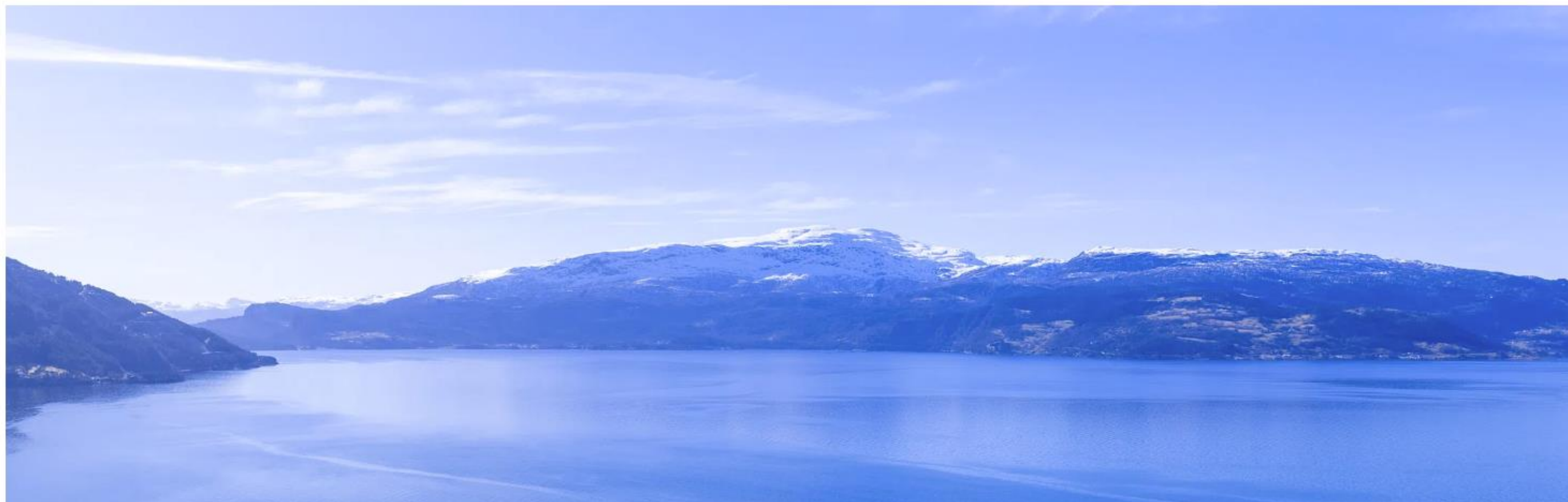
Understanding benthic impacts of salmon farming and how to minimize them

Jesse Trushenski / Lofotseminaret / 10-12 June 2026 / Henningsvær



# Som om 17 millioner mennesker gjør fra seg rett i havet

Nye tall om utslippene fra norsk fiskeoppdrett.



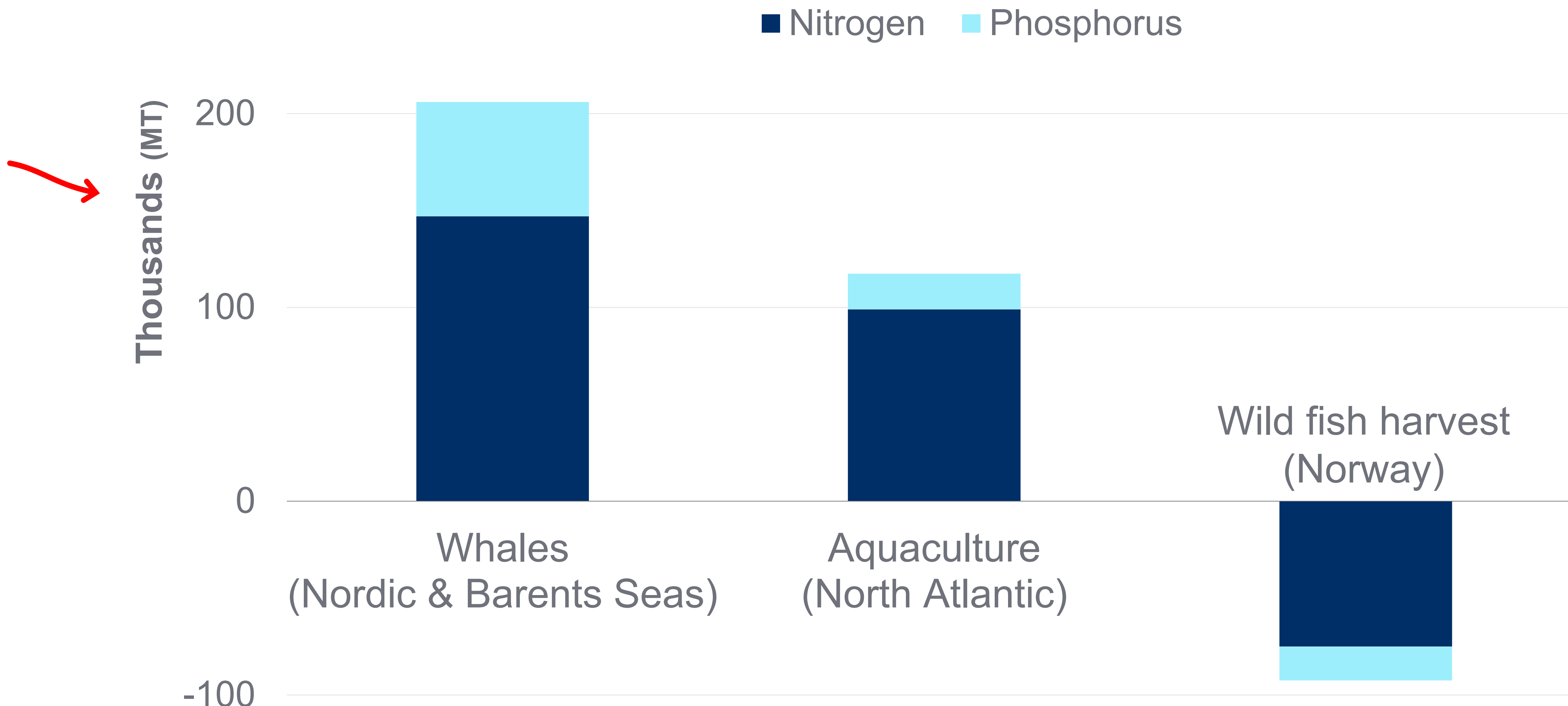


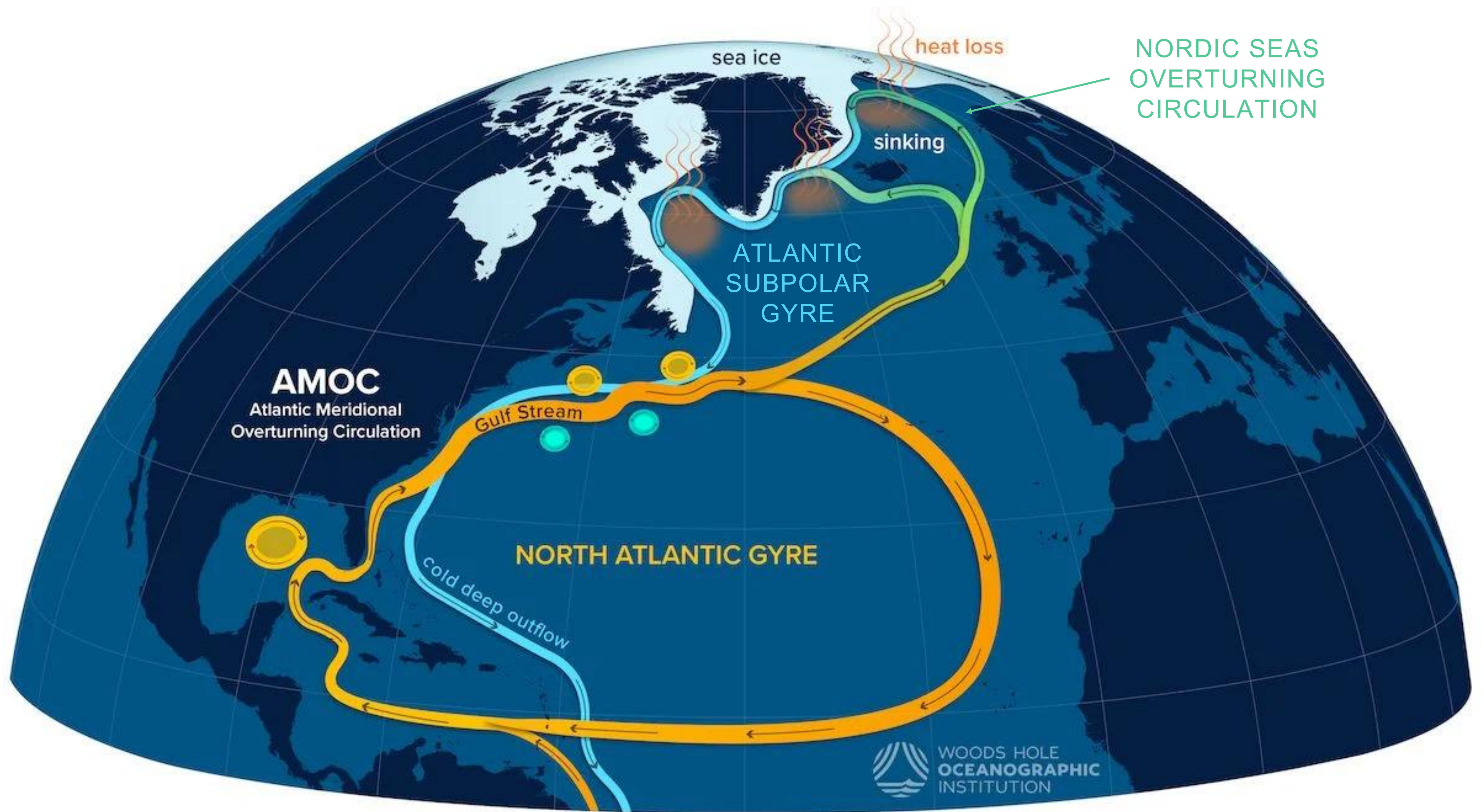
## Bardekvalane har sommarjobb som gjødselspreiar



