



Prey switching by yellow-eyed penguins attributable to recreational over-fishing?

Chris Lalas and Hiltrun Ratz Penguin Rescue, Moeraki, New Zealand e-mail: penguins@xtra.co.nz

Introduction

Yellow-eyed penguins (hoiho, *Megadyptes antipodes*) at Otago, South Island, New Zealand, forage across the continental shelf^[1] where they overlap with commercial and recreational fisheries. Previous diet studies of hoiho along Otago Peninsula (≤ 20 km from Dunedin) found blue cod (*Paraperca colias*), a benthic fish targeted by fisheries, numerically accounted for 1% of prey items in 1984–86^[2] and 2% in 1991–94^[3], rising to 24% in 2016^[4]. The rise in importance of blue cod might be attributable to an anthropogenic cause: seafloor degradation by bottom fishing gear can impede the growth rate of juvenile blue cod^[5] and perhaps increase their availability as hoiho prey^[6]. However, their relatively large size as prey (up to 25 cm) may cause spillages when adults feed their chicks (“feeding spills”), leading to chick starvation^[8]^[6].

Our study

Here we investigate the chronology, extent and impact of prey switching to blue cod by hoiho through two decades locally along Otago Peninsula and 50 km further north at Moeraki, North Otago. Data for hoiho diet were derived from two sources. Feeding spills were collected during nest checks 1–2 times weekly at four of the colonies on Otago Peninsula through 16 breeding seasons 1997–2012, followed by nest checks 3–5 times weekly at the two colonies at Moeraki through five seasons 2014–2018. Casts were collected whenever encountered at Moeraki throughout five years, June 2014–May 2019.

