Drivers of sea lice consumption in lumpfish (*Cyclopterus lumpus*): Effects of prey availability, lumpfish size, and deployment strategy

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FIRUM
knowledge for sustainable aquaculture

Østerø et. al. (in prep.)

Background

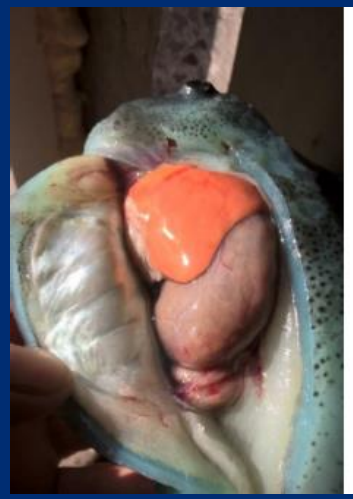
Sea lice remain a major constraint in salmon farming. Lumpfish are used as cleaner fish in cold-water salmon aquaculture, but effect is highly variable.
→ Temporal variation and between farm variation.

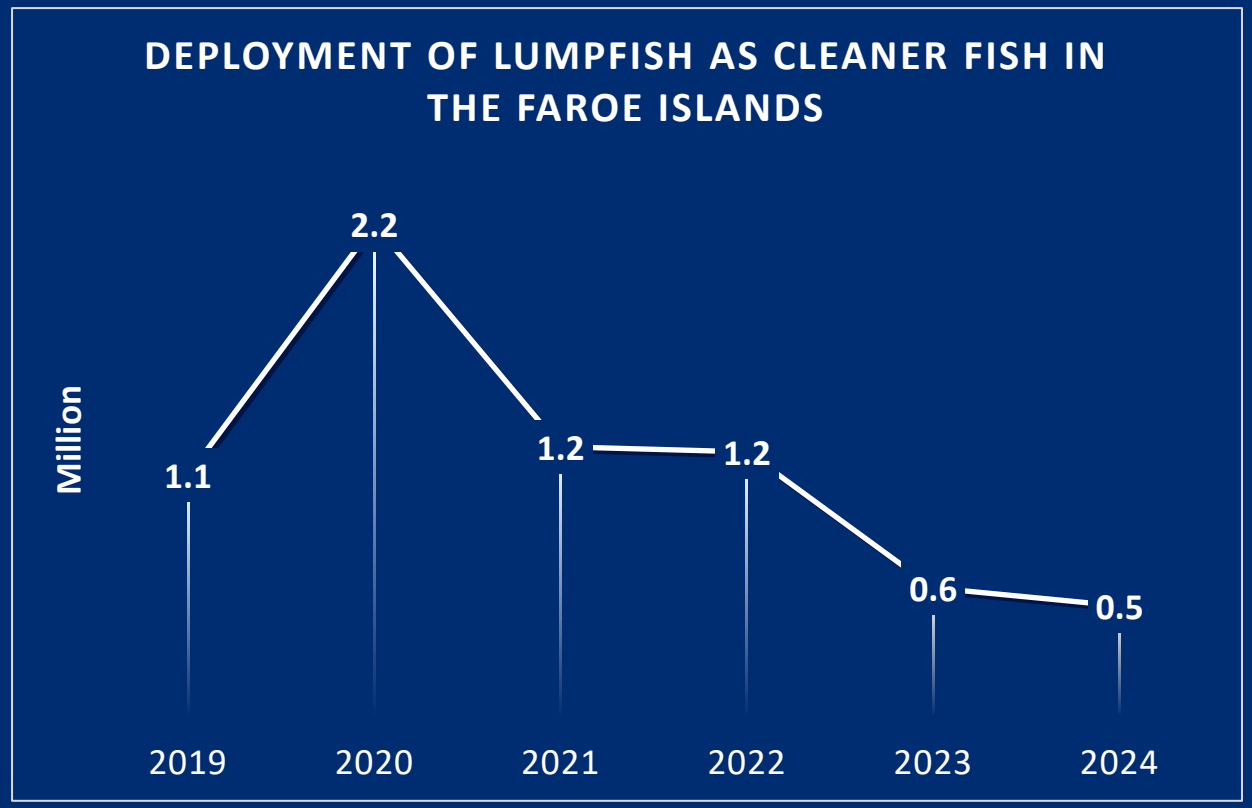
Only a small proportion actively consume lice:

- 13.5% lice ingestion in 5 Faroese farms (all species)
- 3.1% *L. salmonis* in 80 Norwegian farms
  (Eliasen 2018; Engebretsen 2023)

