dummy

AES Technical

2023-01-04

Deliverables:

- Develop growth model
- Develop production plan
- Perform system mass balance equations
- Develop prototype system

Growth Modeling

Growth model based on data supplied from SyAqua Americas 95$^{\text{th}}$ st.facility.

Litopenaeus vannamei growth characteristics:

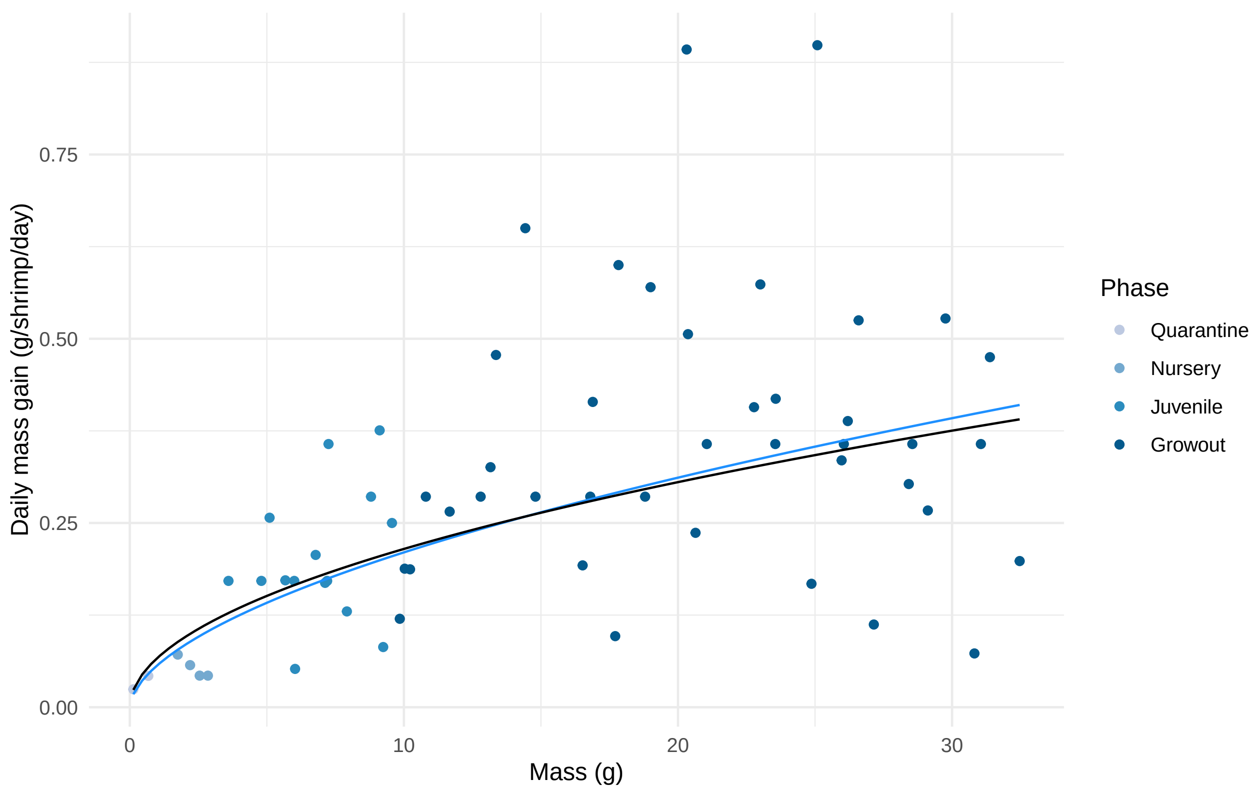

Figure 1: Daily growth rate by mass - datapoints from SyAqua 95^{th}st. (blue - arithmetic model, black - geometric model).

From the growth model, an estimate of white-leg shrimp body mass - as a function of time from introduction - can be calculated.

