Estimation of feed loss from two salmon cage sites in Queen Charlotte Sound

Prepared for NZ King Salmon

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Frontispiece: Study cage a the Ruakaka site, showing ropes supporting the sampling traps (photo: Dan Cairney, NIWA).

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Executive summary

The amount of feed not consumed by the stock was estimated at two salmon-farm sites in Queen Charlotte Sound, Ruakaka (a low-current site) and Clay Point (a high-current site). Wastage was estimated during morning and afternoon feeds at both sites by placing eight traps in the water column between the feeding depth of the salmon and the floor of the cage. Numbers of pellets collected were very small (0-2 per trap) during all feeds at both sites, and wastage represented less than 0.3% of the total feed supplied, and usually less than 0.1%. These values compare very favourably with those quoted in the literature (5% or more) and suggest that feed monitoring is effective at these farms.

1 Introduction

Uneaten feed may represent a significant economic loss to salmon farms and also contributes to their environmental effects through deposition of organic matter and other components of the feed on the seabed below and around the farm. Published estimates of rates of loss from Atlantic salmon farms in Europe and North America range from 1-20%, but improved feed-monitoring systems and husbandry practices have probably reduced this to around 5% since those estimates were made (Chamberlain & Stucchi 2007). A recent study at a farm for King salmon in the Marlborough Sounds (Ruakaka Bay, Queen Charlotte Sound), however, recorded feed losses of only 0.01 – 0.015% (NZKS 2011, unpublished study).

The New Zealand King Salmon Company Ltd (NZ King Salmon) has engaged NIWA to assist in quantifying the proportion of salmon feed that is wasted during routine feeding. This was measured using collectors at two salmon farms in the Marlborough Sounds (including the previously-studied Ruakaka Bay farm).

The results of the study, with estimates of the percentage of feed wasted, are presented in this report.

2 Methods

2.1 Farm layouts and feeding systems

Sampling was done at two farms, one in Ruakaka Bay, Queen Charlotte Sound and one at Clay Point, Tory Channel (Figure 1). The former is regarded as having low current speeds and the latter as having high speeds (due to its location in the ca 1.5 km-wide channel between Arapawa Island and the mainland). Average and maximal current speeds at Ruakaka are 3.7 cm s^{-1} and 17.5 cm s^{-1}, respectively and those at Clay Point are 19.6 cm s^{-1} and 109 cm s^{-1}, respectively (measured at 20 m water depth by ADCP over 30 d deployment: Nigel Keeley, Cawthron Institute, pers. comm.). Minimal speeds at both sites are ca 0 cm s^{-1}.

Experimental cages have a mesh size of 70 mm and each of the farms is surrounded by a predator net of 204-mm mesh (measured on the diagonal). The inner nets at Ruakaka are cleaned by in-water water-blasting approximately once every 15 days and nets are lifted and water blasted every 3 months in summer and every 4-5 months in winter. Inner nets at Clay Point are cleaned by in-water water-blasting approximately once every 15 days in summer and once every 21 days in winter. The nets are lifted out of the water once every twelve months, dried and cleaned.

The feed used at both farms was Skretting 9 mm Orient 3000 extruded pellets. The unit weight of the pellets was 0.869 g (equivalent to 1,151 pellets kg^{-1}) (Ben Wybourne, Skretting, pers. comm.). The sinking rates of pellets may vary from batch to batch, but for the 9-mm Orient pellets sinking rates are typically 7.4 m $minute^{-1}$ (Ben Wybourne, Skretting, pers. comm.).

Fish in each of the experimental cages were ca 2 years old, but may have originated from different selective breeding regimes.