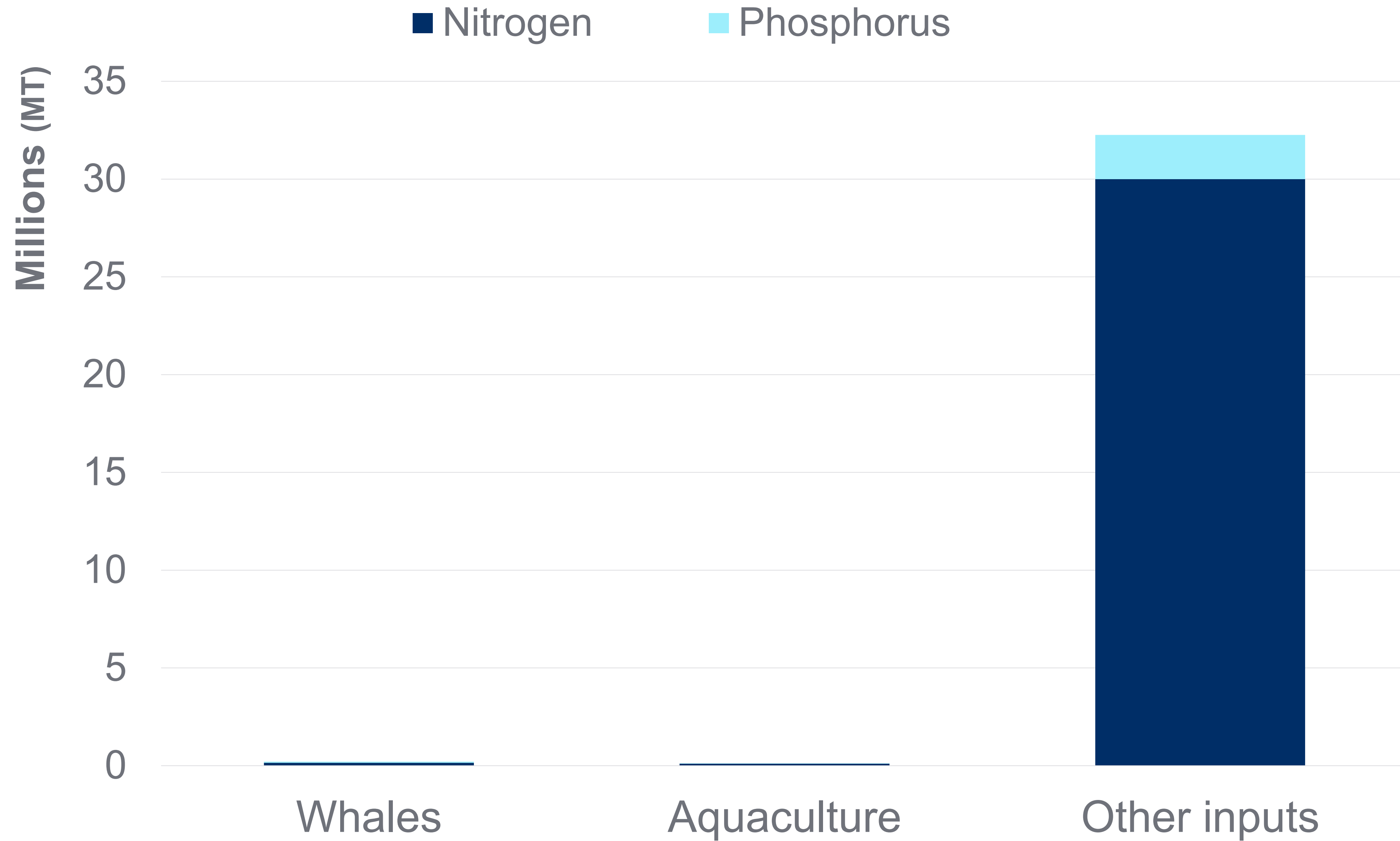
Bardekvalar gjer ofte frå seg, før dei dukkar djupt. Dette er ein knølqual som er i ferd med å dukke ned.  
Fotograf: Carla Freitas / Havforskningsinstituttet












We still need to think about waste



Production limits are determined by benthic impacts



 **standard  
norge**


**Norsk Standard  
NS 9410:2016**

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ICS 13.020.40; 65.150  
Språk: Norsk

**Miljøovervåking av bunnpåvirkning  
fra marine akvakulturanlegg**

Environmental monitoring of benthic impact from marine fish farms



Provided by Standard Online AS for Uni Research AS 2016-02-05

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Group I parameters ————— FAUNA



Group II parameters ————— CHEMICAL



Group III parameters ————— SENSORY



# LOCALITY CONDITION SCORE



# Group I parameters

# FAUNA



**MORE SENSITIVE**



**MORE TOLERANT**



# Group I parameters

# FAUNA

Fauna?

Yes

No



Group I parameters

FAUNA

Fauna?