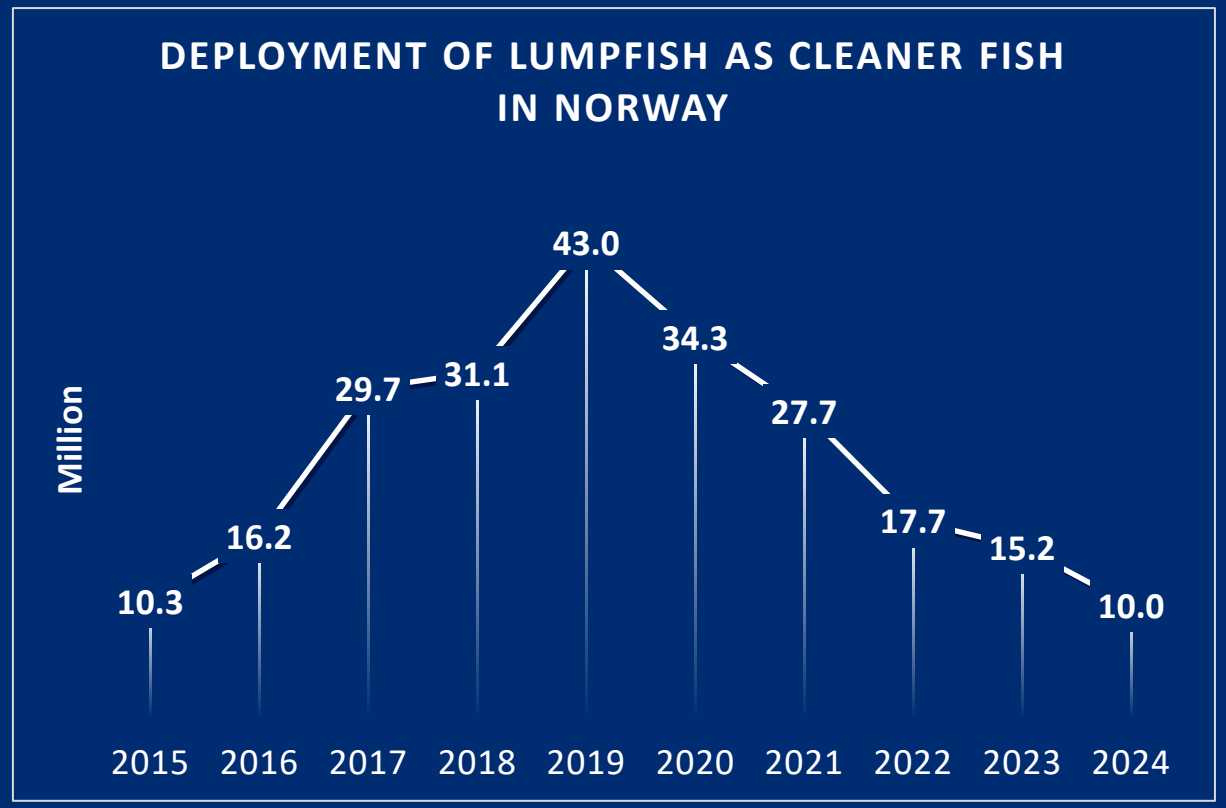
Drivers of grazing variation are individual and ecological:

- Smaller fish graze more (peak efficiency <100 g)
- Alternative prey matters:
  – Zooplankton ↓ grazing
  – Biofouling often ↑ grazing
- Operational context: more grazing when lice levels are higher





Faroese Food and Veterinary Authority



Fiskeridirektoratet, Akvakulturstatestikk: rensefisk

Welfare issues, high mortalities and varying effects on sea lice

Aim

- Improve predictability of lumpfish delousing by quantifying drivers of salmon lice consumption.
- **Research questions**
  - How does alternative prey influence grazing?
  - How do lice levels on salmon influence grazing?
  - How does body size relate to grazing?
  - How does body condition relate to grazing?

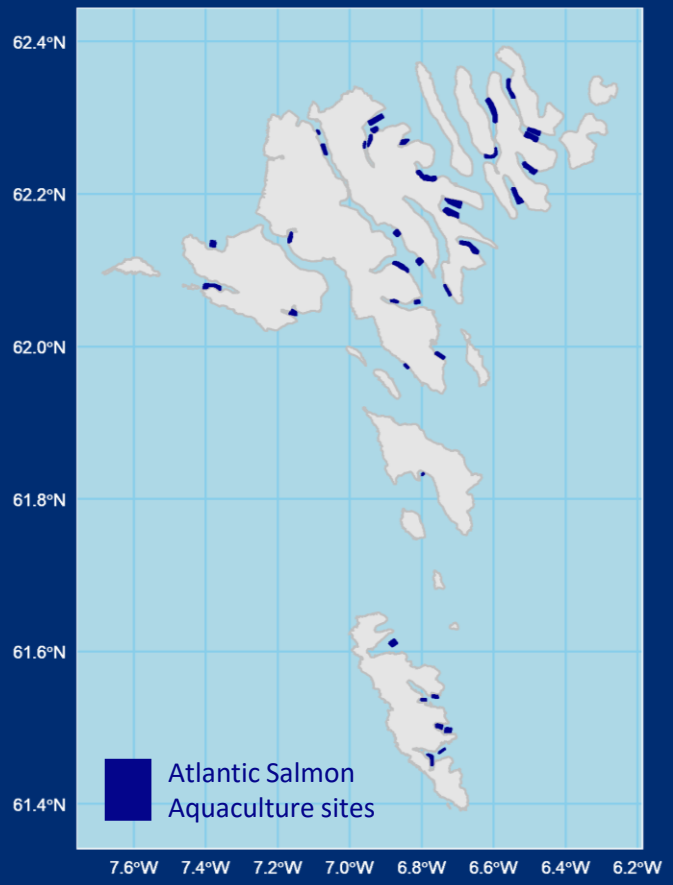
Improve deployment strategy and lumpfish use

Method

Setting: The Faroe Islands

- Among 5 largest Atlantic salmon producers (3%)
- Water temps ~6–10°C. Little to no stratification.
- 25 Atlantic salmon farming sites (fjords & more exposed areas).
- Sites:
  ~12 circular cages,
  diameter of 160 m,
  up to 30 m deep.

  Emphasis on strong biosecurity, long fallowing periods and deployment of large smolts (~425 g in 2021).



National lice thresholds (*L. salmonis*.):
1 adult female in August to April.
0.5 adult female in May to July.