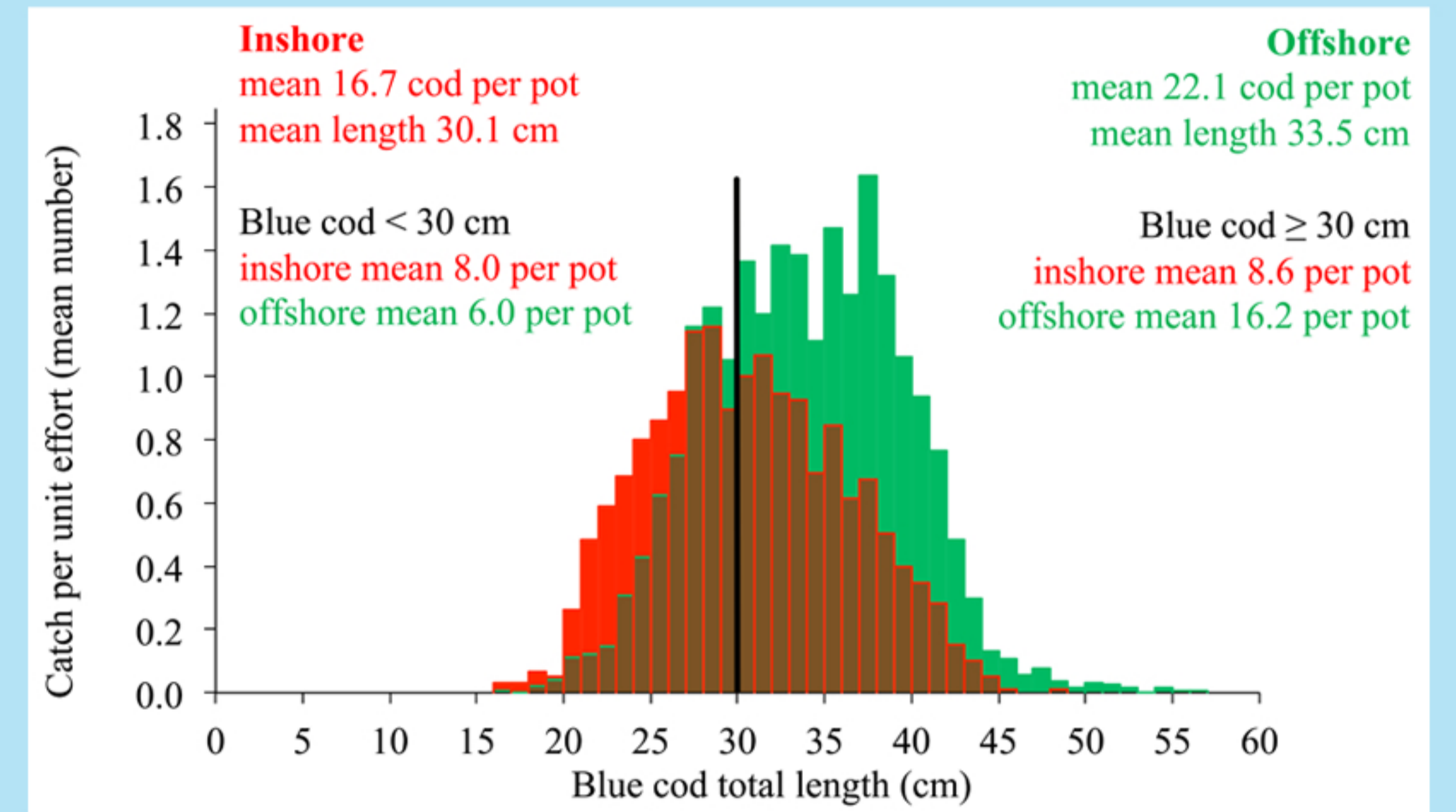


Blue cod is the most important marine recreational fishing species in Otago.