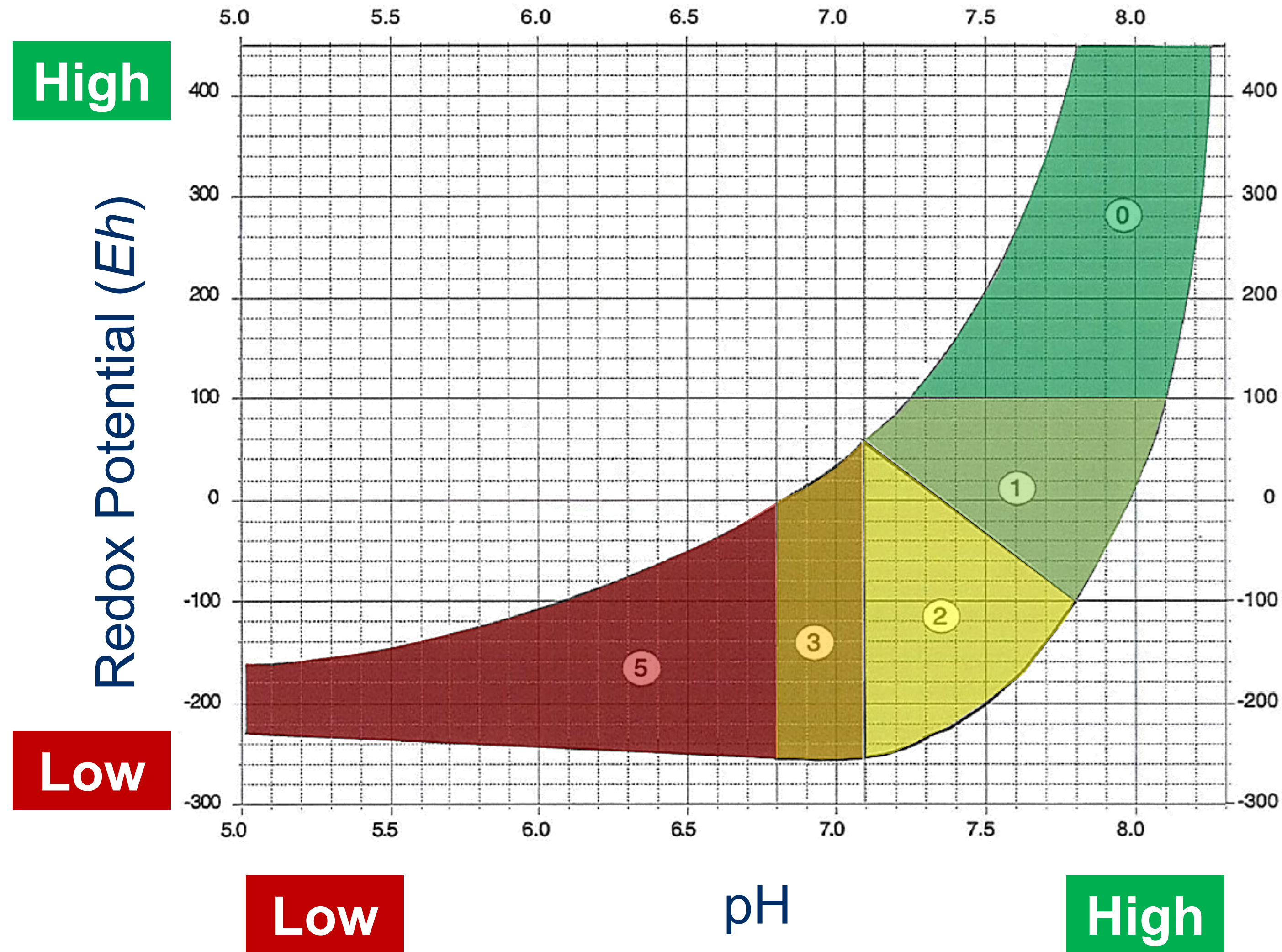
Yes

No

Group I parameters do not contribute to the final score



# Group II parameters ————— CHEMICAL



# Group III parameters

# SENSORY

Gas bubbles?

No

Yes

Color?

Light / grey

Brown / black

Smell?

No

Some

Strong

Consistency?

Firm

Soft

Loose

Grab volume?

$< \frac{1}{4}$

$\frac{1}{4} - \frac{3}{4}$

$> \frac{3}{4}$

Thickness  
of mud?