Lumpfish are the only cleaner fish used

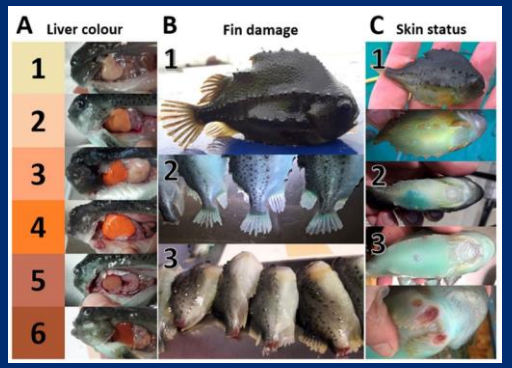
Data and sampling (2015-2025)

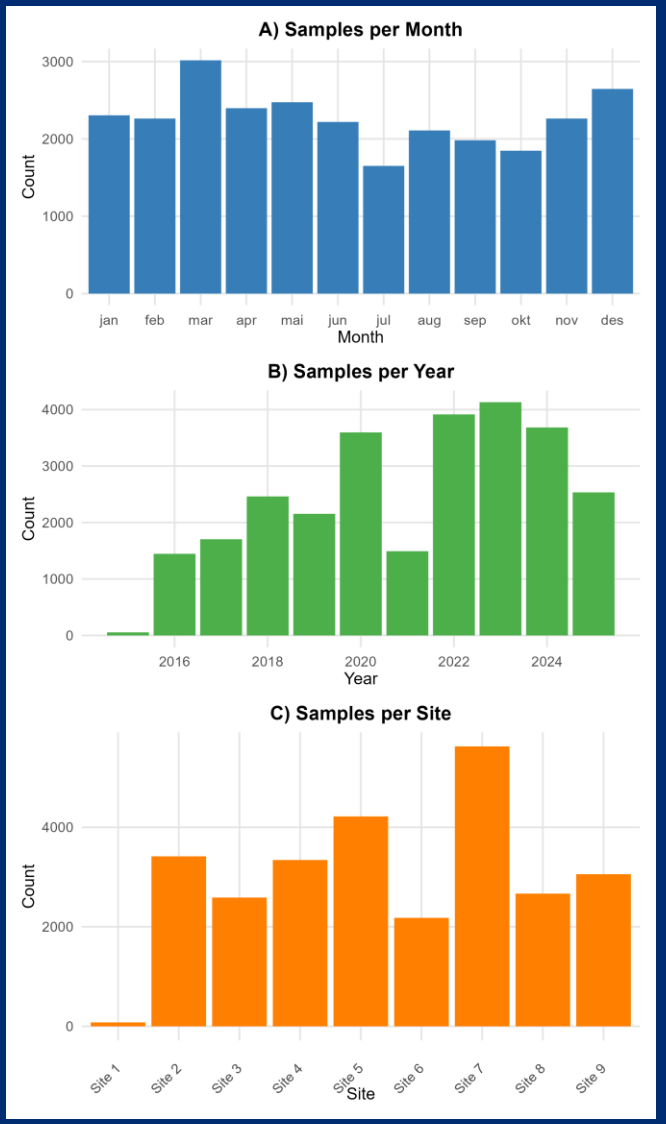
- Per fish:
  - >28,000 individuals; routine welfare sampling (monthly/fortnightly)
  - Length, weight, OWIs, stomach contents
  - Body condition based on wild lumpfish
    Ws from Østerø et al. 2024
    Wr = 100 × W / Ws
  - Stomach content: lice, feeds, zooplankton, biofouling

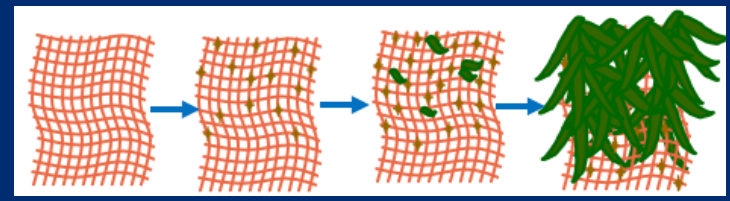
- Per sea cage:
  - Salmon lice levels.
    → Third party (Firum) sea lice monitoring forthnightly

    →Adjusted with digestion windows (AF ~12.9 d; LM ~6.4 d, Eliasen et al. 2025)

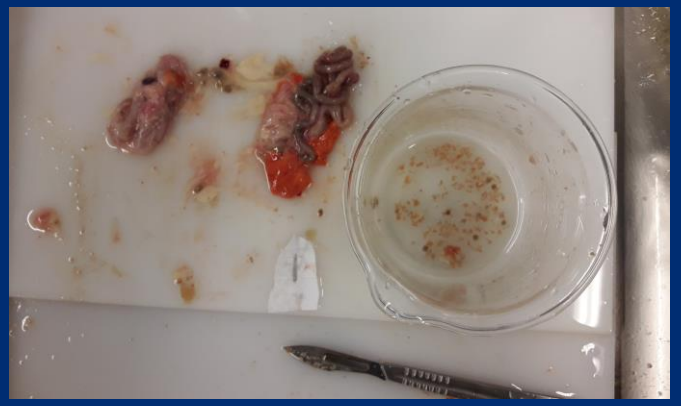
  - Net fouling: 1 clean – 4 heavy seaweed







Lice ingestion prevalence



- Highly zero inflated
- Any lice present in stomachs: **8.17%** (2,343 / 28,677)
- *L. salmonis* present in stomachs: **3.56%** (1,021 / 28,677)