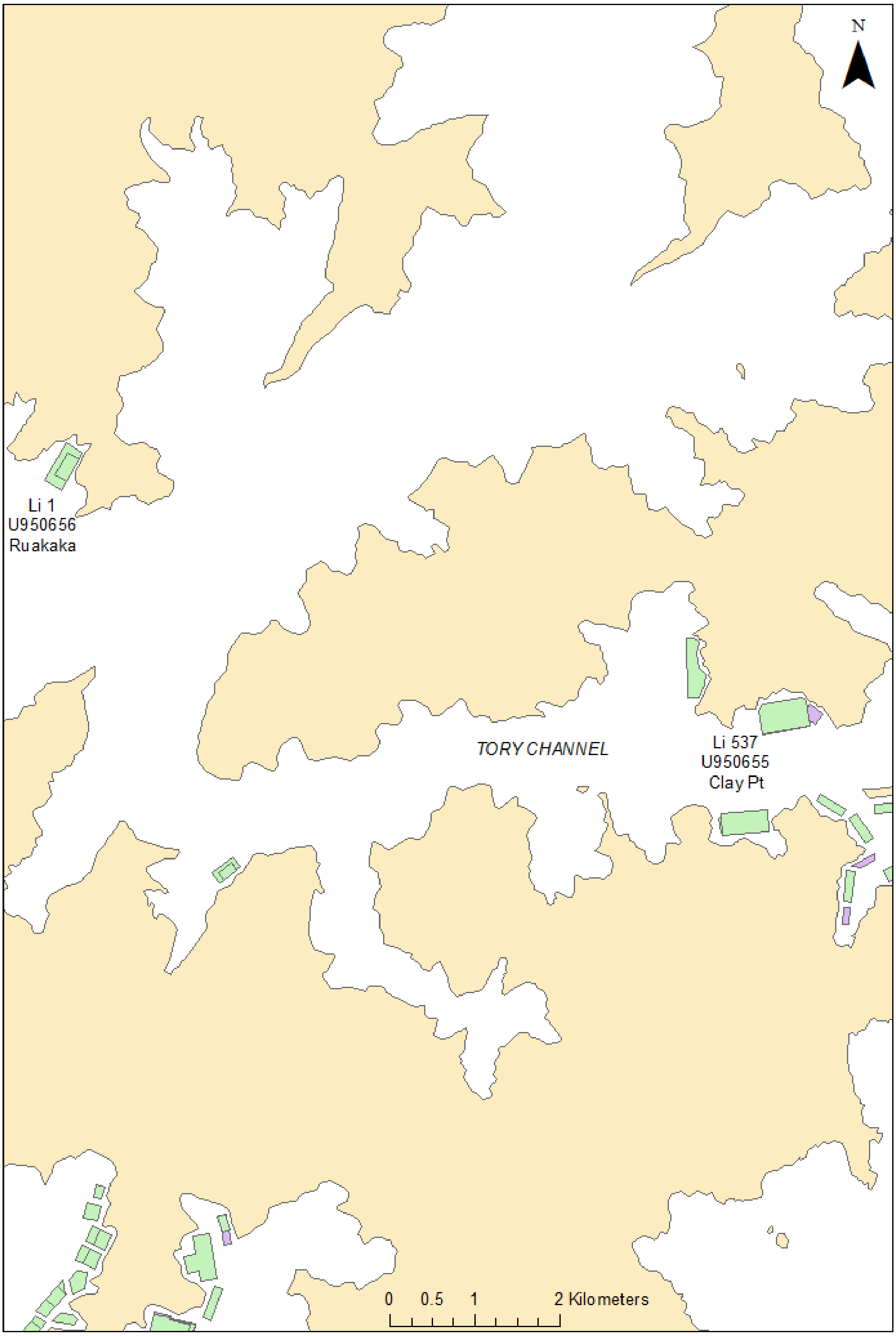

Figure 1: Map of Tory Channel showing the Ruakaka and Clay Point farms.

2.1.1 Low-current site, Ruakaka

Cage size and arrangement

At the time of sampling, this farm consisted of 12 square cages (each cage 20 m x 20 m) used for on-growing and arranged in two adjacent, parallel rows. The depth of the net in each cage was 17 - 22 m (being deepest in the centre) and water depth at this site was ca 33 m. There were also eight smaller experimental cages at the site, attached to the end of one of the main rows of cages.

At the time of sampling, the study cage (L3B) contained 26,117 fish with an average weight of 2.659 kg (total biomass 69,438 kg). Fish are currently fed twice daily, in the morning and afternoon. In the near future these fish will move to a once-a-day feeding routine.

Feeding monitoring

Feed dispensing and monitoring is done via an Akvasmart AQ1 automated feeder system (Figure 2), with both feeding rate and amount adapted to fish appetite. Feed is dispensed into the cage via a central spinner feeder. The electric spinner is mounted on the bottom of a 350-kg plastic hopper and dispenses the pellets over a circular area ca 12-m diameter and centred below the spinner. An infra-red optical sensor is attached to the bottom of a 1.55-m diameter pellet-collector cone which is mounted in the cage at 5 m depth (below the fishes main feeding area). As uneaten pellets fall below this depth they are detected by the sensor and feeding is shut off at a given threshold, in this case 8-12 pellets. Settings are adjusted via AkvaControl computer software.