$< 2 \text{ cm}$

$2 - 8 \text{ cm}$

$> 8 \text{ cm}$



# Group III parameters

# SENSORY

Methane,  
carbon dioxide

**Yes**

**No**

Anoxia,  
iron sulfides

**Light / grey**

**Brown / black**

Anoxia,  
hydrogen sulfide

**No**

**Some**

**Strong**

Fluffy sediment

**Firm**

**Soft**

**Loose**

Fluffy sediment

**< 1/4**

**1/4 - 3/4**

**> 3/4**

Fluffy sediment

**< 2 cm**

**2 - 8 cm**

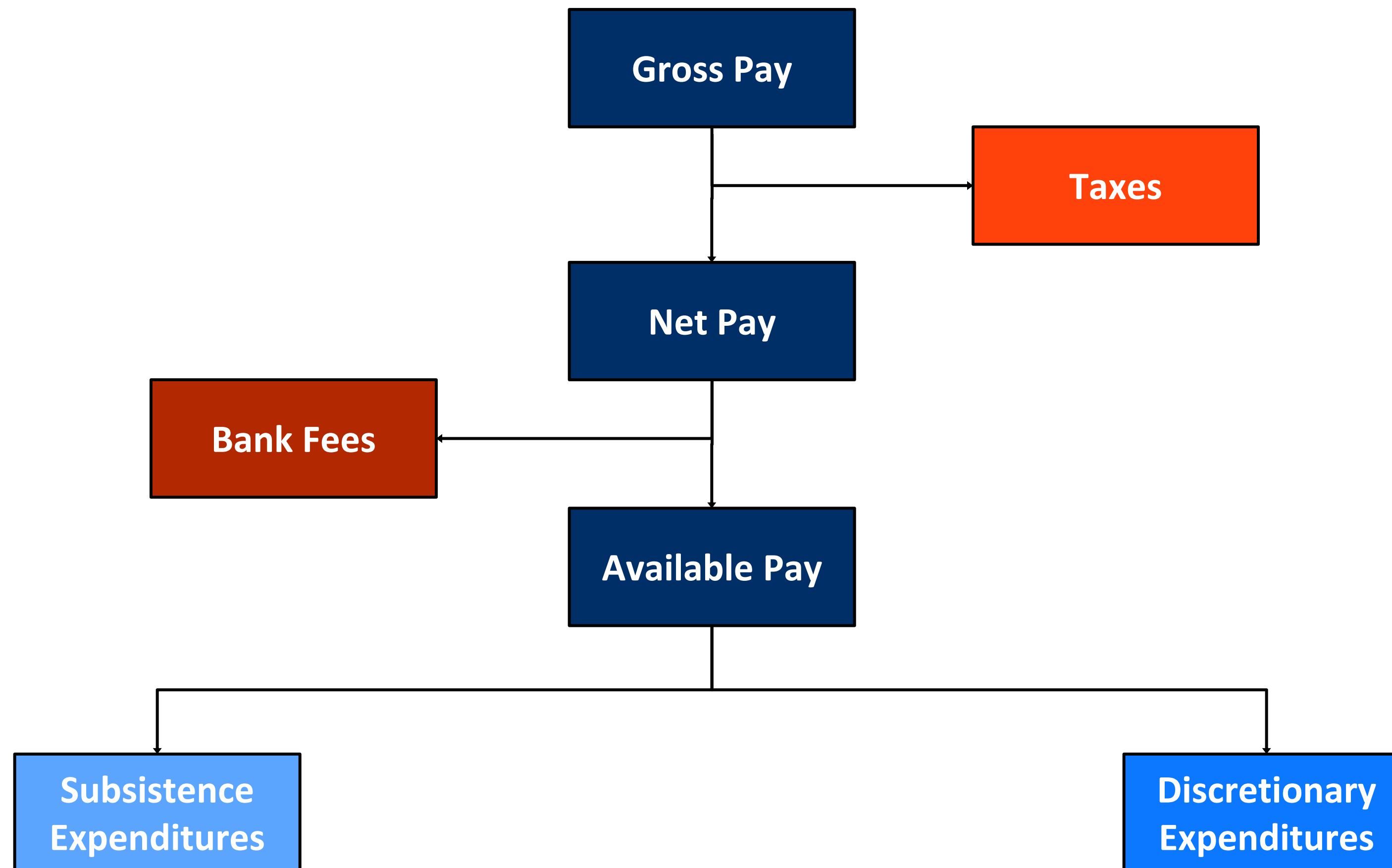
**> 8 cm**



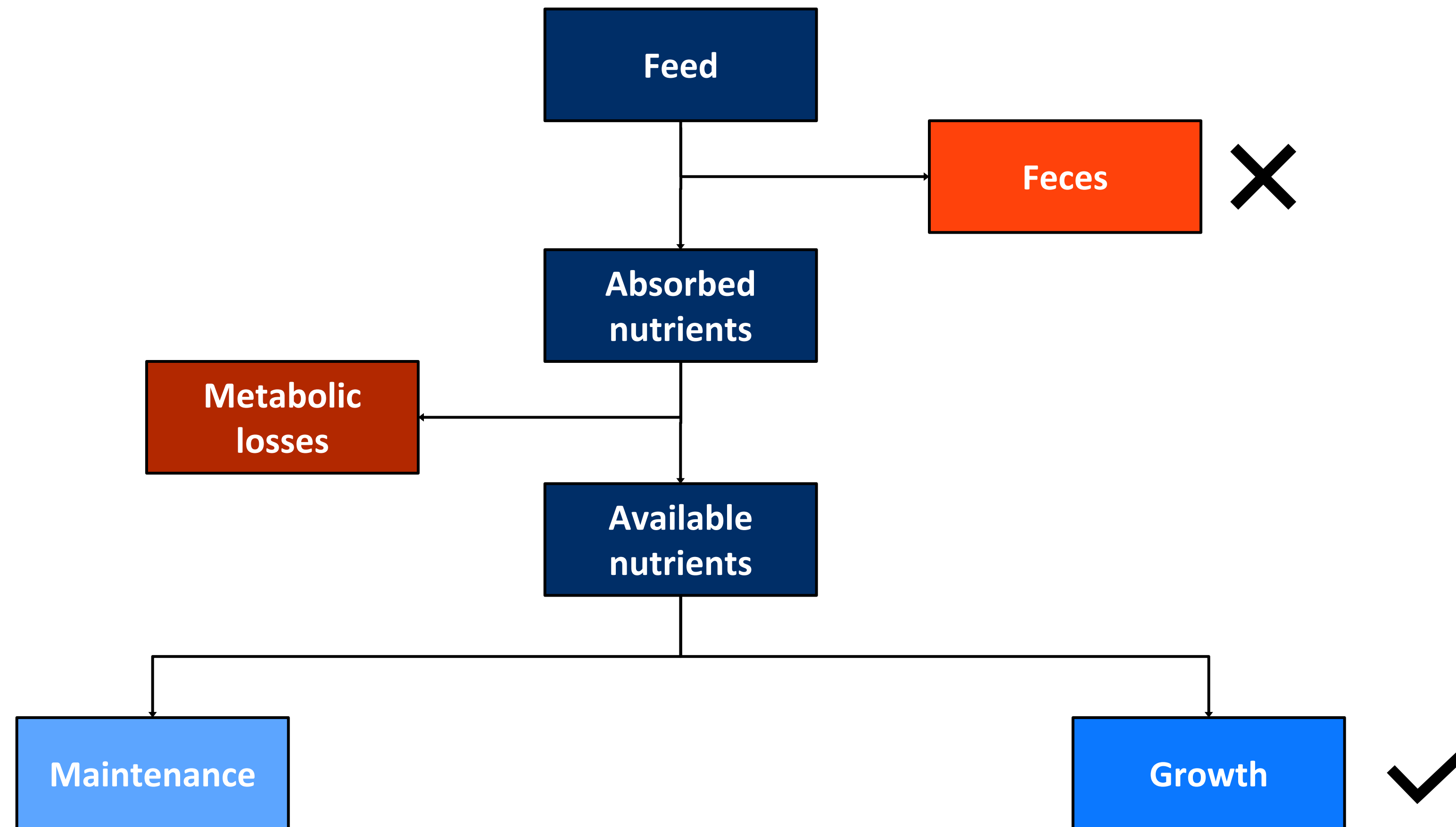
What makes sediment acidic,  
gaseous, anoxic, and fluffy?