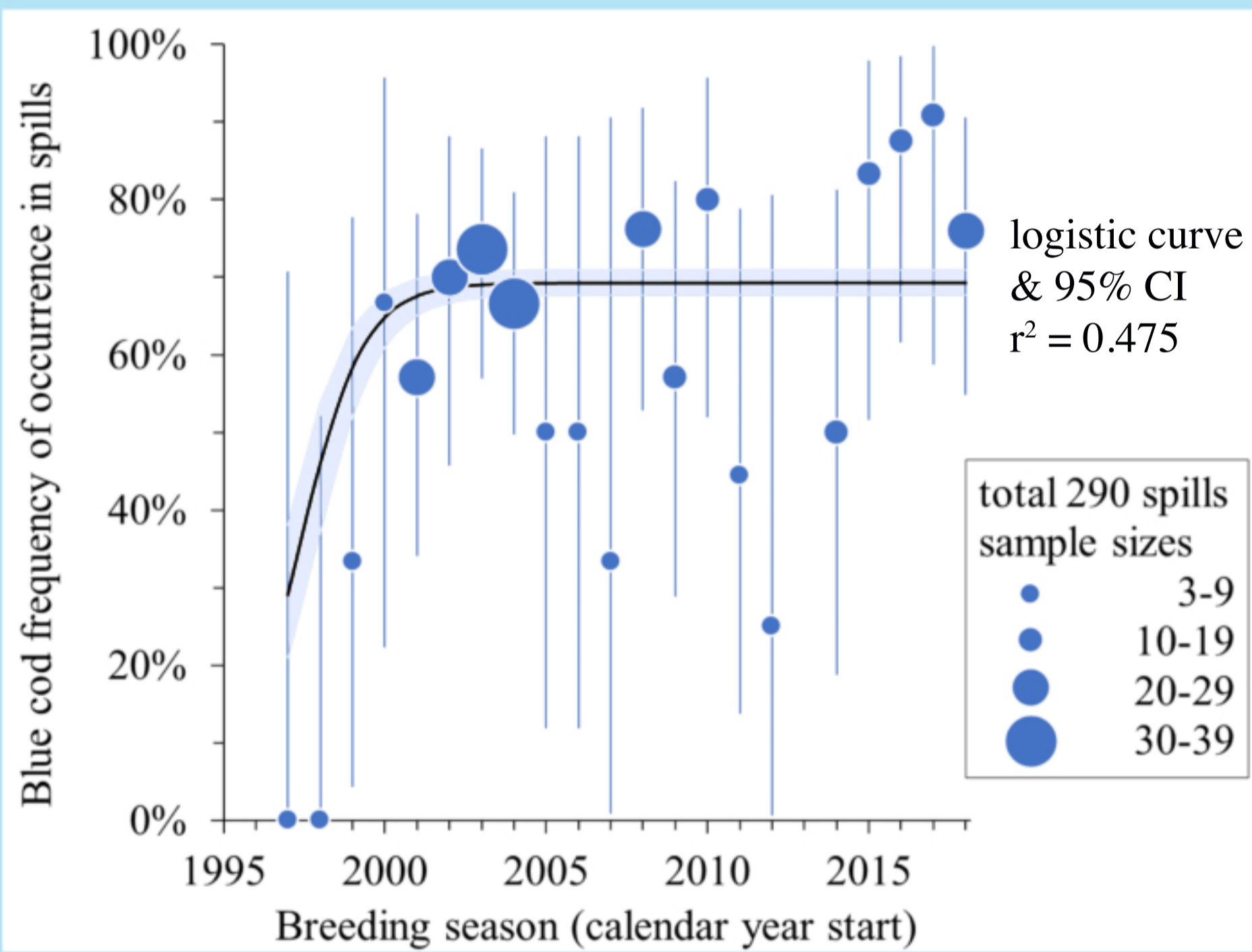
- Can be long-lived (> 30 years)
- Grows to 70 cm total length
- Minimum legal size is 30 cm