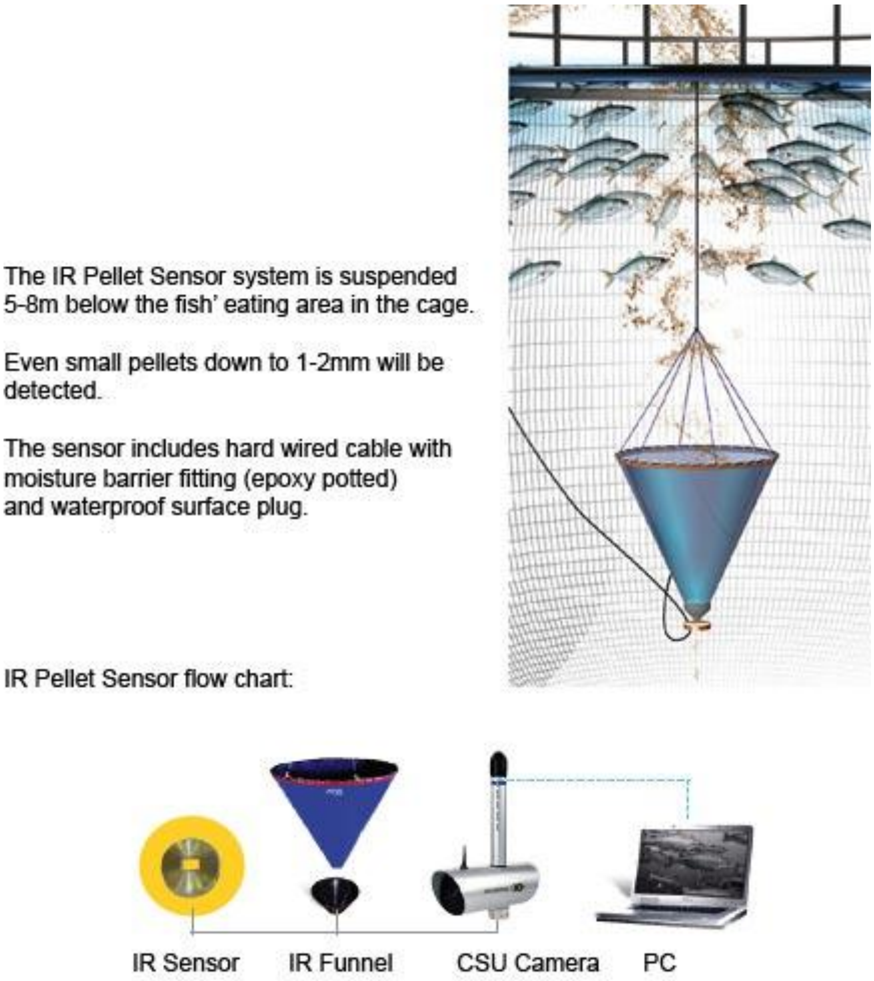

Figure 2: **Diagram of the Akvasmart AQ1 Feeder system, showing method of deployment and flow chart for the feed management system (source: Akvasmart website, http://www.akvagroup.com).**

2.1.2 High-current site, Clay Point

Cage size and arrangement

At the time of sampling, this farm consisted of 12 square cages (each cage 30 m x 30 m) used for on-growing and arranged in two adjacent, parallel rows. The depth of the net in each cage was 24 - 27 m (being deepest in the centre) and water depth at this site was 30 - 40 m.

At the time of sampling, the study cage (C4) contained 71,966 fish with an average weight of 1.795 kg (total biomass 129,172 kg). Fish are currently fed twice daily in the morning and afternoon. In the near future these fish will move to a once-a-day feeding routine.

Feeding monitoring

Feed is dispensed into the cage via a pneumatically-operated, central Akvasmart Rotor Spreader, which has adjustable aluminium rotor pipes that give a circular pellet spread of 2 – 15-m diameter (Figure 3).

Feed monitoring is done by a farm worker who feeds to satiation by utilizing an underwater camera system mounted at 5 m depth. When one or more pellets fall within range of the camera the fish are deemed to be satiated and the feeder is shut down via a computer link. Experienced feeders can vary the feeding rate and feeding duration using the computer control system. It is common practice to vary the feed rate during the feed, with introductory feed rate are often 1/3rd less than on-going feed rates so that the maximum rate occurs once the fish are actively feeding.