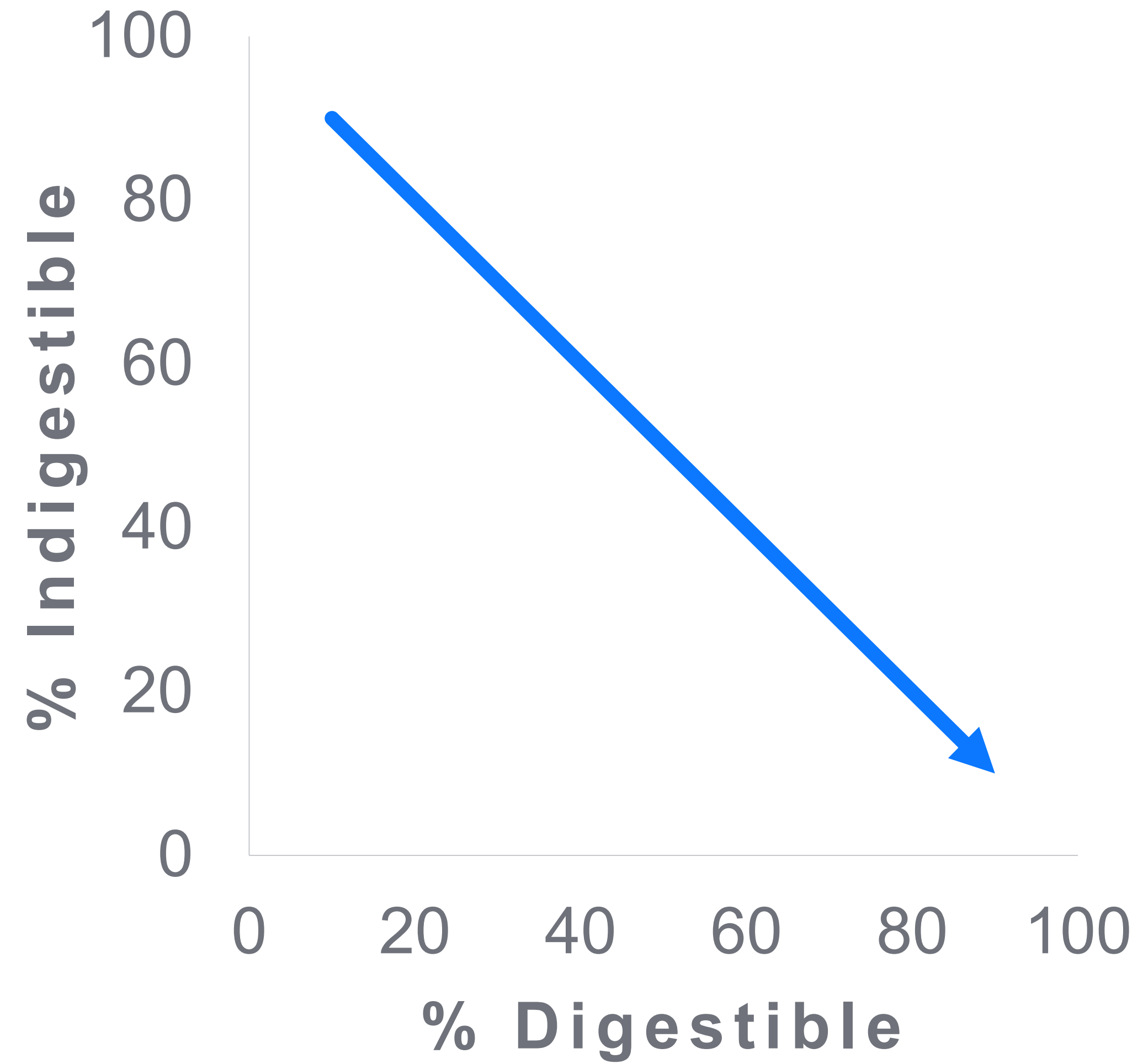
# Basic household budget



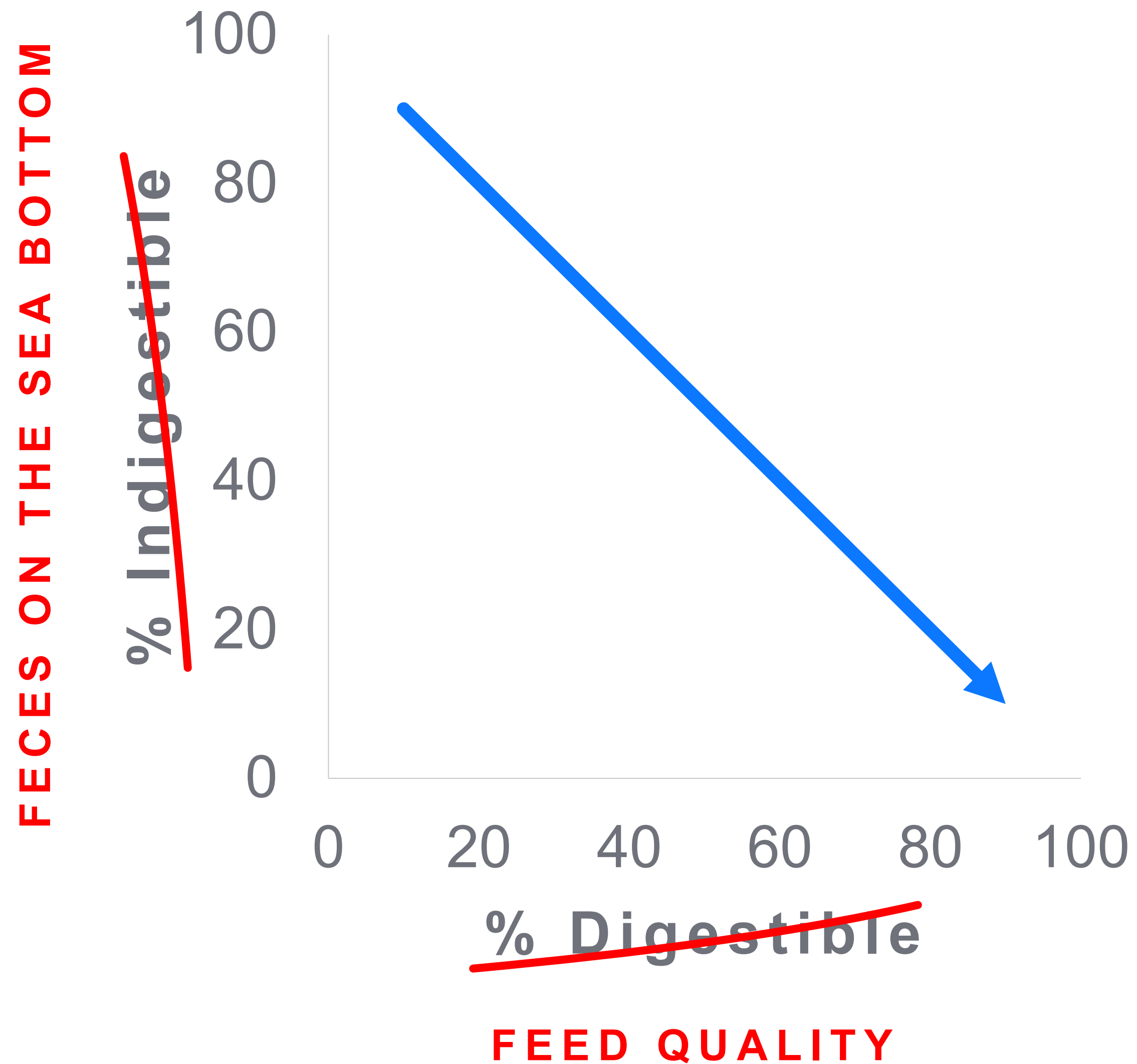
# Basic bioenergetic budget



# Poor quality feed affects waste outputs



# Poor quality feed affects waste outputs



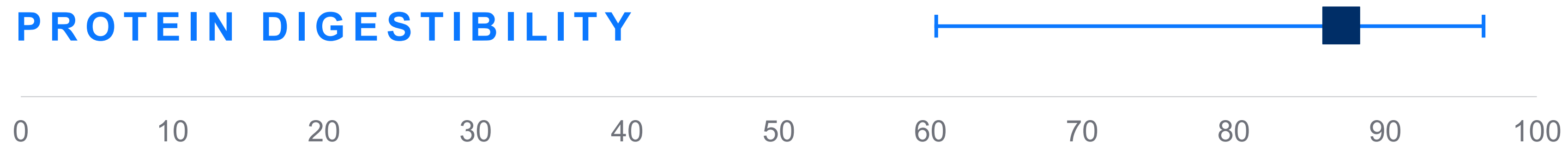
Number of feed and feces samples (n) by year and feed company in a field study monitoring apparent feed digestibility in commercial Atlantic salmon production.

Feed company	Year, n (%)			
	2010	2011	2012	2013
Company 1	29 (82.9)	79 (60.3)	48 (44.0)	13 (54.2)
Company 2	0 (0)	26 (19.9)	17 (15.6)	2 (8.3)
Company 3	6 (17.1)	24 (18.3)	29 (26.6)	9 (37.5)
Company 4	0 (0)	0 (0)	11 (10.1)	0 (0)
Company 5	0 (0)	2 (1.5)	4 (3.7)	0 (0)
Total	35	131	109	24