Statistical model: Zero-inflated negative binomial

→ 59% of lumpfish never eat lice (structural zeros)

1) Structural zeros

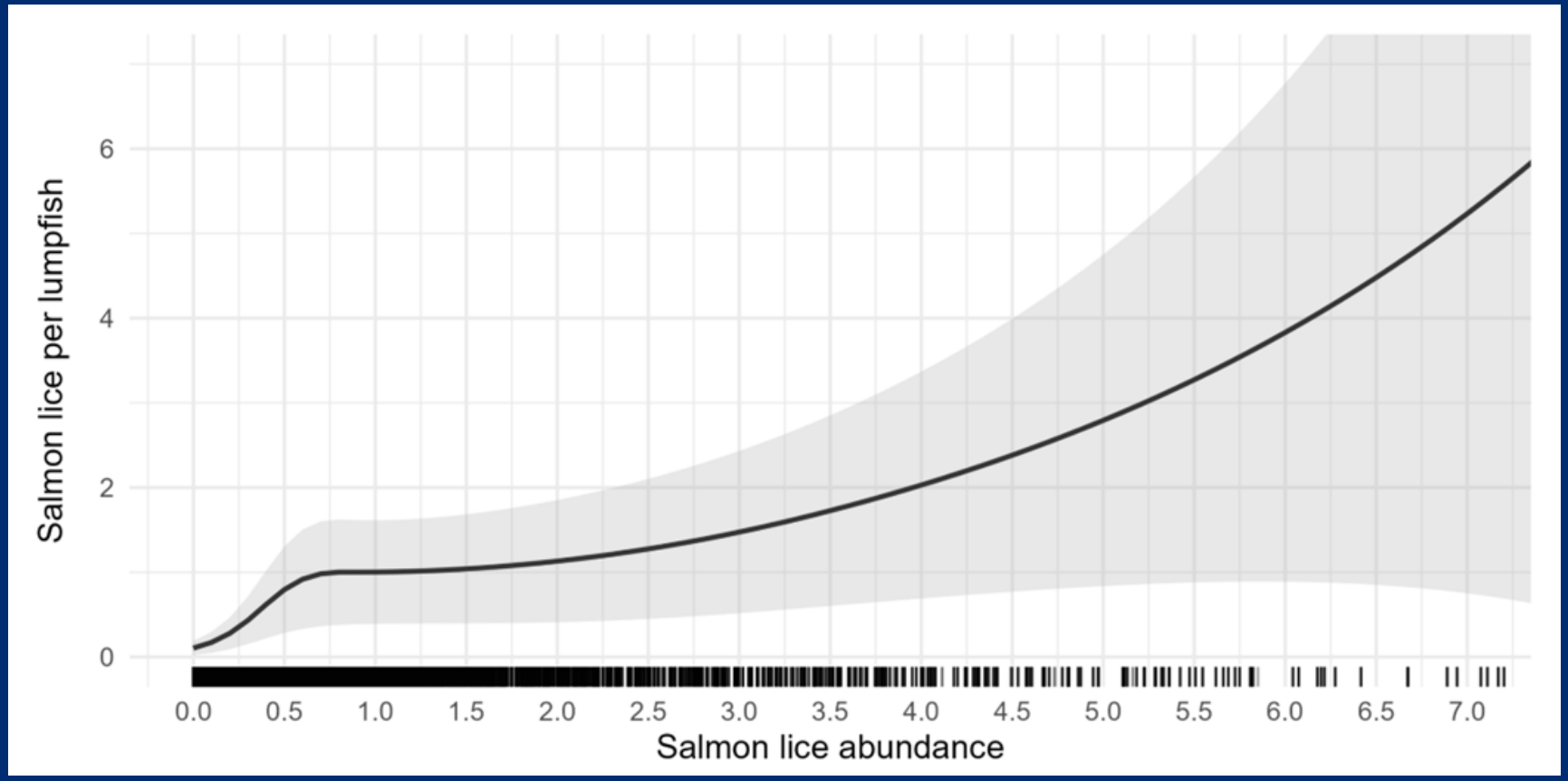
signficant predicors: *L. salmonis* on salmon, lumpfish weight, body condition, altenative prey (salmon feed, lumpfish feed, net associated organisms), net fouling