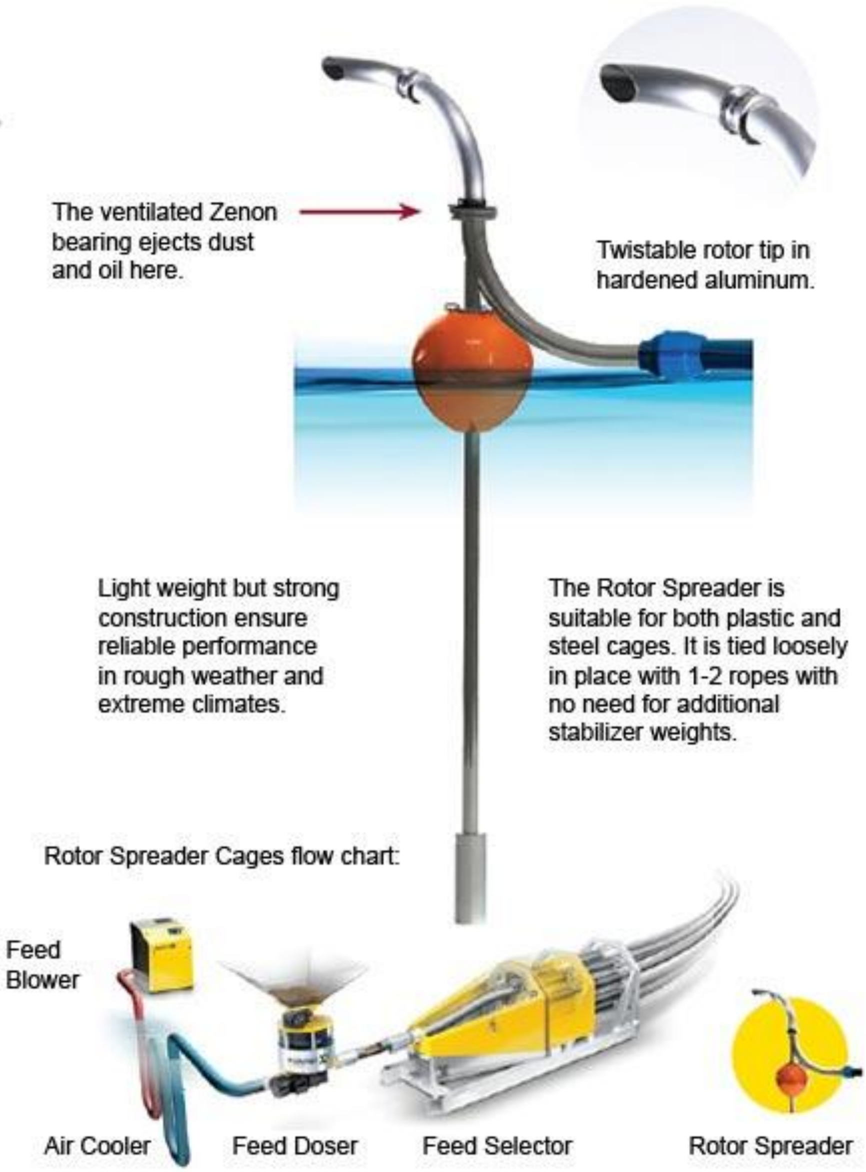

Figure 3: **Diagram of the Akvasmart Rotor Spreader feeding system, showing method of deployment and flow chart for the feed management system (source: Akvasmart website, http://www.akvagroup.com).**

2.2 Measurement of feed wastage

Samples of uneaten feed were collected using traps consisting of cones suspended on ropes at a depth of ca 17 m inside the cage. Each trap (the pellet-sensor cone from the Akvasmart feed monitoring system) consisted of a 1.55-m diameter stainless-steel outer ring with a canvas or mesh cone attached to it (one cone was 1.28 m diameter). The bottom of the cone was closed off in order to retain any pellets falling into it.

Eight traps (seven 1.55 m diameter, one 1.28 m diameter) were deployed in a single cage at each farm (Ruakaka and Clay Point) at each time of sampling. Although the feed is dispensed over a limited proportion of the total cage area (see above), natural water currents and currents created within the cage by the movements of the fish are likely to disperse the pellets beyond this area as they fall through the water column within the cage. Consequently, the sampling traps were distributed systematically across the area of the cage rather than focussing their distribution below the feeder (Figures 4 and 5).