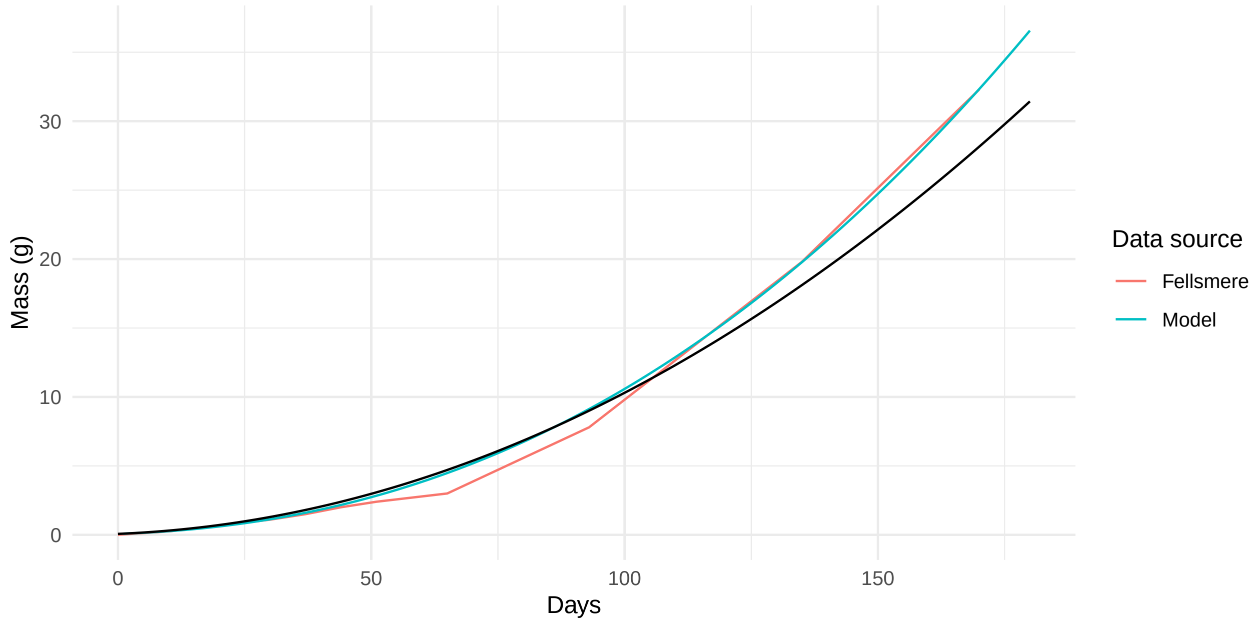

Figure 2: Estimated shrimp mass at time from introduction (blue - arithmetic model, black - geometric model).

Projected day to attain key bodyweights:

- Estimated growth day for 1.2g shrimp: Day 31
- Estimated growth day for 3g shrimp: Day 53
- Estimated growth day for 5g shrimp: Day 69
- Estimated growth day for 10g shrimp: Day 97
- Estimated growth day for 32g shrimp: Day 169

Production Plan

Review production plan(s) to achieve:

- 95^{th} st. 2022. Day 150 harvest 2200 individual 32g shrimp per raceway.
- 95^{th} st. 2022. Day 180 harvest 600 individual 32g shrimp per raceway.
- 95^{th} st. 2023. Day 169 harvest 1200 individual 32g shrimp per raceway.
- 95^{th} st. 2023. Day 184 harvest 1000 individual 32g shrimp per raceway.
- 95^{th} st. 2023. Day 199 harvest 600 individual 32g shrimp per raceway.
- 101^{st} st. Day 169 harvest 1200 individual 32g shrimp per raceway.
- 101^{st} st. Day 184 harvest 600 individual 32g shrimp per raceway.
- 101^{st} st. Day 199 harvest 600 individual 32g shrimp per raceway.

System Occupation 95$^{\text{th}}$ st. 2022:

- Quarantine 30 days.
- Nursery 30 days.
- Juvenile 30 days.
- Grow-out up to 90 days.
- Depuration 4 days.

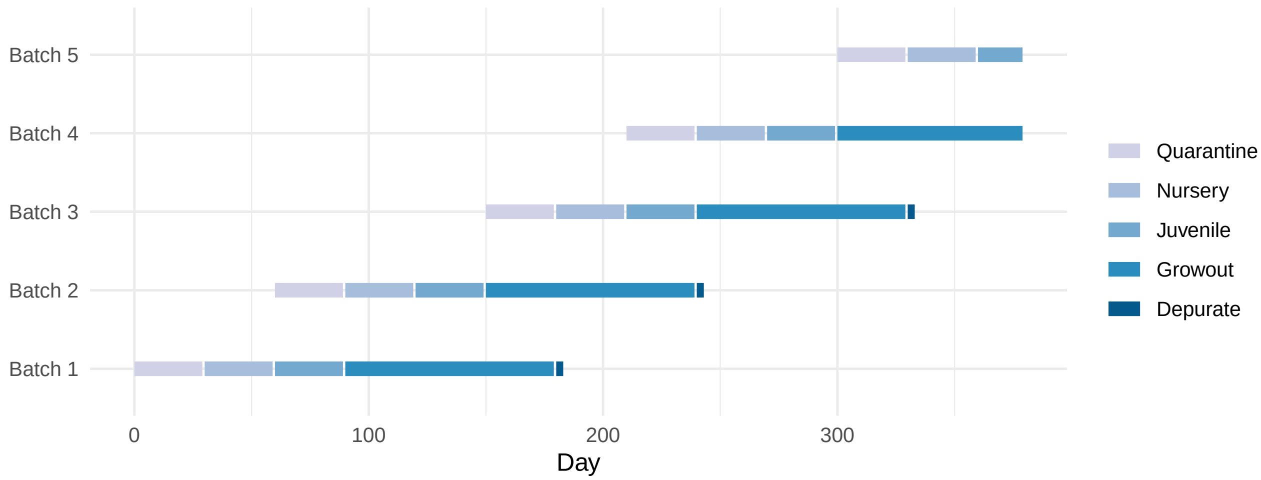

Figure 3: 95th$st.$ (2022). production schematic.

System Occupation 95$^{\text{th}}$st 2023:

- Quarantine 30 days.
- Nursery 60 days.
- Grow-out up to 110 days.
- Depuration 4 days.