2) Potential grazers

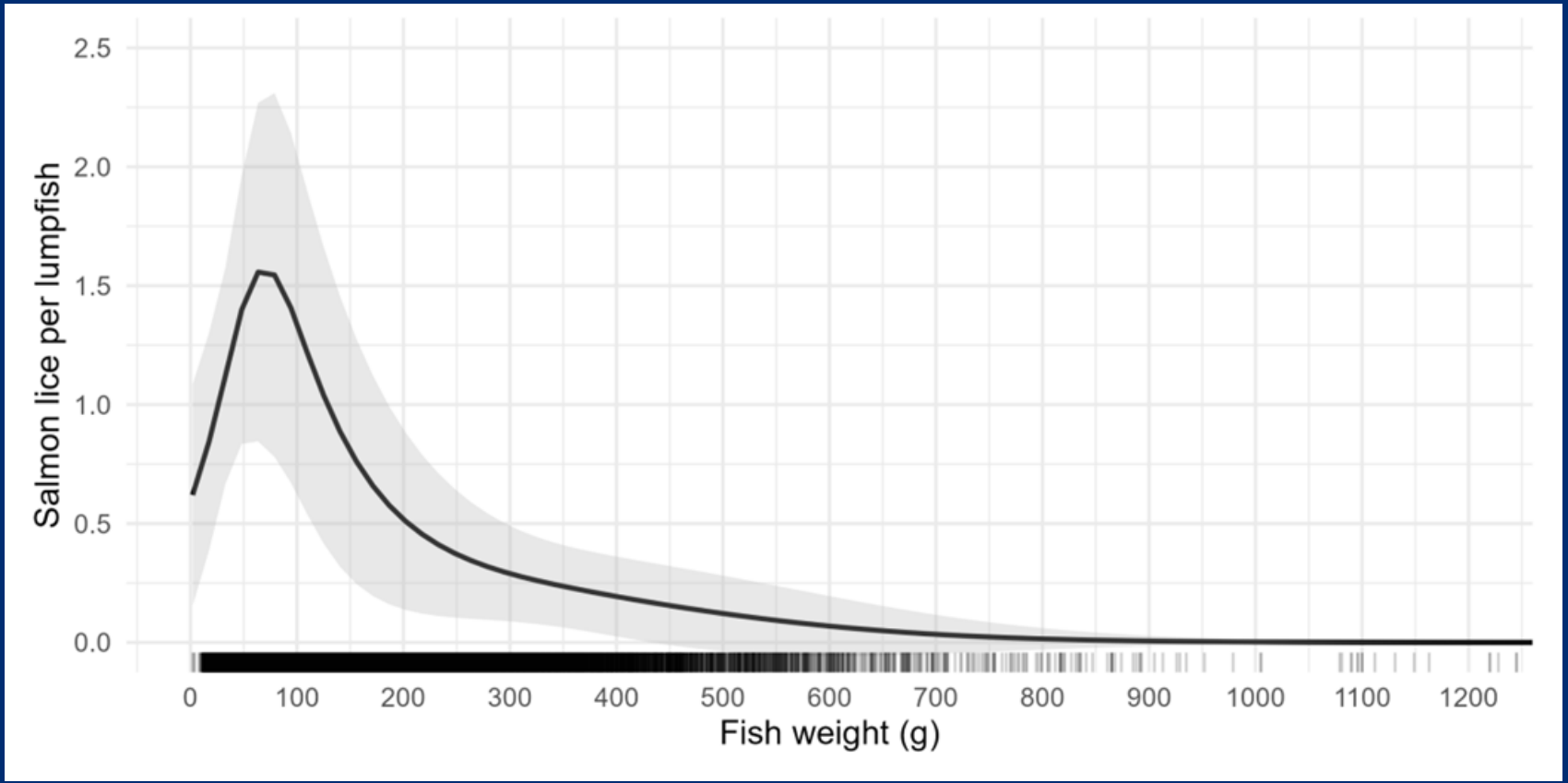
significant predictors: *L. salmonis* on salmon, lumpfish weight, alternative prey (jellyfish, zooplankton, salmon feed, lumpfish feed), net fouling

Effect of salmon lice abundance on salmon

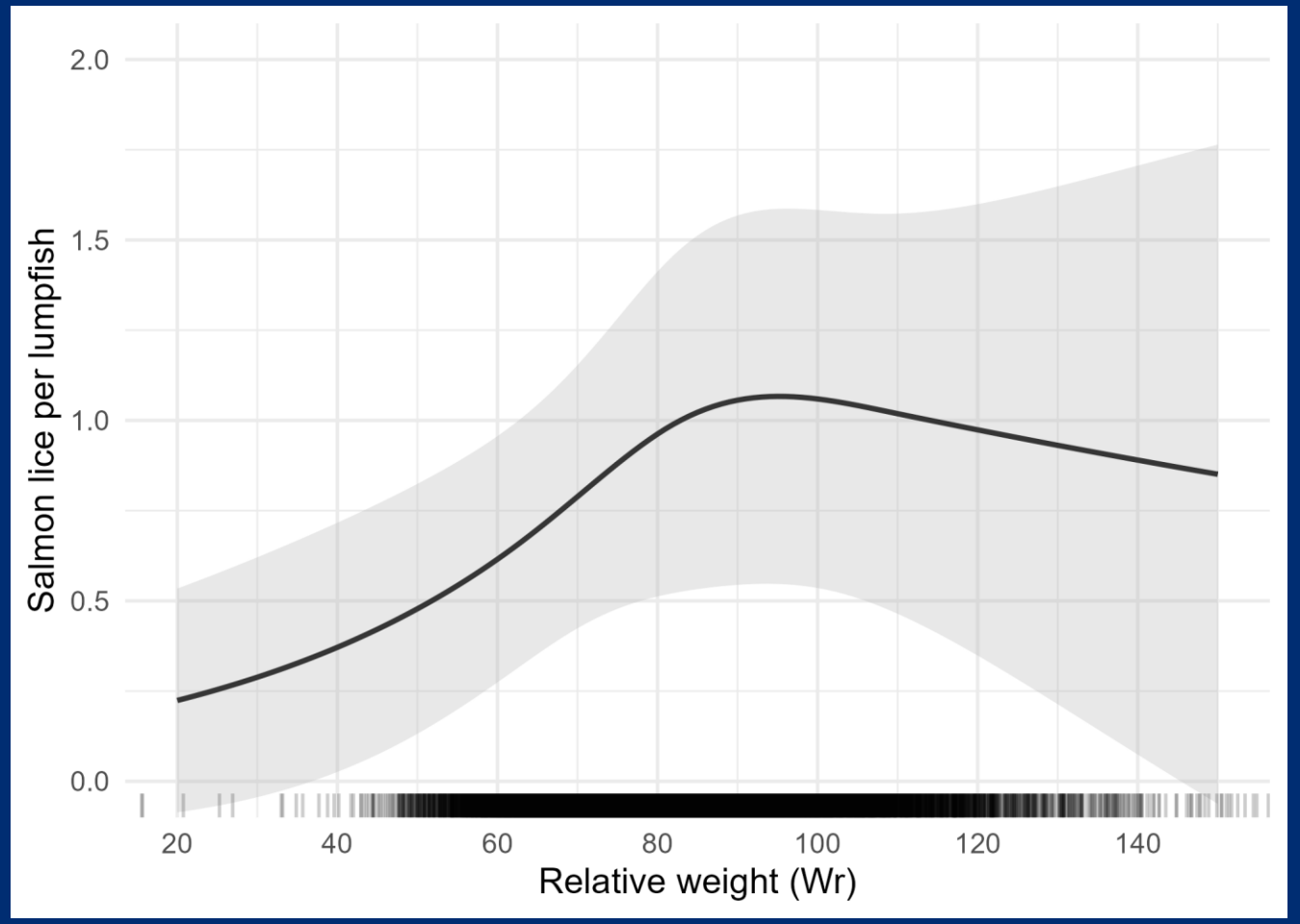
Steep increase in salmon lice consumption to 0.7-0.8 salmon lice per salmon, plateau and high uncertainty