Water currents inside cages are likely to be affected by the movements of the fish, stratification of the water column, the porosity of the net and background water movements (tidal and other flows) (Craig Stevens, David Plew, NIWA, pers. comm.). Work in Norway and Scotland suggests that water movements induced by the movement of the fish may dominate flow within the cage.

Sampling was done over two feeding periods at each farm, including both the morning and afternoon feeds (see Table 3.1). The Ruakaka farm was initially sampled on 22 September 2011 (morning feed: 07:30 NZST) but on this occasion there was a failure of the feed monitoring system, resulting in the system failing to shut down once the fish stopped feeding. Consequently, an unrepresentatively large amount of uneaten feed was collected in the sampling traps. The sampling was, therefore, repeated on 26 September (afternoon feed: 16:30 NZST) and 27 September (morning feed: 07:30 NZST). Sampling at the Clay Point farm was done on 22 (afternoon feed: 14:25 NZST) and 23 September (morning feed: 10:00 NZST). Traps were deployed at least one hour before the start of feeding. They were recovered after the end of feeding and the numbers of pellets in each trap was counted. Numbers of pellets were converted to weights using the unit weight of a pellet (0.869 g).

Water temperature, water clarity (secchi depth), dissolved oxygen, the total amount of feed distributed and the duration of each feed were recorded.

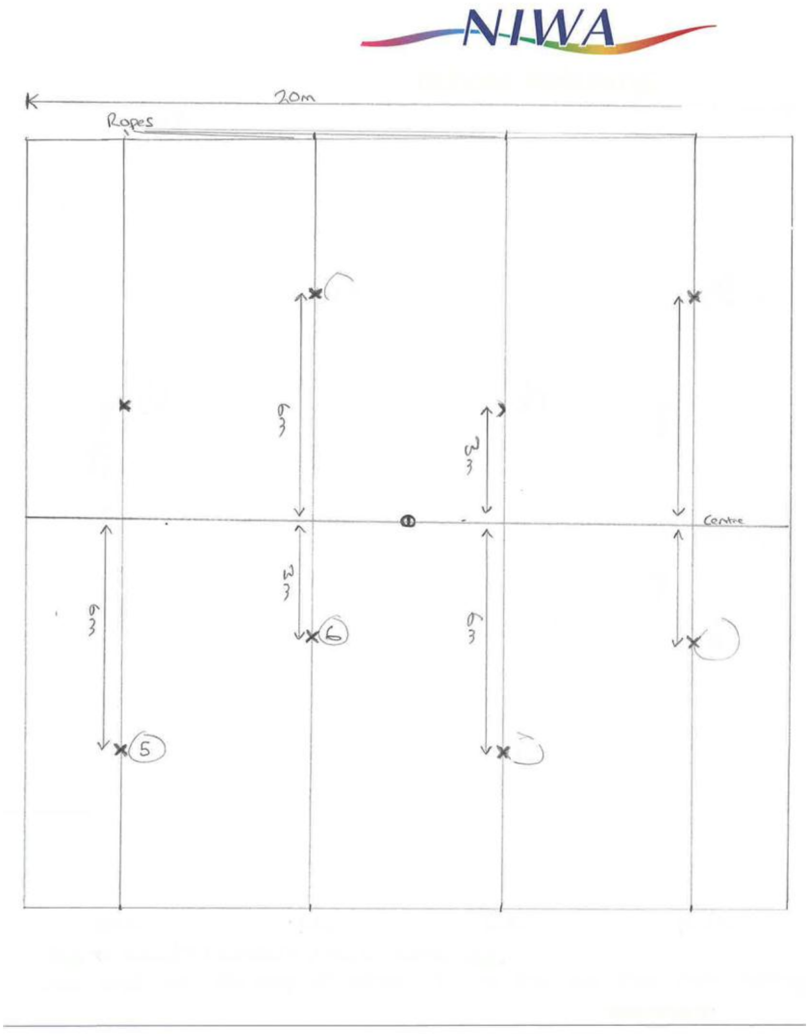

Figure 4: **Diagram of the position of sampling traps within the cage at the Ruakaka site.**