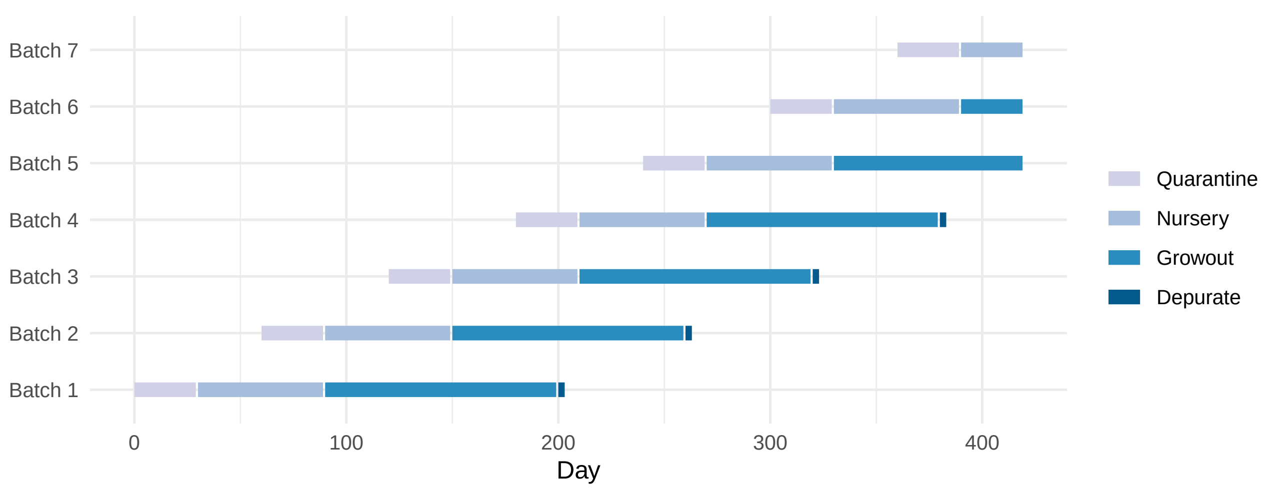

Figure 4: 95th$st.$ (2023). production schematic.

System Occupation 101stst 2024:

- Quarantine 30 days.
- Nursery 60 days.
- Grow-out up to 110 days.
- Depuration 7 days.

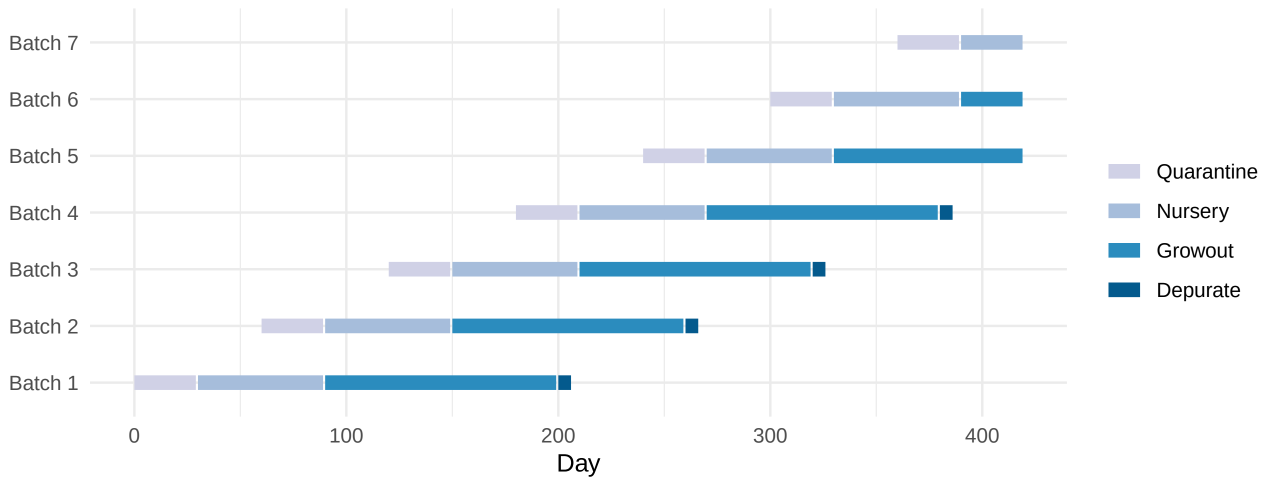

Figure 5: 101^{st}st. (2024). production schematic.

System Loading

Parameters used:

- Quarantine survival 80 %
- Nursery survival 80 %
- Juvenile survival 80 % (95thst 2022 only)
- Growout survival 80 %

95th st. 2022 system designations:

- Quarantine - initial population of 35000 individuals of body-weight 0.07 : 1.2
- Nursery - divide 19500, 1.2g, shrimp between 3 independently operating tank(s), raise to 3g.
- Juvenile - rear 15000, 3g, shrimp within 1 tank(s), raise to 10g.
- Growout - rear 11000, 10g, shrimp within 2 tank(s), raise to 32g.
- Depuration - purge up to 1600, 32g shrimp - split between 4 tank(s), operated by 1 treatment system(s).

95th st. 2023 system designations:

- Quarantine - initial population of 65000 individuals of body-weight 0.07 : 1.2
- Nursery - divide 44000, 1.2g, shrimp between 2 independently operating tank(s), raise to 10g.
- Growout - rear 16500, 10g, shrimp within 3 tank(s), raise to 32g.
- Depuration - purge up to 1600, 32g shrimp - split between 4 tank(s), operated by 1 treatment system(s).