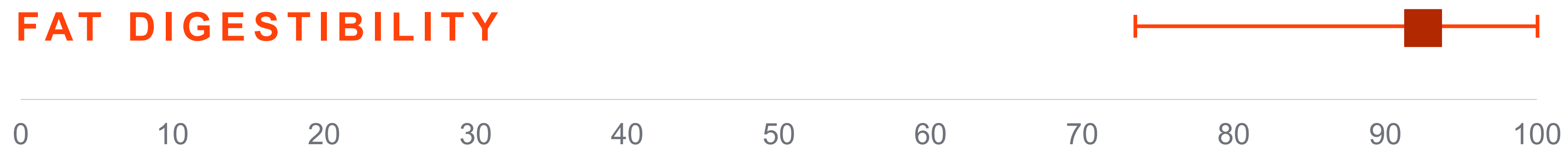
**DIGESTIBILITY VALUES VARY WIDELY THROUGHOUT NORWAY**

**TRUE DIGESTIBILITY WAS LOWER THAN DECLARED IN NEARLY ALL CASES**

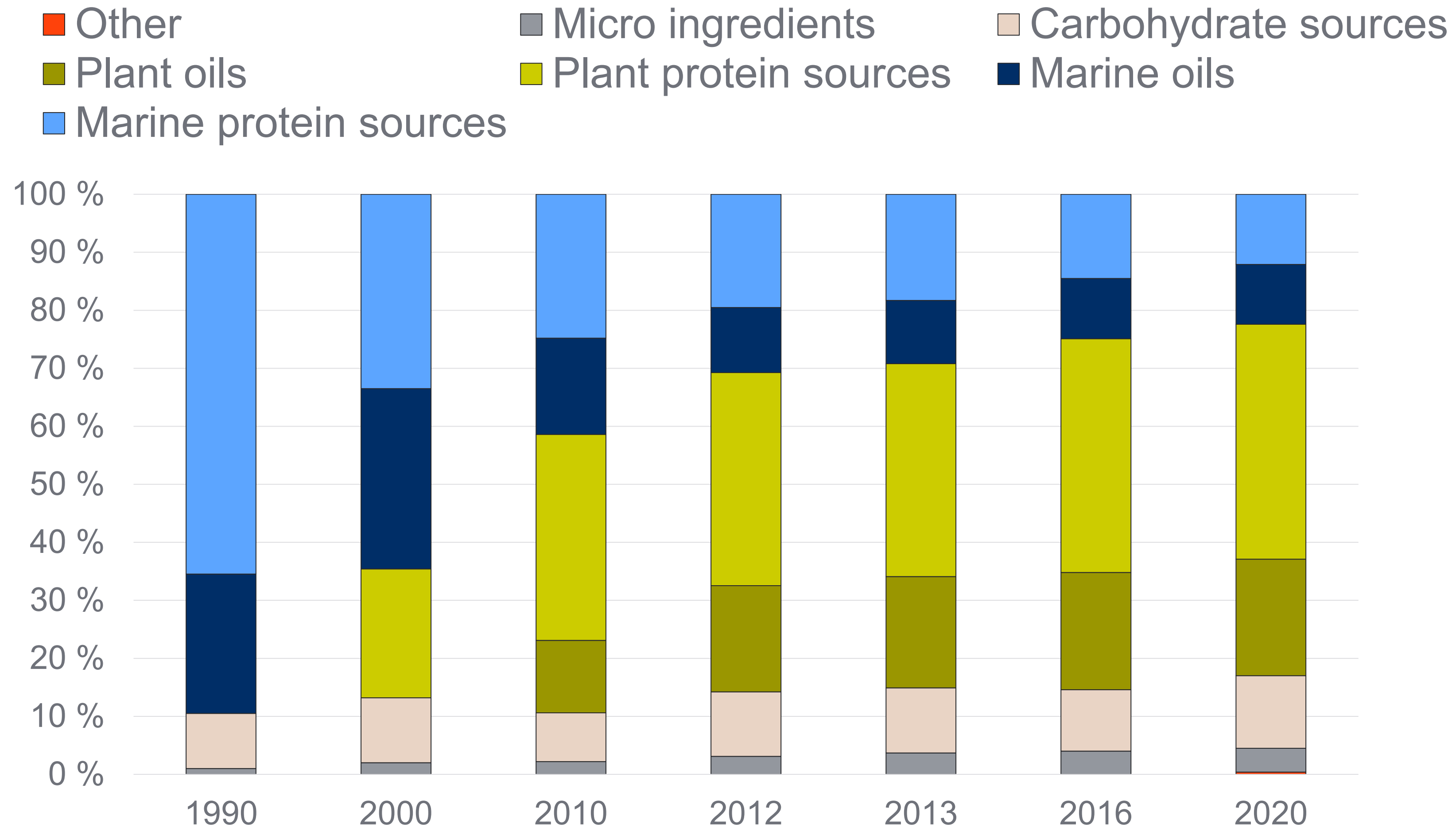
### PROTEIN DIGESTIBILITY



### FAT DIGESTIBILITY

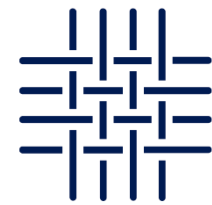


# Marine ingredients have been replaced by plants



# Transition to plant-based feeds means...

MORE CARBOHYDRATES,  
DIGESTION INHIBITORS



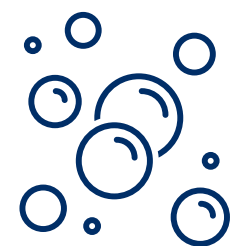
LOWER DIGESTIBILITY



ANTI-NUTRITIONAL FACTORS



LOOSE, PARTICULATE FECES



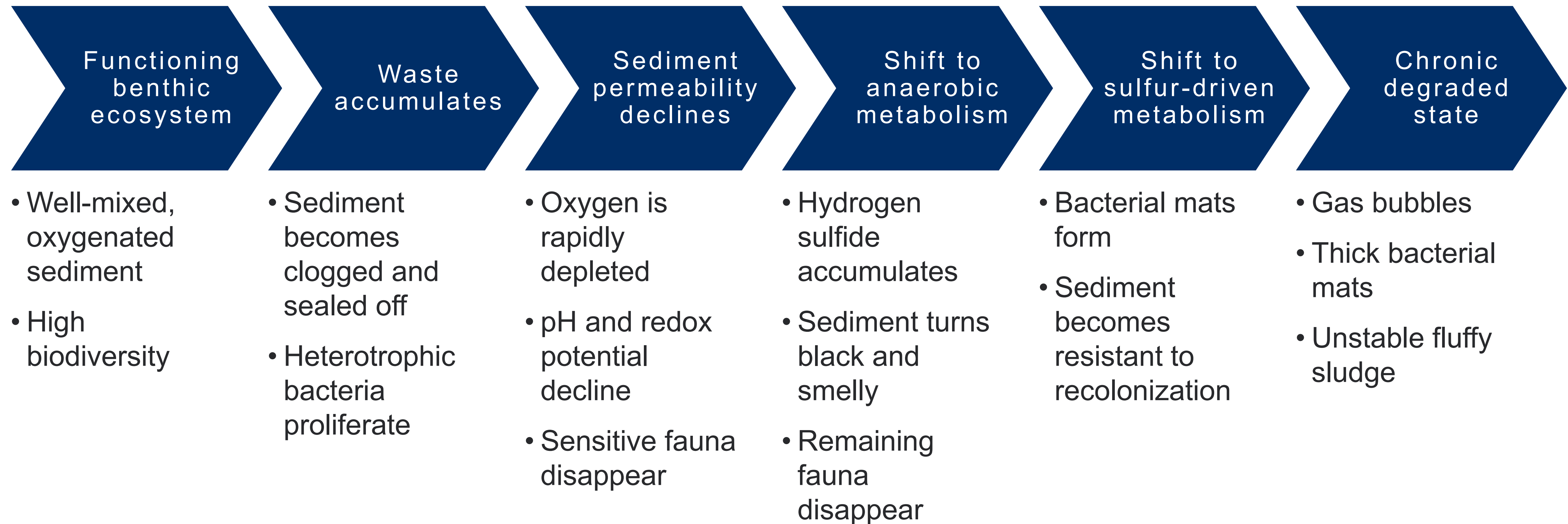
GREATER NUTRIENT LOSSES



- Plant proteins contain 'hidden' fiber and other carbohydrates, phytic acid and enzyme inhibitors that interfere with digestion
- More feces per unit feed consumed
- Non-starch polysaccharides, saponins, lectins, and others cause gut damage and diarrhea
- Feces settles poorly, is rapidly metabolized by bacteria
- Reduced growth, greater oxygen consumption per unit feces



**FINE PARTICULATE WASTE  
& MORE NUTRIENTS  
ACCELERATE THIS PROCESS**



## FECES

## SEDIMENT

1 g carbon → 2.7 g of oxygen demand  
1 g nitrogen → 4.6 g of oxygen demand

Protein  
Digestibility

95% → 85%



3 × oxygen demand

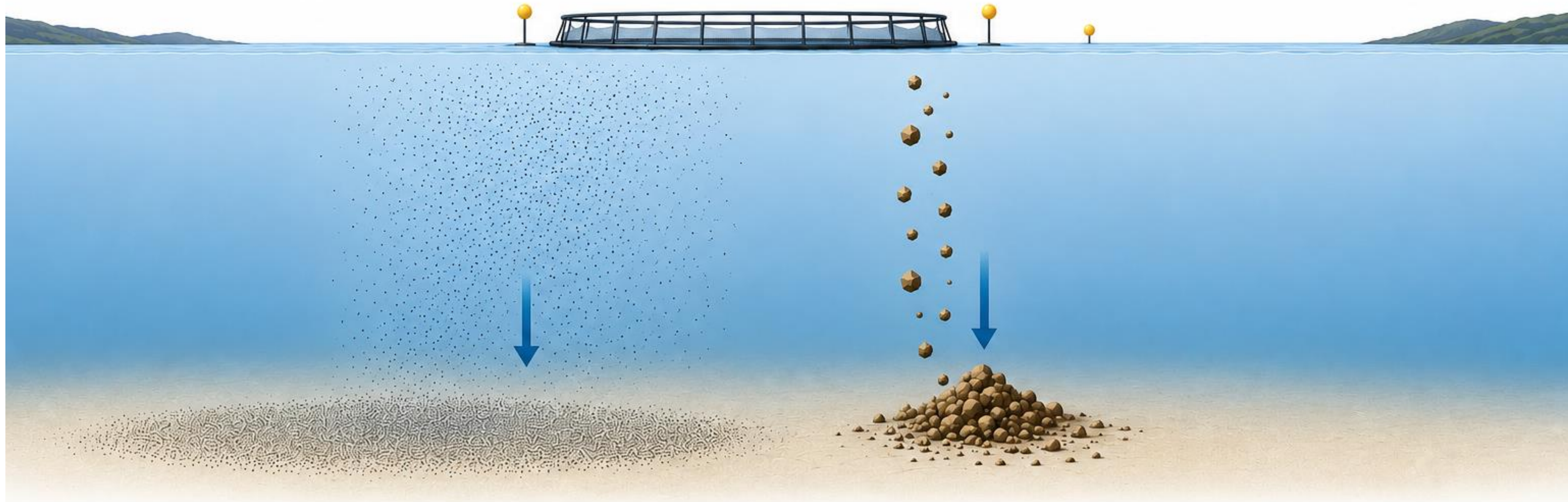


## FINE PARTICULATES

- Very small particles
- Remain suspended longer
- Sink slowly with low velocity
- Can travel long distances
- Form uniform layers on the seafloor

## LARGER SOLIDS

- Larger, heavier particles
- Settle quickly
- Limited horizontal transport
- Create localized deposits and mounds



### DEPOSIT CHARACTERISTICS

Fine particulates form thick, continuous layers that can cover large areas.