Effect of lumpfish weight



Effect of body condition (Wr)

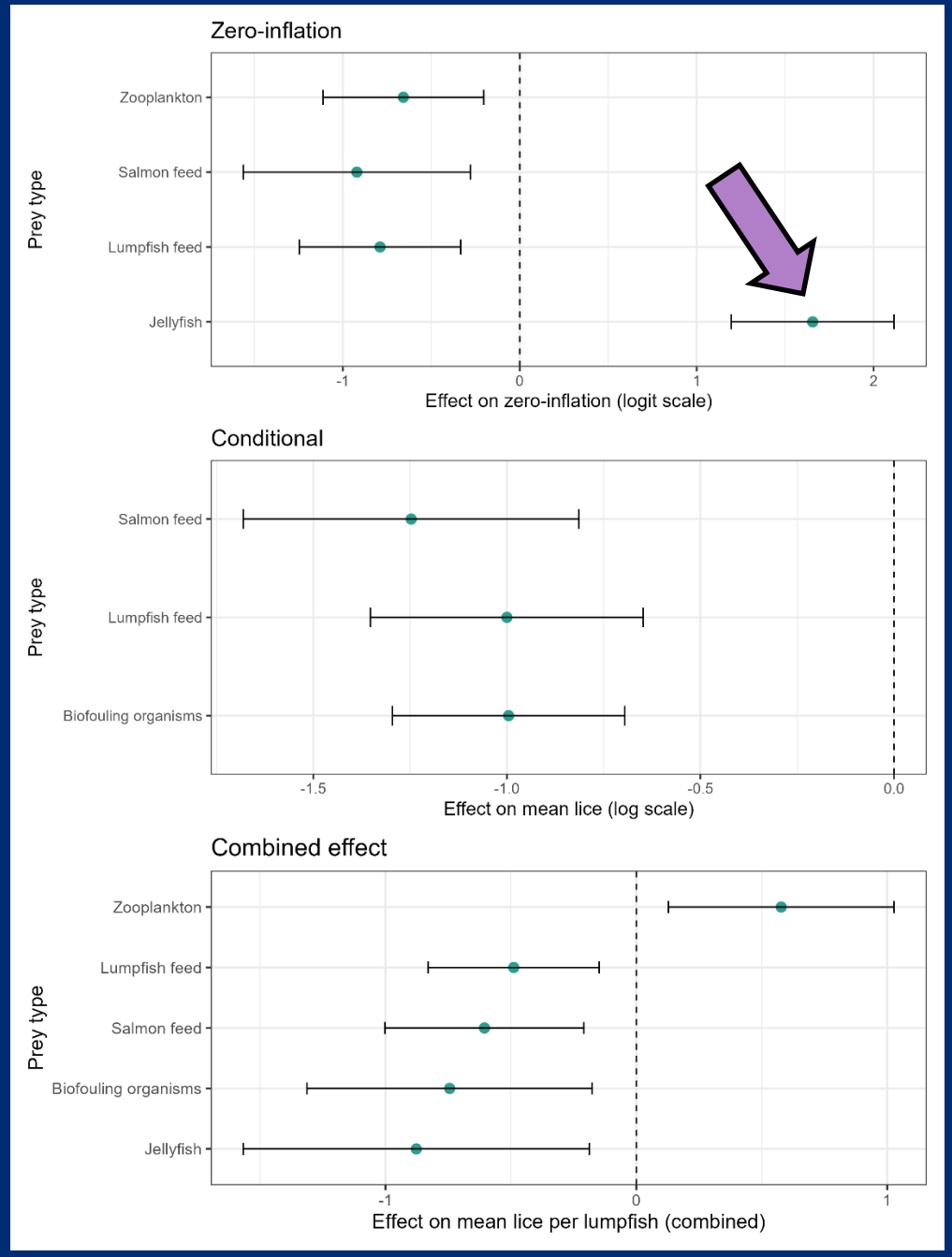


Wr = 100 is optimal body condition based on Østerø et al. (2024)

Alternative prey effects

- Zero-inflation (P[non-grazer] ↑/↓)
  - **Jellyfish** ↑ (β ≈ +1.66, p<0.001)
  - Zooplankton ↓ (β ≈ −0.66, p=0.005)
  - Lumpfish feed ↓ (β ≈ −0.79, p < 0.001)
  - Salmon feed ↓ (β ≈ −0.92, p = 0.005)

- Count model (expected lice ↓)
  - Salmon feed ↓ (β ≈ −1.24, p<0.001)
  - Lumpfish feed ↓ (β ≈ −1.00, p<0.001)
  - Biofouling org. ↓ (β ≈ −0.99, p<0.001)



Highest predicted grazing occurs when:

✓ Lice levels on salmon ≈ ≥0.7 fish^{-1}
✓ Lumpfish weigh 70–80 g
✓ Body condition Wr ~90–100

Predictions drop sharply when alternative prey present (feed, fouling).