Evidence for recreational overfishing of blue cod

Carbines & Beentjes conducted surveys of blue cod at North Otago (the region that encompasses our study area at Moeraki) in 2005^[9] and 2009^[10]. Blue cod were less abundant and smaller at heavily fished inshore sites than at less fished offshore sites. They attributed the likely cause of these differences to the heavier recreational fishing pressure at inshore sites. Small fish were more likely to escape from pots (the shortest retained was 16 cm) and so they were under-represented in samples.



We graphed the combined results from both surveys. The average catch rate of blue cod at inshore sites was 24% less than at offshore sites. However, in marked contrast, the catch rate of fish < 30 cm was 33% higher at inshore sites. These results indicate that heavily-fished/overfished areas have a greater abundance of blue cod available as prey for hoiho than more lightly-fished areas.

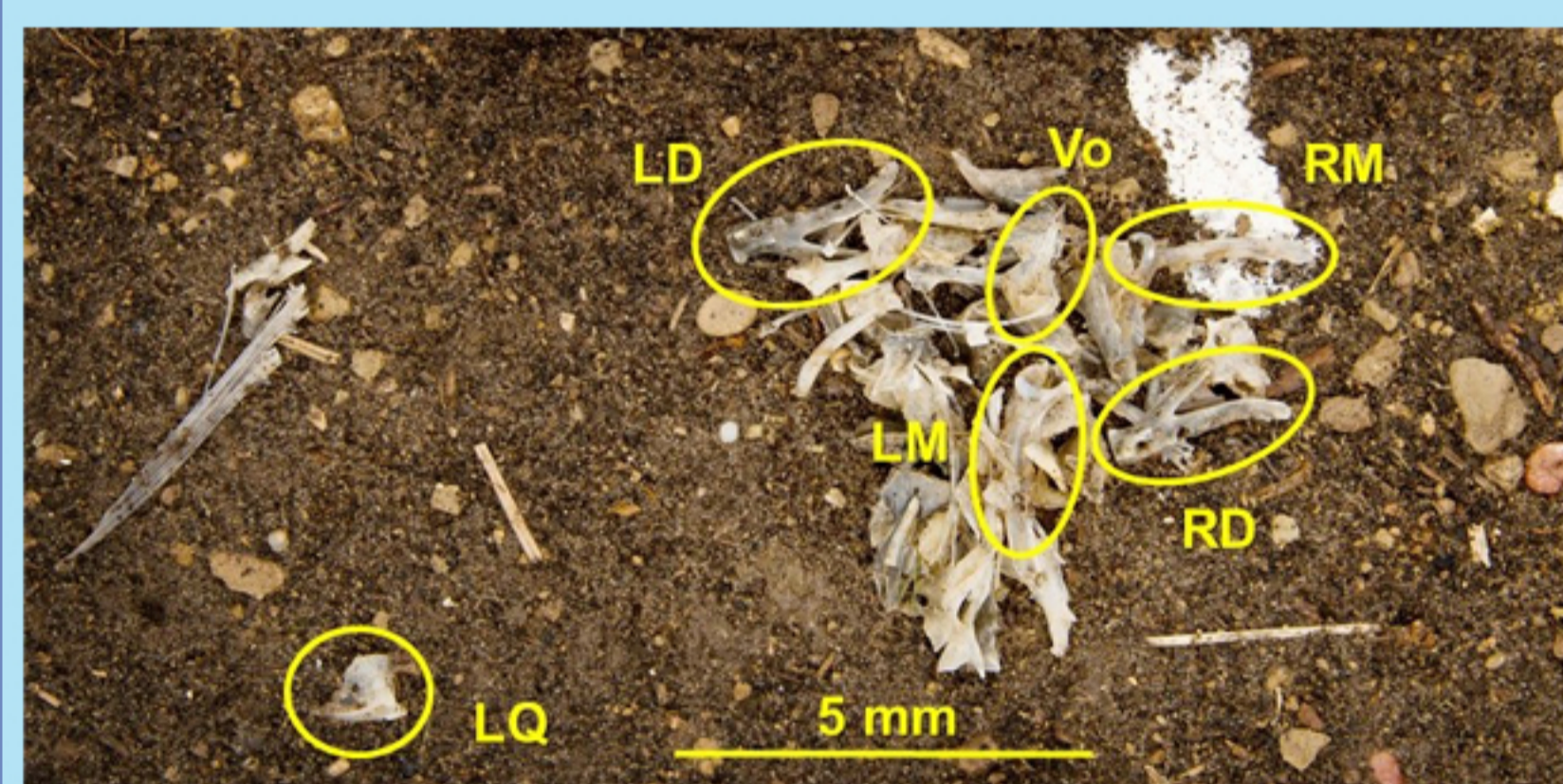


Chronology of prey switching to blue cod

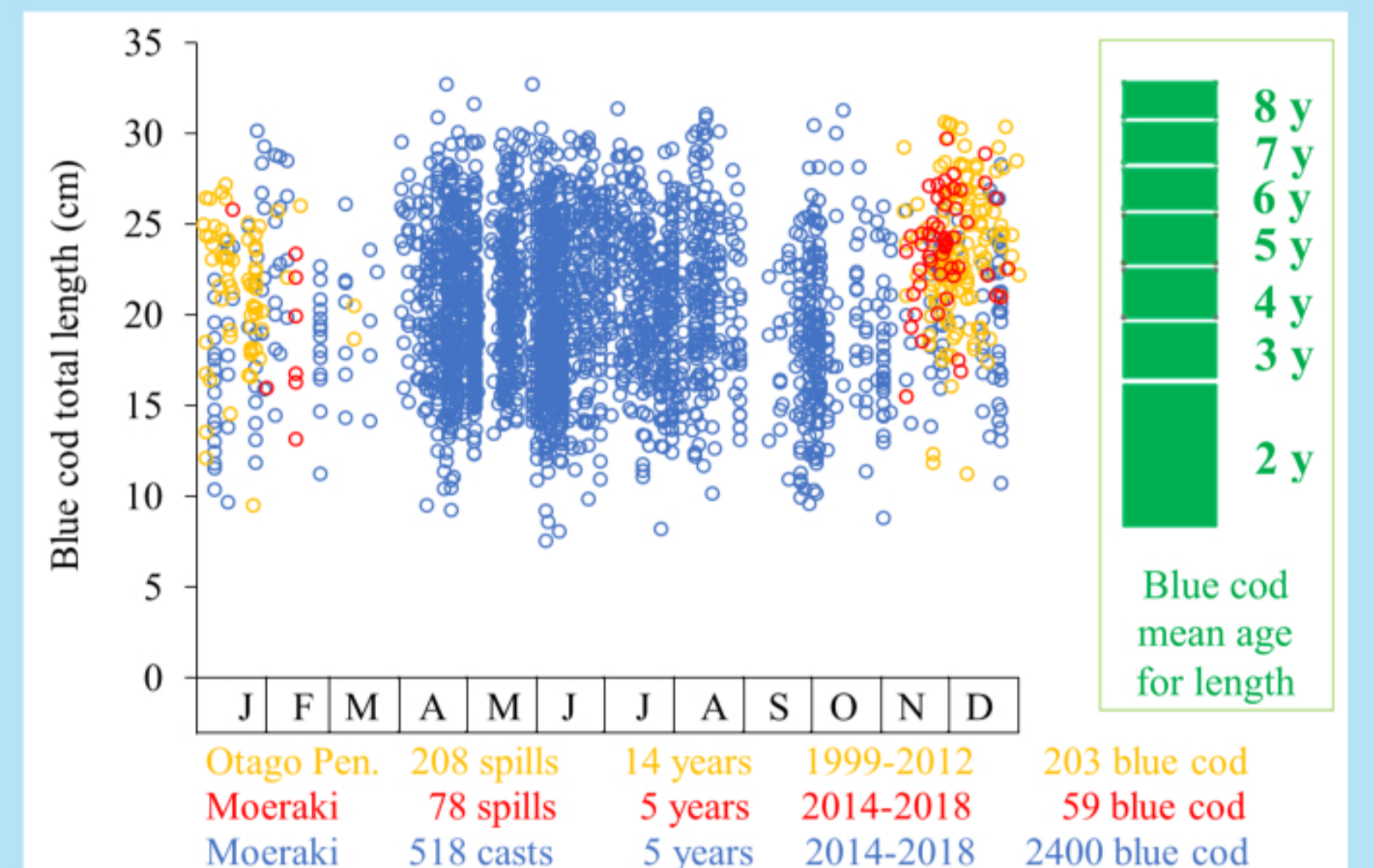
Here the annual occurrence of blue cod is plotted for hoiho feeding spills collected through 21 breeding seasons. The weighted logistic regression indicates that prey switching to blue cod likely occurred through less than a decade: beginning in the mid 1990s and reaching an asymptote of 69% in the early 2000s.