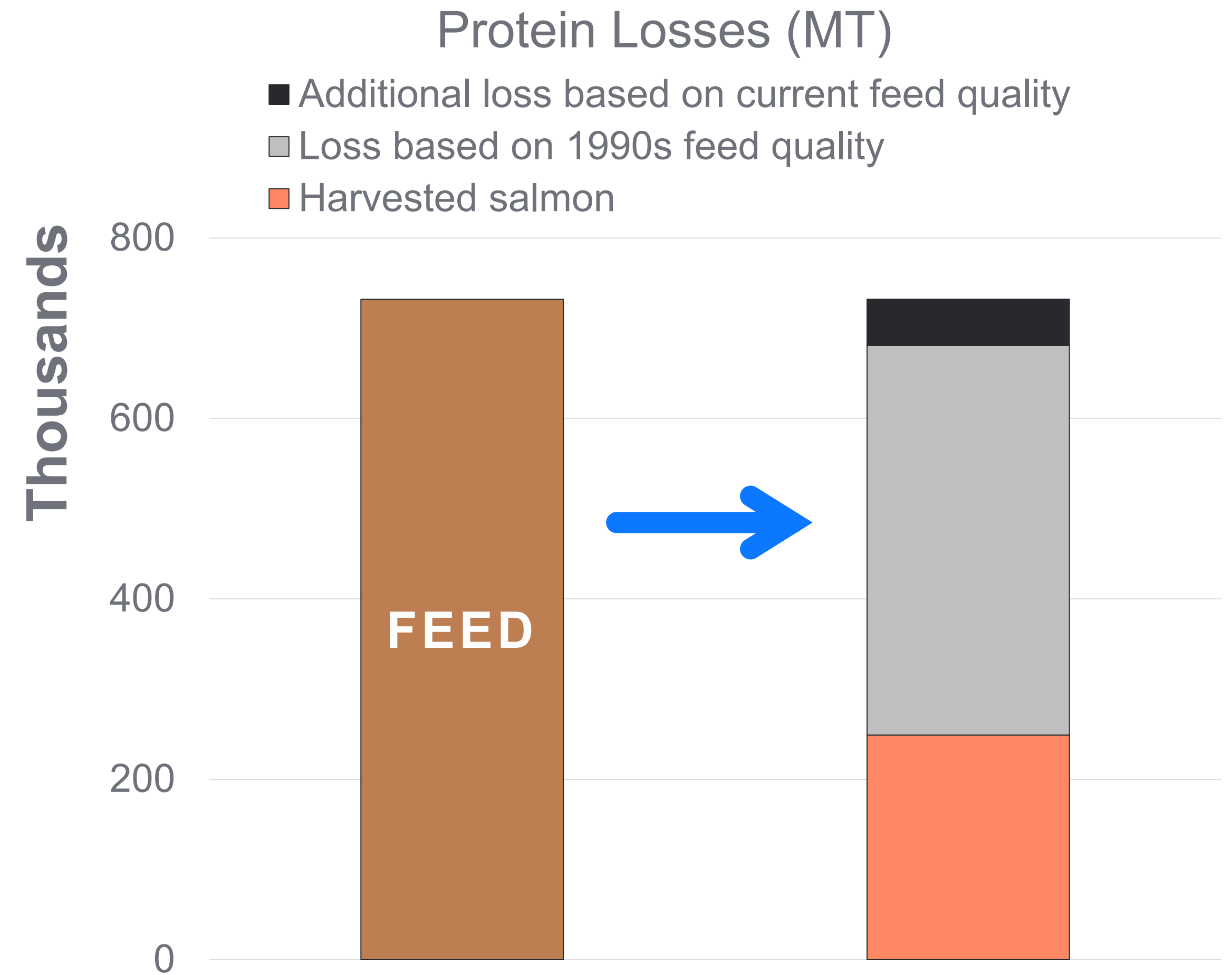
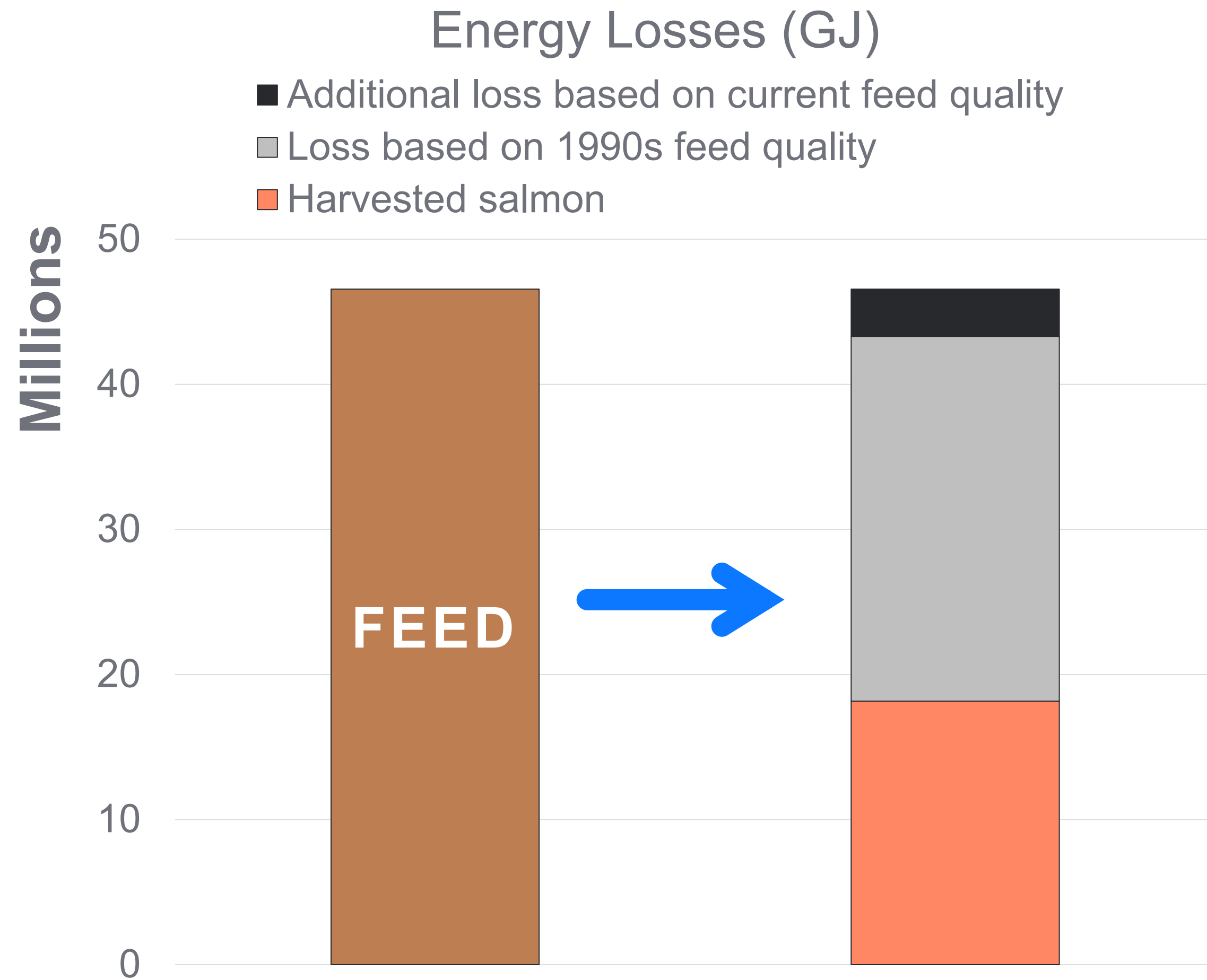


### DEPOSIT CHARACTERISTICS

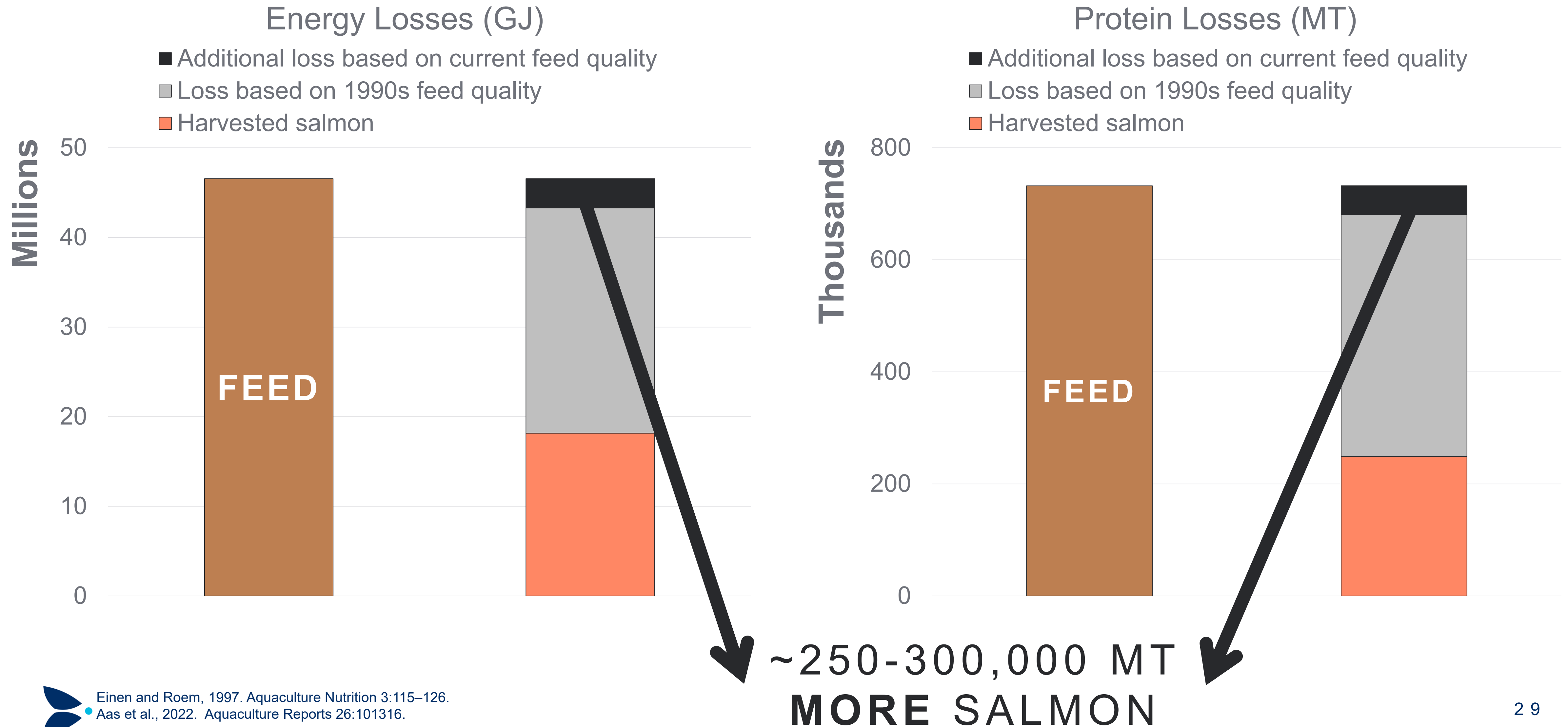
Larger solids form thin, localized deposits and mounds near the source.