Takeaway:

Grazing occurs only when conditions align — appropriate size, motivation, and opportunity.

Temporal variation in prey availability

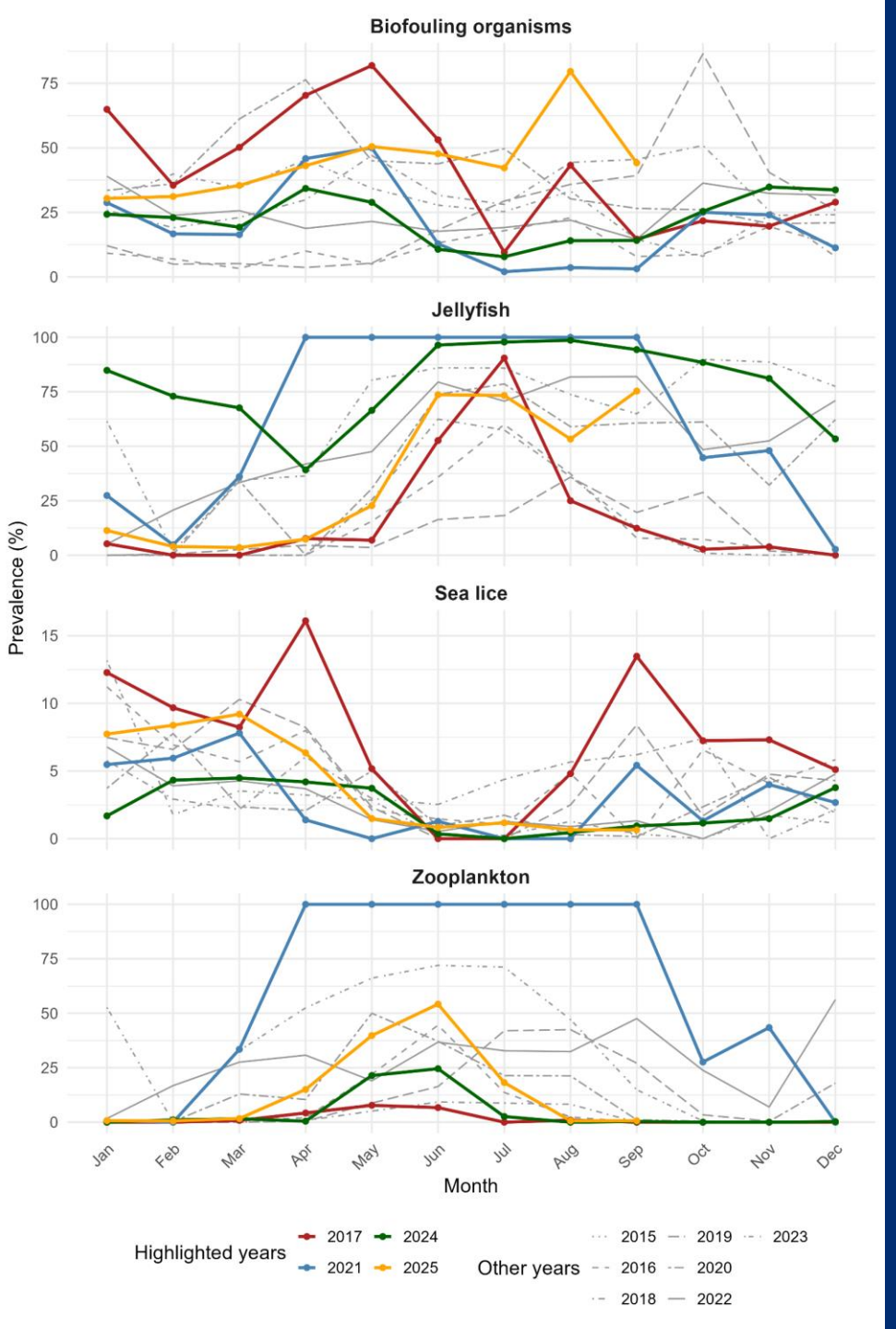
Biofouling organisms
- Throughout most of the year

Jellyfish
- Substantial interannual fluctuations

Sea lice
- Relatively low frequencies (<15%), with minor peaks in spring and autumn. Pronounced opposite pattern as jellyfish (e.g. 2017)