101st st. 2024 system designations:

- Quarantine - initial population of 65000- 100000 individuals of body-weight 0.07 : 1.2
- Nursery - divide 46000 - 69000, 1.2g, shrimp between 2 independently operating tank(s), raise to 10g.
- Growout - rear 20800 - 31200, 10g, shrimp within 4 - 6 tank(s), raise to 32g.
- Depuration - purge up to 1600, 32g shrimp - split between 4 tank(s), operated by 1 treatment system(s).

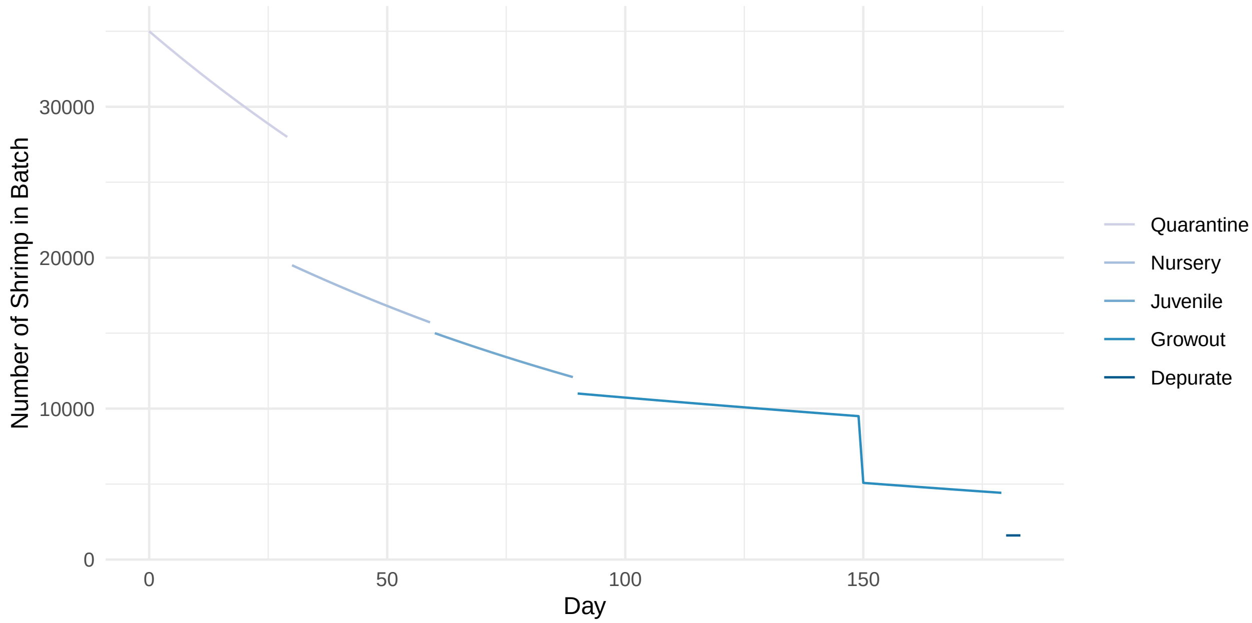

Figure 6: Total number of individuals per phase ($95^{th}st$. 2022).

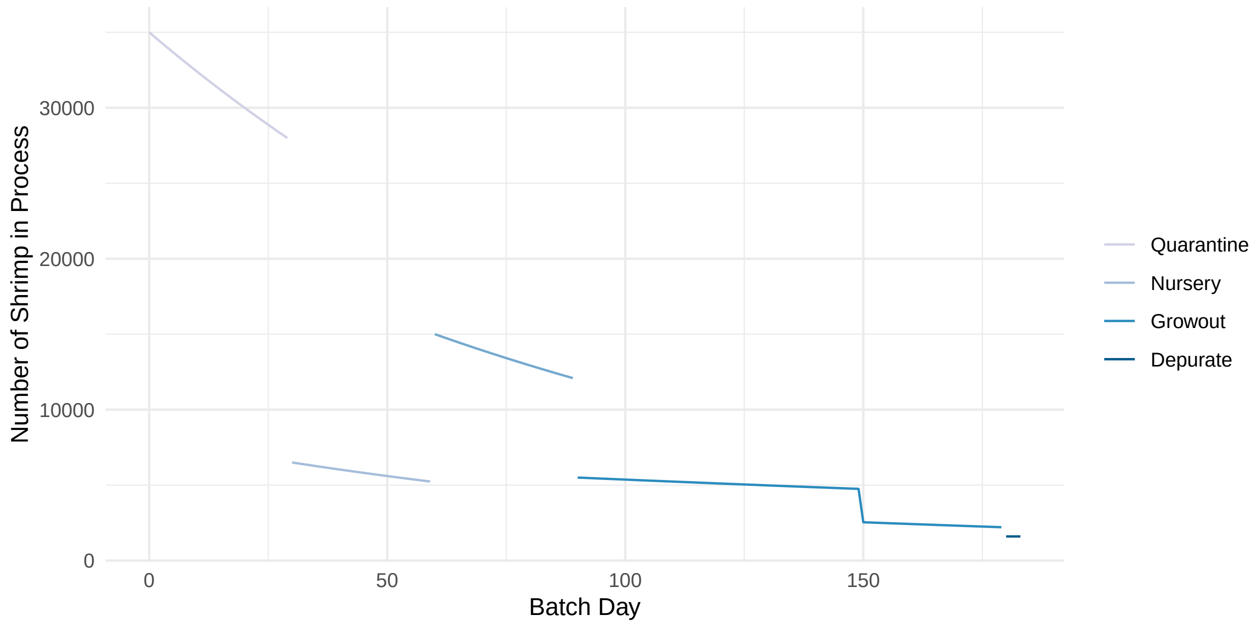

Figure 7: Total number of individuals per process ($95^{th}st$. 2022).