Hoiho casts

Hoiho casts (regurgitations of resilient prey remains; no tissue) include uneroded remains indicative of one day's food. Unfortunately, cast contents can be scattered (up to 1m²) and tiny bits are easily missed, especially in vegetation. Blue cod have relatively large bones and are likely to be represented accurately. Blue cod (2,452 fish = 322 kg) occurred in 92% of the 562 casts and accounted for 65% of the total number and 85% of the total biomass from the 24 fish species recorded.

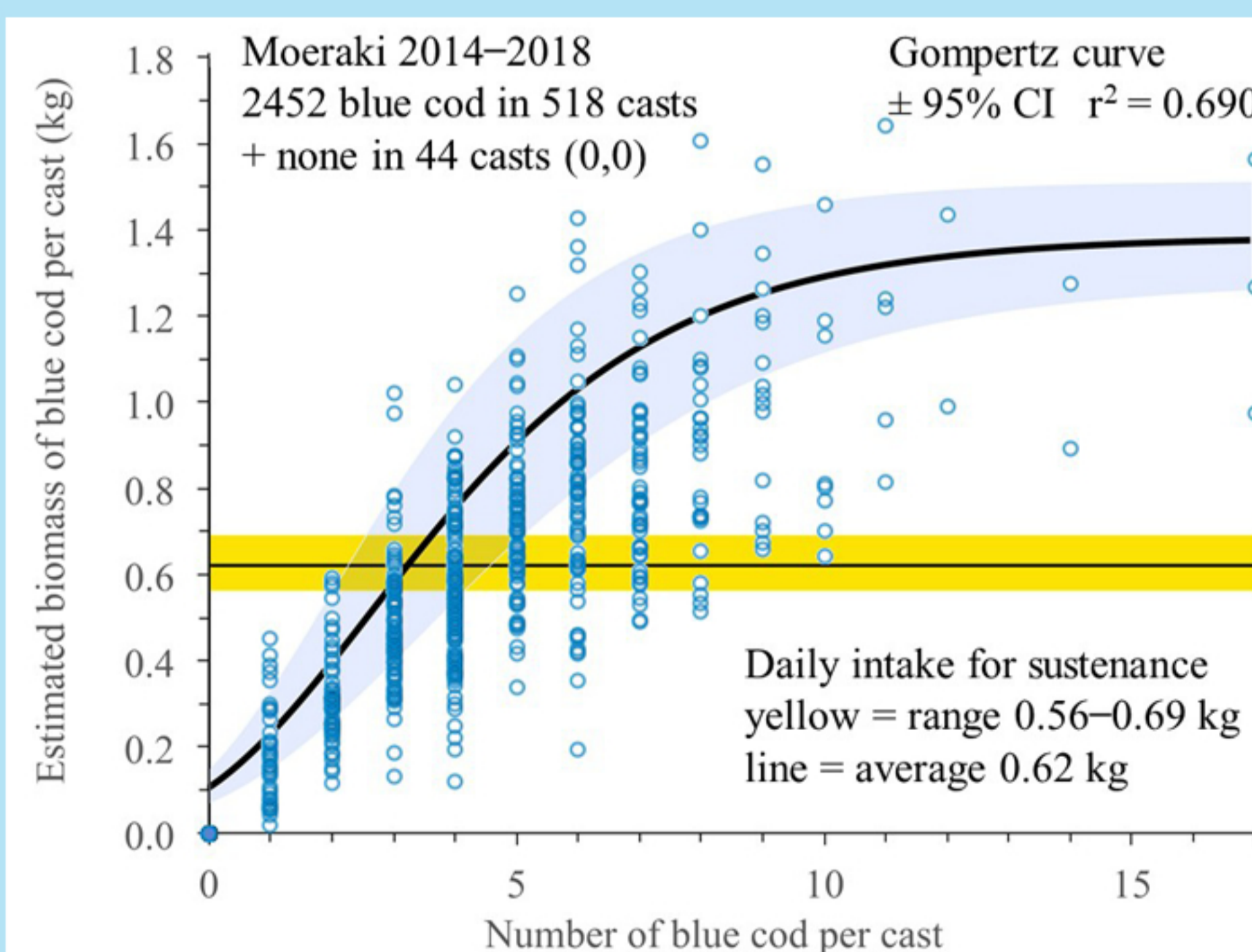


A mercifully simple and coherent hoiho cast—the only prey remains are blue cod bones deposited in a heap with little scatter on bare ground. Several of the diagnostic bones used in prey size calculations are encircled: LD left dentary; LM left maxilla; LQ left quadrate; RD right dentary; RM right maxilla; Vo vomer.



Size of blue cod as prey

The size of blue cod eaten by hoiho averaged 20.4 cm (range 7.6–32.7) from casts and 22.8 cm (range 9.5–30.6) from feeding spills. There was no obvious seasonal trend in size. Blue cod age for length at North Otago^[11] shows that prey encompassed seven cohorts.