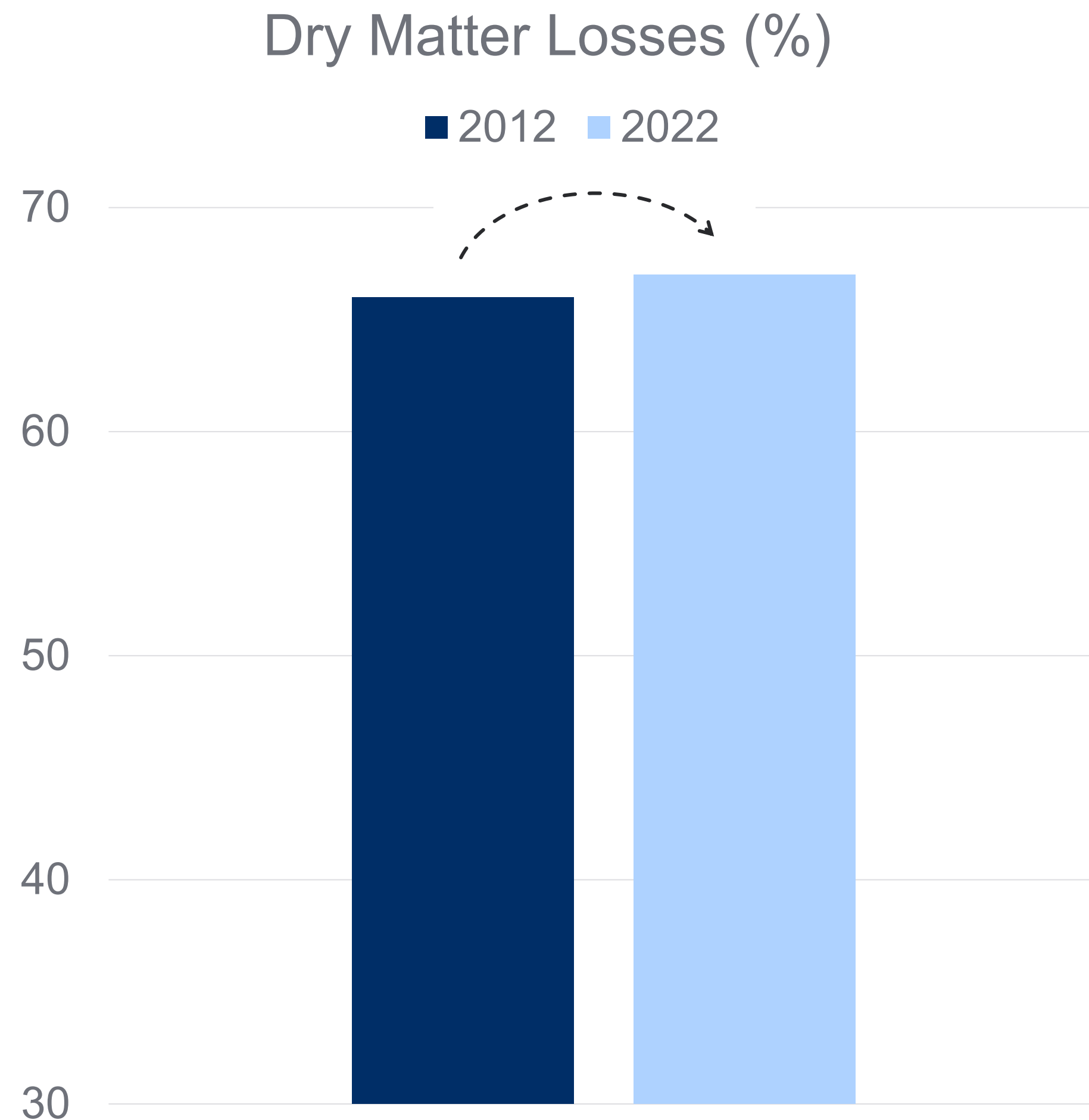
# Nutrient losses—feed input vs. harvested salmon



# Nutrient losses—feed input vs. harvested salmon



# Nutrient losses—feed input vs. harvested salmon



In 2012, 66% of dry matter in feed was lost—today the number is 67%

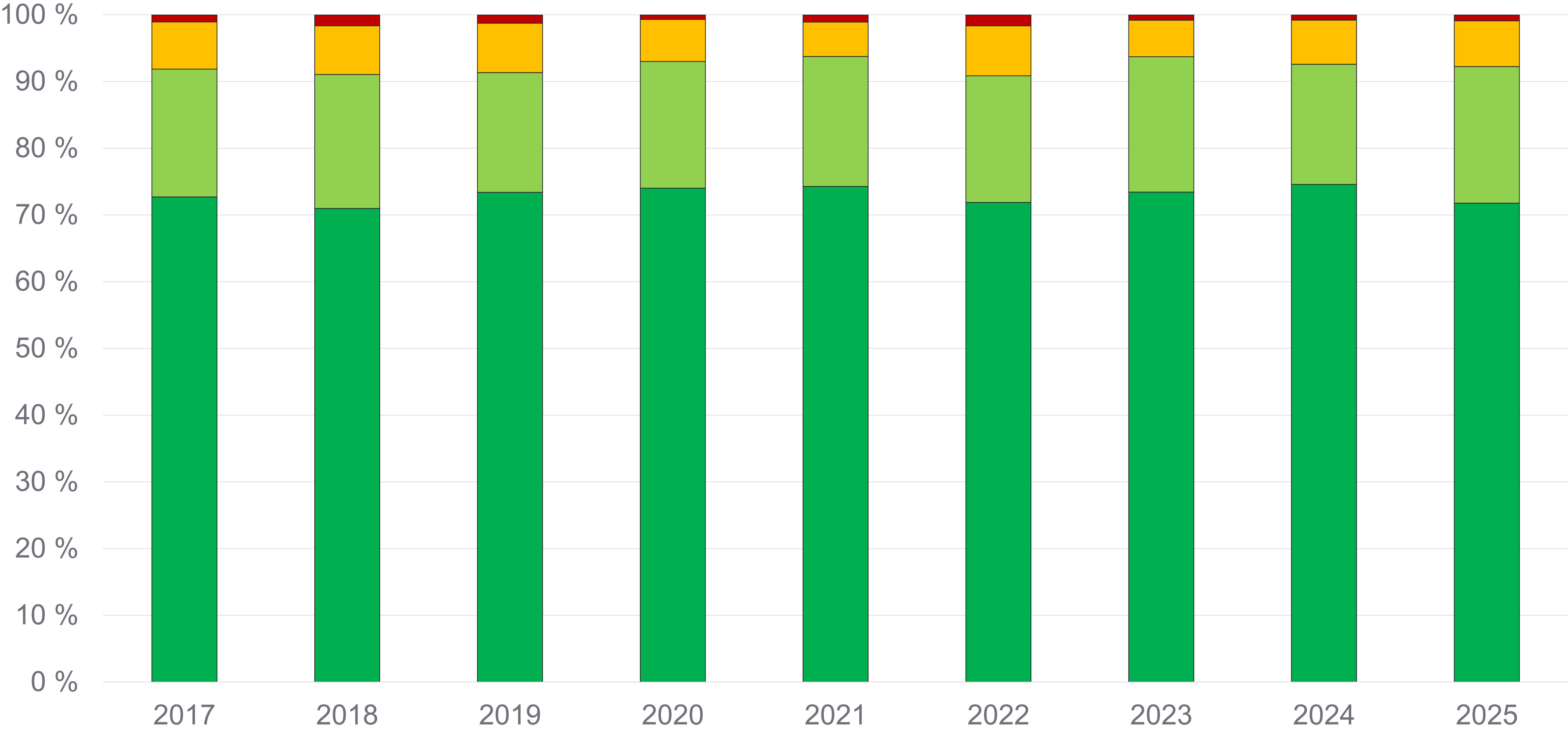
17,493 MT additional loss per year

Solids represent roughly 1/3 of loss

**6 MT more waste on the seafloor per site**

# B-survey Conditions Over Time

Very Good Good Bad Very Bad



## Getting to the bottom of things

- Eutrophication is complex
- Oversimplifications that blame aquaculture are click-bait
- Salmon farmers must still consider waste outputs
  - Production is limited by benthic impacts
  - More waste indicates lost growth potential
- High quality feed reduces benthic impacts
  - Improved digestibility = more growth, less feces
  - Fewer anti-nutritional factors = less diarrhea and fines
  - Lower nutrient inputs = lower oxygen demand