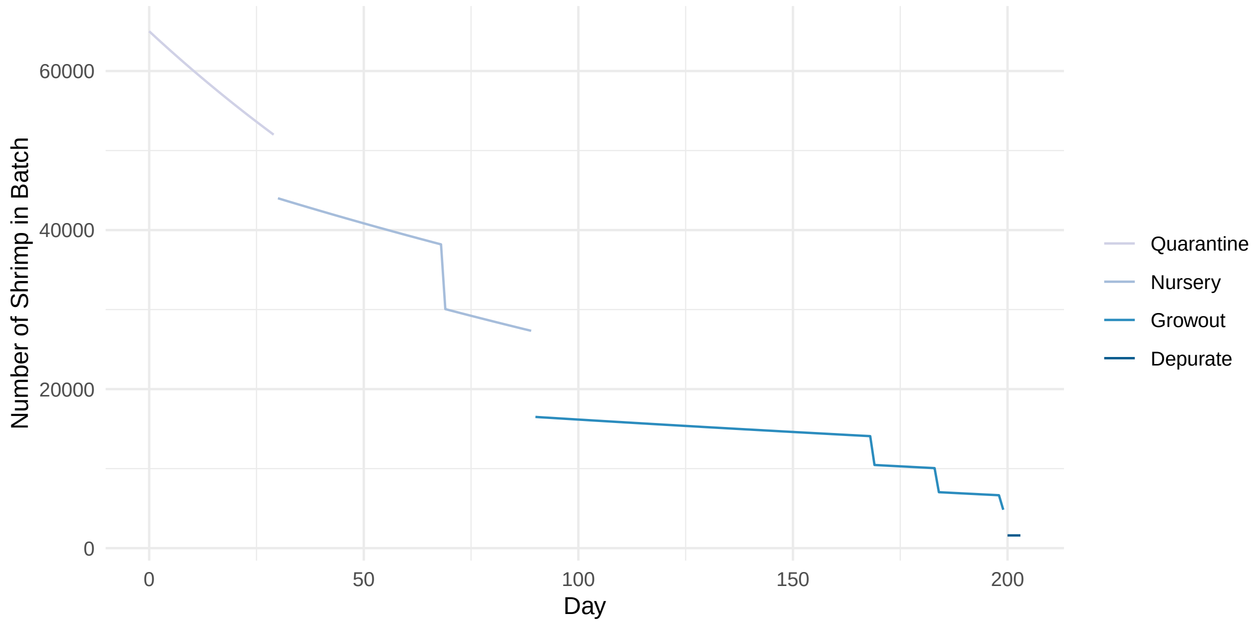

Figure 8: Total number of individuals per phase ($95^{th} st.$ 2023).

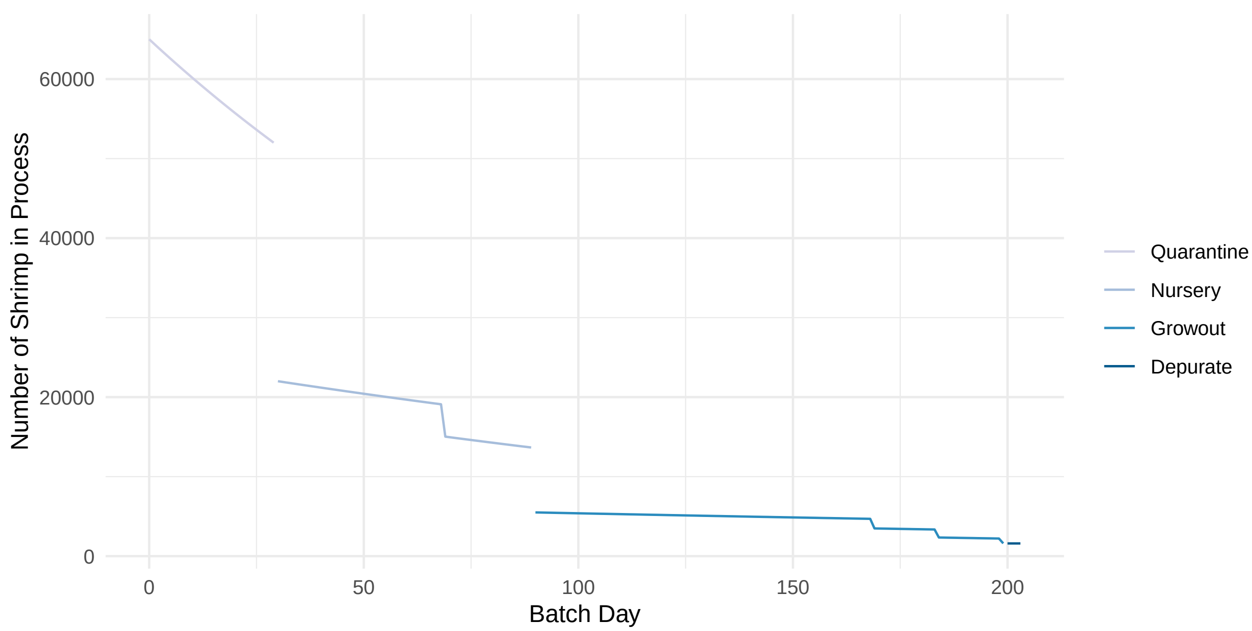

Figure 9: Total number of individuals per process ($95^{th} st.$ 2023).