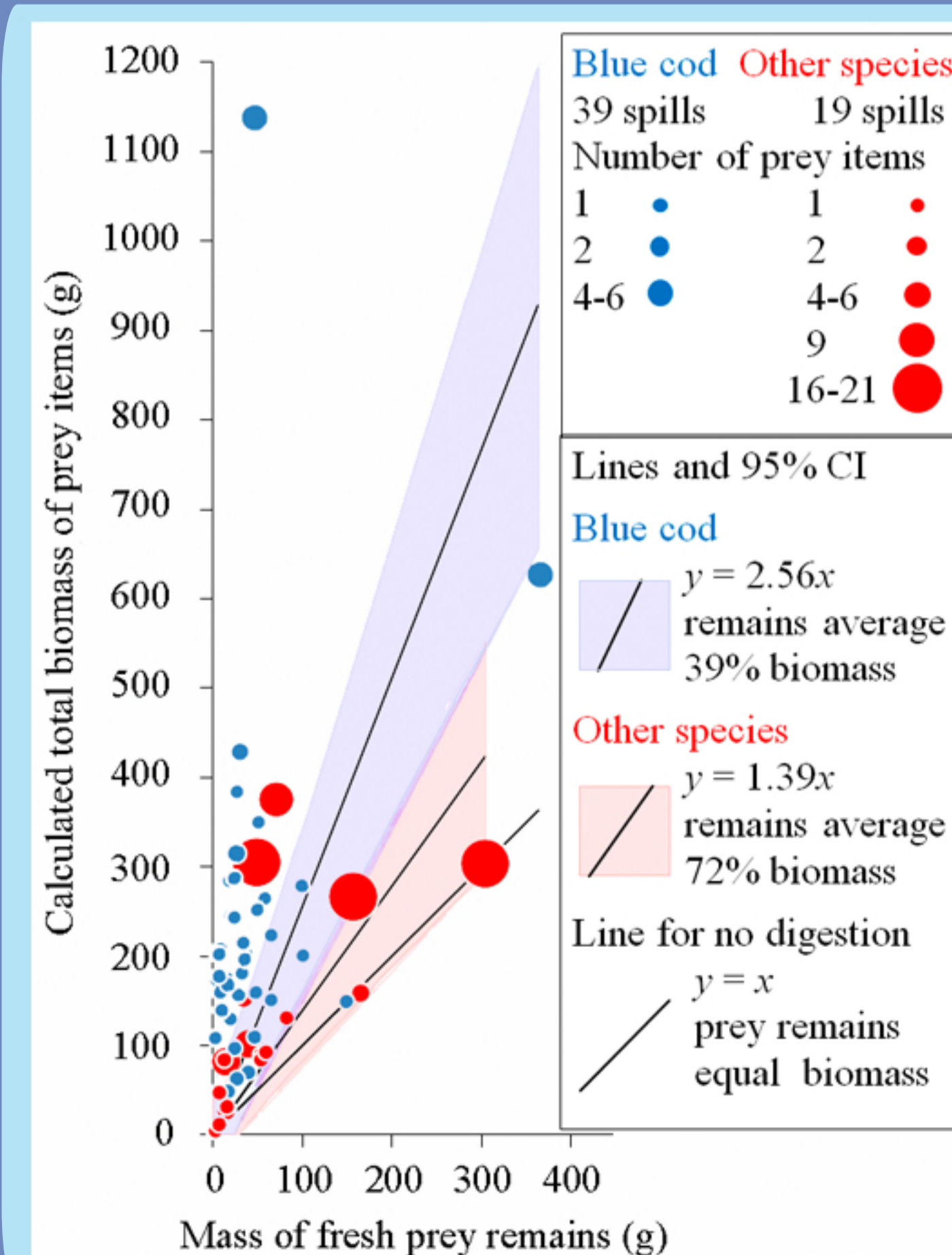


How much is enough?

We calculated estimates for the biomass of blue cod required to satisfy hoiho daily intake by substituting values into equations for a similar-sized ecological equivalent, gentoo penguin (*Pygoscelis papua*)^[11]. The energy content of blue cod was set at 5.0 kJ/g, the value for familial *Pseudoperca ramsayi*^[12]. Results are depicted for hoiho average 5.0 kg and for normal range 4.5–5.5 kg.

The for each blue cod eaten averaged 0.13 kg. Hence hoiho are satiated by only five blue cod per day.

The total daily total biomass of blue cod in the 518 casts averaged 0.62 kg. This was the same as the average daily requirement for self-sustenance.



Are losses due to feeding spills likely cause of chick starvation?

Through the five seasons 2014–2018 we found 74 feeding spills, with 89% fairly evenly spread through the first six weeks after hatching. For this duration, the 394 chicks hatched would have received a rough estimate of 24,260 meals. The 66 losses only accounted for a trivial 0.3% of these meals.

The 74 spills consisted of 53 with only blue cod, 16 with only other species and five with both. For those with fresh contents, the relationship between biomass and mass of prey remains indicated that significantly less ($t = 8.338$, $p < 0.001$) sustenance is lost in spills of blue cod (33% biomass lost) than in spills of other species (72% biomass lost).

Conclusions

Prey-switching has occurred—Blue cod rose from obscurity through the decade 1995–2005 to become the main prey species of hoiho; perhaps now targeted in preference to traditional prey.

Prey-switching caused by overfishing by recreational fishers? Probably yes—but relies on the assessment that recreational overfishing has reduced the average size of blue cod and increased the abundance of smaller fish being correct.

Good news or bad news?—a matter of opinion It's all bad news if you believe all anthropogenic changes are bad. Alternatively, overfishing blue cod has good aspects for hoiho targeting blue cod:

- Large prey size: hoiho satiated with only five per day.
- Spillages during transfer of food to chicks are not a cause of chick starvation.
- Prey size spans six cohorts—reduces the likelihood of food shortage generated by prey cohort failure.

Manifestations of Satan?—Those who consider piscivores as pariahs should be demanding a hoiho cull. Here is an opportunity to use an iconic species to refute this logic.

References

- [1] Mattern et al. 2007. Mar Ecol Prog Ser 291: 43–52
- [2] van Heezik 1990. New Zeal J Zool 17: 201–212
- [3] Moore & Wakelin 1997. Mar Ornithol 25: 17–29
- [4] Mattern & Ellenberg 2016. CSP 16205-1 POP2016-05
- [5] Carbines et al. 2004. Aquatic Conserv 14: 491–504
- [6] Mattern et al. 2013. PLoS One 8:e84381
- [7] Mattern et al. 2018. PeerJ 6:e5459
- [8] Browne et al. 2011. Austral Ecol 56: 99–108
- [9] Carbines & Beentjes 2006. NZ Fisheries Rep 2006/29
- [10] Carbines & Beentjes 2011. NZ Fisheries Rep 2011/36
- [11] Eder & Lewis 2005. Mar Ecol Prog Ser 291: 43–52
- [12] Hinke & Trivelpiece 2011. Polar Biol 34: 1579–1590