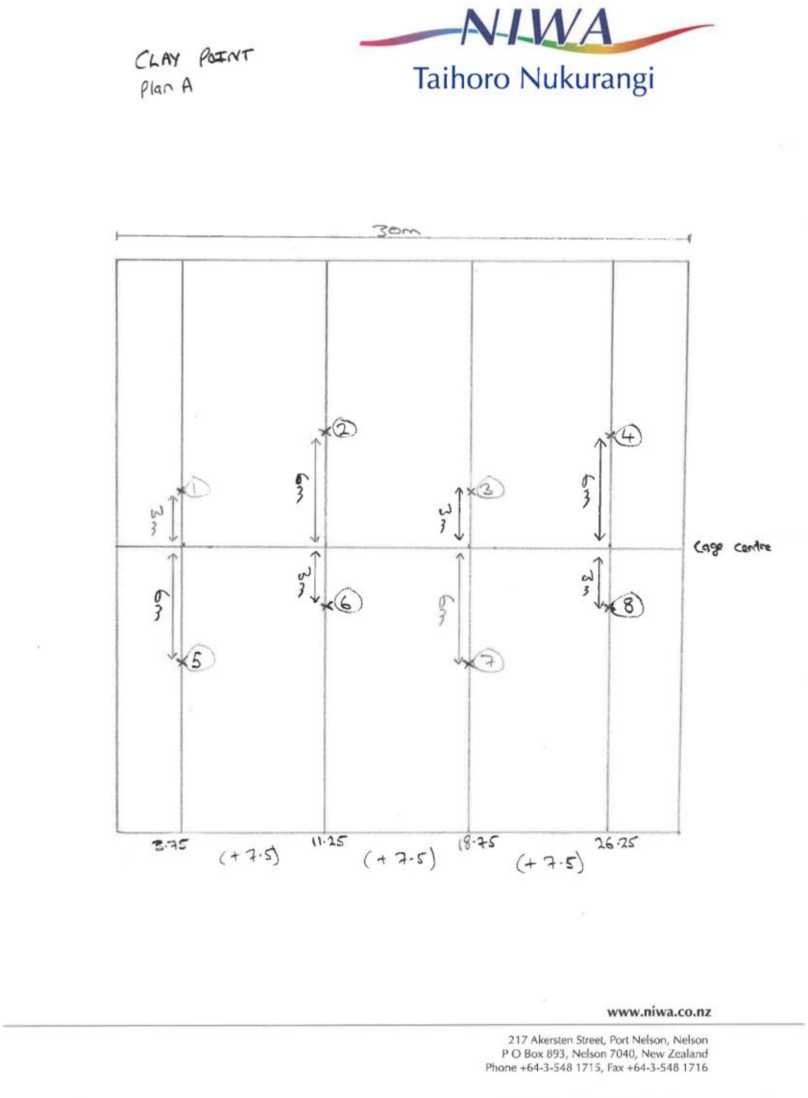

Figure 5: Diagram of the position of sampling traps within the cage at the Clay Point site.

3 Results

Numbers of pellets collected were very small, and most traps contained no pellets at the end of the feeding period (Table 3.1). As mentioned above, due to failure of the feed monitoring system at the Ruakaka site an unrepresentatively large amount of uneaten feed was collected in the sampling cones during the first sampling. The fish also appeared reluctant to feed during this sampling, possibly because of the presence of fur seals inside the predator net. Nevertheless, the results of this sampling are also presented here because, although they do not provide a useful estimate of the amount of uneaten feed during a normal feeding, they do allow us to map where feed is deposited after it falls through the water column within the cage.

The total area of the traps deployed at each time of sampling (seven 1.55 m diameter plus one 1.28 m diameter) was 14.50 m^2 ([7 x 1.887] + [1 x 1.287]). This represents 3.625% of the total area of a 20 x 20 m cage and 1.611% of a 30 x 30 m cage.

Table 3-1: Number of feed pellets and environmental data recorded at the Ruakaka and Clay Point farms. Eight sampling traps were deployed at each time of sampling at each farm (see text for details). 'nr' not recorded. * on this occasion the feed monitoring equipment failed and did not stop feed distribution when the fish stopped feeding. ** this sample consisted of two small pieces of pellet..