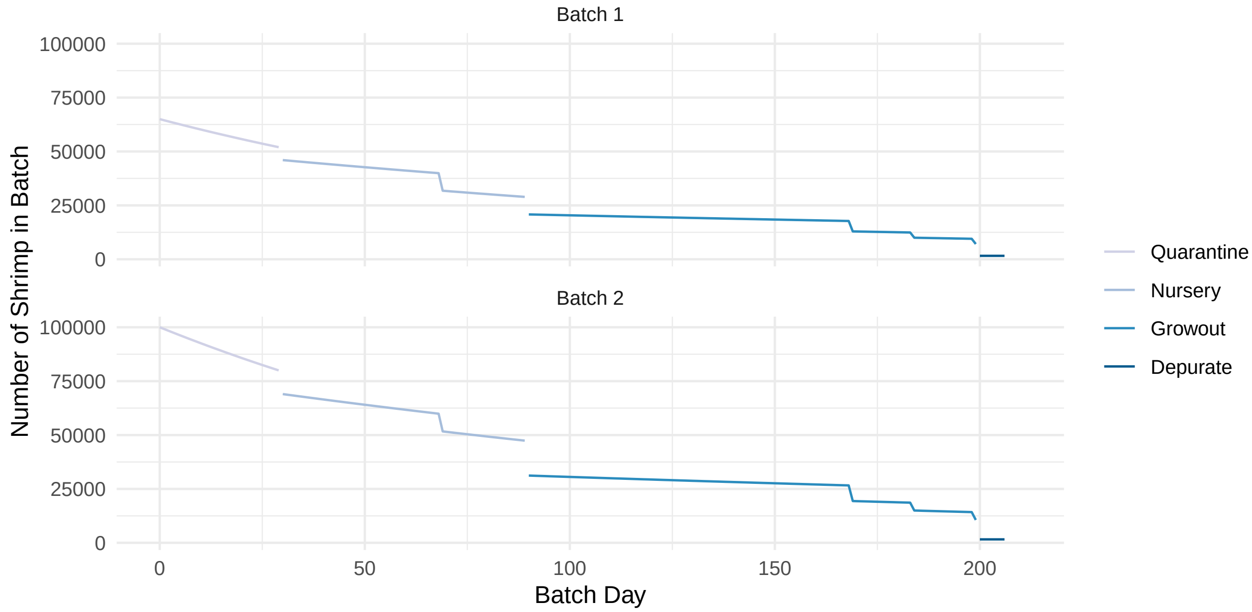

Figure 10: Total number of individuals per phase ($101^{st} st.$ 2024).

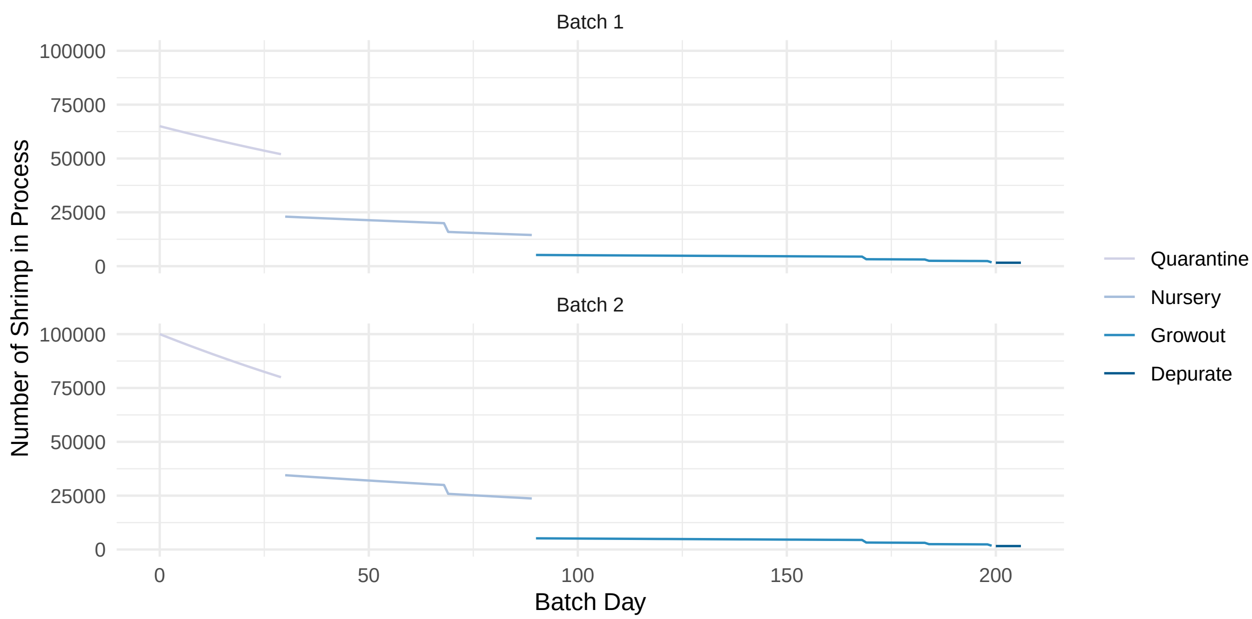

Figure 11: Total number of individuals per process ($101^{st} st.$ 2024).