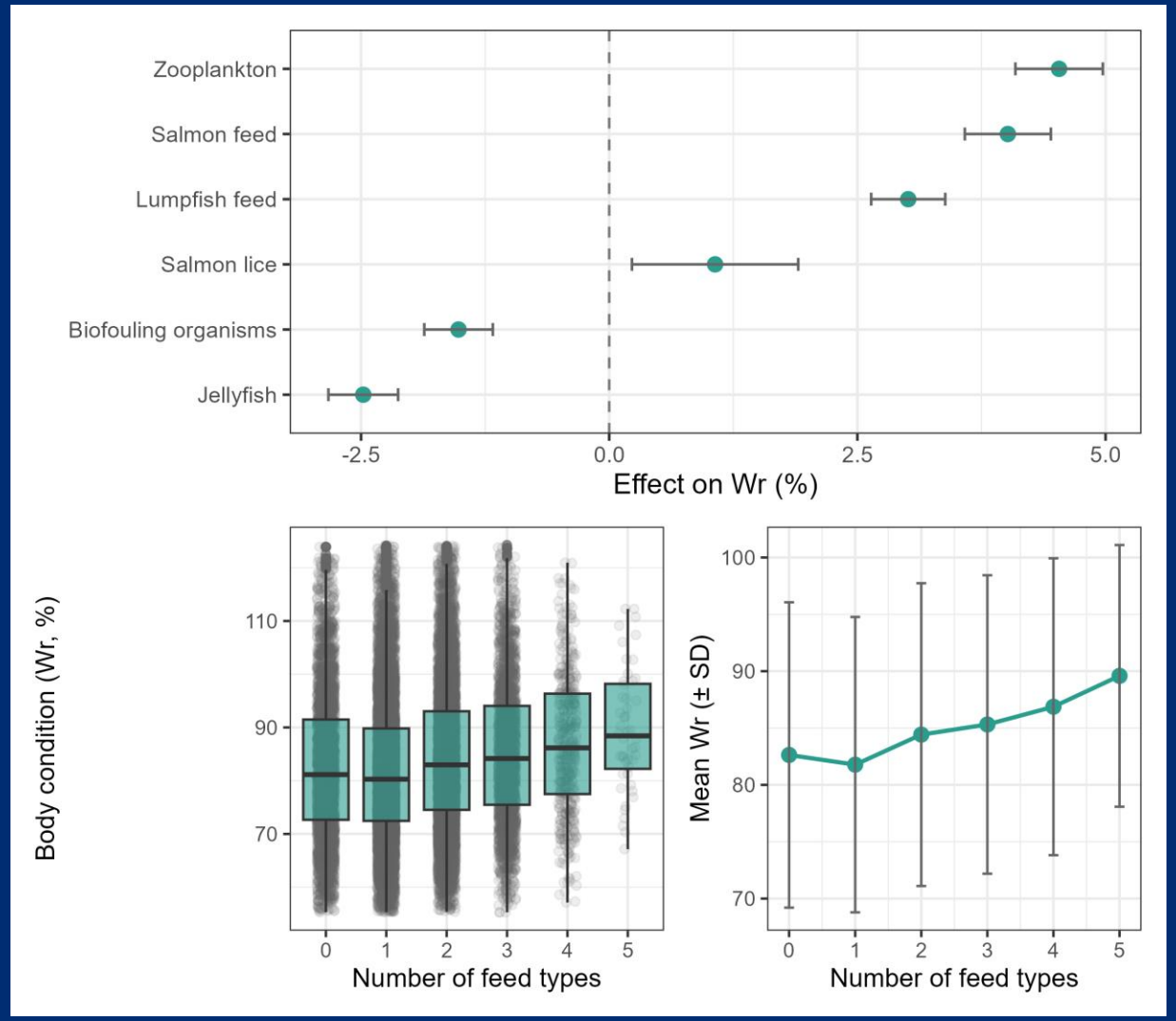
Zooplankton
- Highest during spring and summer

→ Lumpfish encounter highly fluctuating prey environments across deployment periods



Effects of prey types on lumpfish body condition (Wr)

- Feeding on zooplankton, salmon feed, or lumpfish feed is associated with higher body condition.Biofouling organisms have a small positive effect on Wr.Jellyfish consumption is associated with lower body condition (−2–3% Wr).Overall Wr increases with the number of prey types consumed → active foragers are in better condition.Take-home message:Lumpfish with diverse diets are in better condition; jellyfish eaters are generally in poorer condition.



Operational recommendations

- Deployment timing
  - Avoid periods dominated by jellyfish or dense zooplankton blooms
  - Target fish size ~70–80 g where feasible
- Cage environment
  - Consider moderate fouling as habitat (balance with biosecurity)
  - Use skirts or barriers to limit jellyfish influx when needed
- Feeding strategy
  - Minimize excess pellet availability around peak grazing periods
- Use low lice limits judiciously: very low ambient lice may hinder initiation of grazing.

Discussion Slide 1 — "Why do lumpfish graze sometimes but not others?"
Key points:
~59% predicted structural zeros — majority do *not* feed on lice.
Grazing depends on **opportunity** (lice availability).
Lumpfish are **generalist feeders**, not obligate cleaners.
Early exposure to lice may be important to *learn* grazing.
Takeaway:
Most lumpfish will not graze unless conditions provide both opportunity and motivation.

Discussion Slide 3 — "Operational implications"
Key points:
Target lumpfish around **70–80 g**.
Maintain **good body condition** (Wr ~90–100).
Allow **moderate net fouling** for habitat structure; avoid heavy fouling.
Minimize feed spill during periods where grazing is desired.
Lice skirts can reduce jellyfish entry.
Final message:
Strategic timing + appropriate size + manageable prey environment = best chance of effective delousing.

Future work

- Prospective trials aligning deployment with prey conditions.
- Behavioral tracking to test learning/opportunity mechanisms.
- Integrate environmental covariates (temp, currents, turbidity, light).
- Quantify jellyfish influx and skirt efficacy at scale.

Acknowledgements

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Thank you!
FIRUM
Hiddenfjord
Raised in the wild
MOWI