									Trap number									
Location	**Date**	**Time**	**Water temp (°C)**	**DO (ppm)**	**Secchi depth (m)**	**Duration of feed (min)**	**Direction of tidal flow**	**Tide time Picton**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean**	**SE**
Ruakaka	22/9/11*	07:30	12.2	8.8	9	26	north	08:15 (0.4) 14:29 (1.0)	234	128	51	3	1	656	54	1	141.00	78.83
	26/9/11	16:30	11.6	7.6	7	nr	south	08:12 (1.3m) 13:22 (0.2m)	0	0	1	0	0	1	0	0	0.25	0.164
	27/9/11	07:30	12.9	8.5	7	nr	north	0858 (1.4) 14:09 (0.1)	0	0	0	0	0	1	0	0	0.13	0.125
Clay Point	22/9/11	14:25	12.6	nr	nr	6	east	08:15 (0.4) 14:29 (1.0)	0	0	0	2	0	0	0	0	0.25	0.250
	23/9/11	10:00	12.6	nr	nr	23	east	09:48 (0.5m) 17:06 (1.0)	1**	0	2	0	0	1	0	0	0.50	0.267

Numbers of pellets caught per trap were converted to weights per trap and these were then scaled up to the estimated weight for the whole cage using the proportion of the area of the trap to the area of the cage. This was done based on each individual trap and also based on the total weight across all traps and the total area of the traps. These values were converted to the percentage of the total feed that was wasted during that feeding event (Figure 6 Table 3.2).

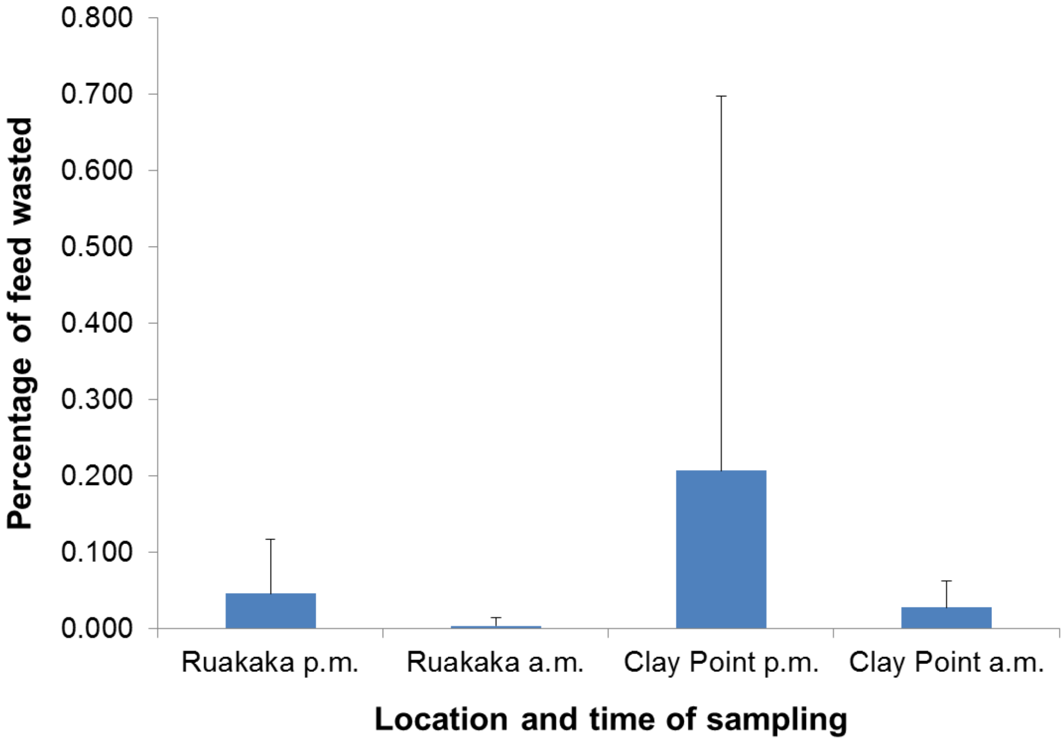

Figure 6: **Average weights of wasted feed (+95% confidence interval) expressed as a percentage of the total feed added.**

Table 3-2: Weights of waste feed in each trap scaled to the area of the cage and expressed as a percentage of the total feed added. The average percentage waste based on individual trap data is shown in the second to bottom row (with 95% confidence interval). The percentage waste based on the total amount of material summed across all eight traps is shown in the bottom row. [1] at the Ruakaka site the weight of feed used is estimated from the amount remaining in the hopper at the end of the feeding period, rather than measured directly.