The following feeding models were developed to estimate system loading across the production cycle through the developmental phases:

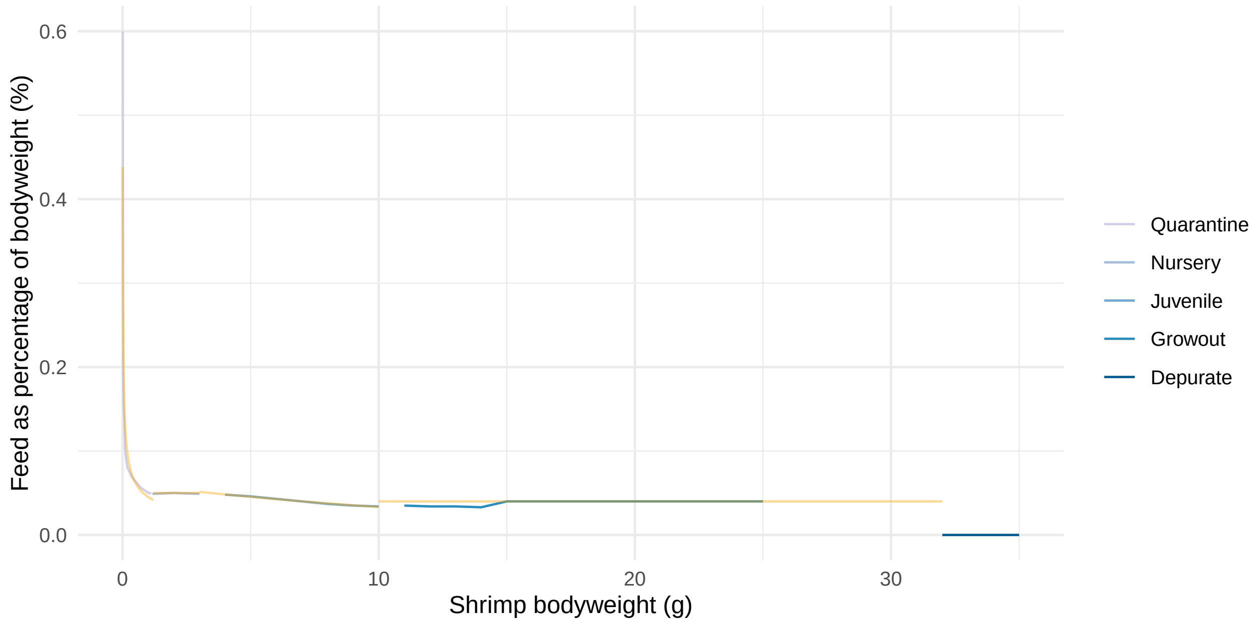

Figure 12: Feeding model - overlaid on feed tables.

95^{th} st. (2022) System Loading:

Feed and protein maximum and average loading rates per day per system (phase).

Table 1: $95^{th}st.$ 2022 facility loading rates (overlapping batches where appropriate).

System	Max n	Feed avg	Feed max	Protein avg	Protein max
quarantine	35000.00	0.85	1.31	0.43	0.66
nursery	19500.00	1.96	2.93	0.79	1.17
juvenile	15000.00	3.33	3.72	1.33	1.49
growout	16079.51	7.40	12.60	2.59	4.41
depurate	1600.00	0.00	0.00	0.00	0.00

Feed and protein maximum and average loading rates per day per process unit (tank or series of connected tanks per phase).

Table 2: $95^{th}st.$ 2022 process unit loading rates (single batch modelled).

System	Max n	Feed avg	Feed max	Protein avg	Protein max
quarantine	35000	0.85	1.31	0.43	0.66
nursery	6500	0.65	0.98	0.26	0.39
juvenile	15000	3.35	3.72	1.34	1.49
growout	5500	3.07	4.63	1.07	1.62
depurate	1600	0.00	0.00	0.00	0.00

95^{th} st. (2023) System Loading:

Feed and protein maximum and average loading rates per day per system (phase).

Table 3: $95^{th} st.$ 2023 facility loading rates (overlapping batches where appropriate).

System	Max n	Feed avg	Feed max	Protein avg	Protein max
quarantine	65000.00	1.59	2.44	0.79	1.22
nursery	44000.00	6.02	8.50	2.41	3.40
growout	31109.12	19.34	25.65	6.77	8.98
depurate	1600.00	0.00	0.00	0.00	0.00

Table 4: $95^{th} st.$ 2023 process unit loading rates (single batch modelled).

System	Max n	Feed avg	Feed max	Protein avg	Protein max
quarantine	65000	1.59	2.44	0.79	1.22
nursery	22000	3.07	4.25	1.23	1.70
growout	5500	3.88	5.92	1.36	2.07
depurate	1600	0.00	0.00	0.00	0.00

Feed and protein maximum and average loading rates per day per process unit (tank or series of connected tanks per phase).