Location	Ruakaka		Clay Point	
Date	26/09/2011	27/09/2011	22/09/2011	23/09/2011
Time	16:30	07:30	14:25	10:00
Total feed (kg)[1]	100	550	50	751
Weight of feed in trap scaled to area of cage (kg)				
Trap 1	0	0	0	0.414
Trap 2	0	0	0	0
Trap 3	0.184	0	0	0.829
Trap 4	0	0	0.829	0
Trap 5	0	0	0	0
Trap 6	0.184	0.184	0	0.414
Trap 7	0	0	0	0
Trap 8	0	0	0	0
Scaled weight of feed in traps as a percentage of the total feed added				
Trap 1	0	0	0	0.0552
Trap 2	0	0	0	0
Trap 3	0.184	0	0	0.11
Trap 4	0	0	1.66	0
Trap 5	0	0	0	0
Trap 6	0.184	0.0335	0	0.0552
Trap 7	0	0	0	0
Trap 8	0	0	0	0
Mean % of total weight (95%CI)	0.046 (0.071)	0.004 (0.010)	0.207 (0.490)	0.028 (0.035)
% of total weight	0.048	0.004	0.216	0.029

4 Discussion

The results of the first feed at Ruakaka, when the monitoring equipment failed, show that most pellets reached the floor of the cage at the trap locations closest to the centre of the cage (traps 2, 3, 6 and 7: Table 3.1). Few pellets were collected at the two traps closest to the northern edge of the cage (traps 4 and 8). A large number of pellets was also collected at trap 1, in the southwestern corner of the cage.

When the monitoring systems were working correctly, the percentage of food wasted was very small, less than 0.3% across all locations and times of sampling and less than 0.1% on three of the sampling events (excluding the first sampling at Ruakaka, when the monitoring equipment failed) (Table 3.2, Figure 6). These values are much smaller than those generally quoted in the literature (e.g. Chamberlain & Stucchi 200&) but similar to those recorded during the earlier study at the Ruakaka site (average wastage 0.012% (±0.0043 SE).

Although the sampled area represented only a small percentage of the total area of each cage (total trap areas were 3.6% of the Ruakaka cage and 1.6% of the Clay Point cage), the sampling traps were distributed across the whole area of the cage and we have no reason to suspect that they underestimated the amount of material reaching the floor of the cage.

An alternative explanation for the small numbers of pellets collected is that the majority of uneaten feed was lost through the sides of the cage as a result of water movement, and did not reach the cage floor. A feed pellet falling the depth of the cage (27 m) at a rate of 7.4 m minute^{-1} (Ben Wybourne, Skretting, pers. comm.) would travel a horizontal distance of ca 110 m in a current speed of 50 cm s^{-1}. As noted above, however, evidence suggests that water movement within cages is not particularly directional or that movement is circular as a result of movement of the fish. Other evidence indicates substantial reductions in rates of flow inside cages compared to outside (Craig Stevens, NIWA, pers. comm.). The direction of tidal flow at the time of the first sampling at Ruakaka was northerly (Table 3.1) but only small numbers of pellets were collected at the traps nearest to the northern boundary of the cage (traps 4 and 8: see Table 3.1). This is not consistent with a large proportion of the uneaten pellets being transported in the direction of the tidal current. This alternative source of loss cannot be discounted, however, since it was not measured directly in this study.

There is some evidence that wastage is larger during the afternoon feeds, although these differences were not statistically significant (as shown by the overlapping confidence intervals in Figure 6, caused by the variation among traps and the small overall number of pellets collected). This is consistent with the fact that the amount of food provided is much larger at the morning feed (550 vs 100 kg at the Ruakaka site, 750 vs 50 kg at Clay Point) and the fish are apparently much less hungry by the time of the afternoon feed. As noted, they were to be switched to once-a-day feeding shortly after the field study.

Wastage also appeared to be greater at the Clay Point site, where feed wastage is monitored by a member of the farm staff via an underwater video camera. Again, however, the differences were not statistically significant and the small numbers of pellets collected makes detailed comparisons unreliable.

5 Acknowledgements

We are grateful to Conor Paul (NZ King Salmon) for setting up the sampling equipment and for doing the repeat sampling at the Ruakaka site, and to the staff at both farms for their help and advice. We also thank Ben Wybourne (Skretting) for information on the feed pellets and Nigel Keeley (Cawthron Institute) for information on current speeds.

6 References

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