101^{st} st. (2024) System Loading:

Feed and protein maximum and average loading rates per day per system (phase).

Feed and protein maximum and average loading rates per day per process unit (tank or series of connected tanks per phase).

\begin{table}

\caption{$101^{st} st. 2024 process unit loading rates (single batch a modelled).}

System	Max n	Feed avg	Feed max	Protein avg	Protein max
quarantine	65000	1.59	2.44	0.79	1.22
nursery	23000	3.22	4.50	1.29	1.80
growout	5200	3.72	5.60	1.30	1.96
depurate	1600	0.00	0.00	0.00	0.00

\end{table}

Water Quality Defining Parameters

Based on feed inputs, the following parameters (inputs or requirements) can be modelled:

- TAN–N Total ammonia nitrogen produced (ionised ammonia + un-ionised ammonia NH_4^+–N + NH_3–N)
- TSS Total suspended solids produced

Table 5: $101^{st} st.$ 2024 facility loading rates (overlapping batches where appropriate).

System	Max n	Feed avg	Feed max	Protein avg	Protein max
quarantine	100000.00	1.95	3.75	0.98	1.88
nursery	69000.00	7.98	14.75	3.19	5.90
growout	49616.34	30.05	43.53	10.52	15.23
depurate	1600.00	0.00	0.00	0.00	0.00

Table 6: 101^{st}st. 2024 process unit loading rates (single batch b modelled).

System	Max n	Feed avg	Feed max	Protein avg	Protein max
quarantine	100000	2.44	3.75	1.22	1.88
nursery	34500	5.02	7.37	2.01	2.95
growout	5200	3.72	5.60	1.30	1.96
depurate	1600	0.00	0.00	0.00	0.00

Table 7: 95^{th}st. 2022 TAN–N system and process loading summary.

System	System max TAN	System avg TAN	Process max TAN	Process avg TAN
quarantine	0.09	0.06	0.09	0.06
nursery	0.17	0.11	0.06	0.04
juvenile	0.21	0.19	0.21	0.19
growout	0.64	0.37	0.23	0.15
depurate	0.08	0.08	0.08	0.08

- CO_2 Carbon dioxide produced
- O_2D Oxygen demand
- Alk Alkalinity demand
- Carb Carbohydrate demand

Nitrogen Management

TAN–N loading

95th st. 2022 TAN–N summary

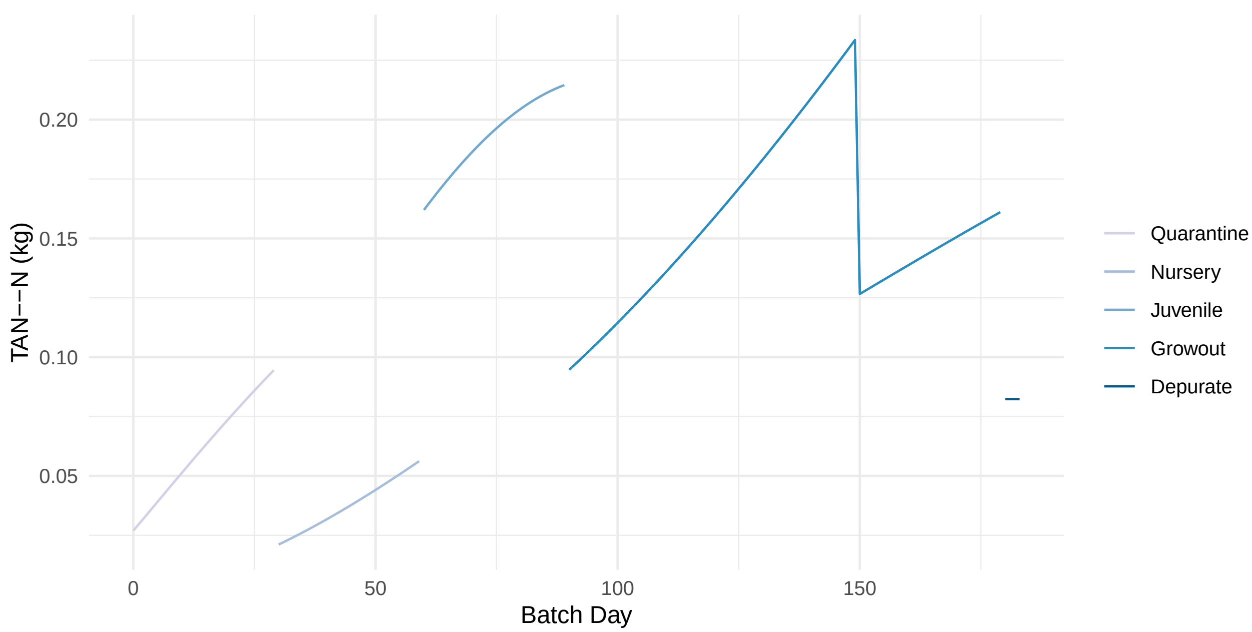

Figure 13: 95^{th}st. 2022 process/ tank TAN–N profile.

95th st. 2023 TAN–N summary

Table 8: $95^{th} st$. 2023 TAN–N system and process loading summary.

System	System max TAN	System avg TAN	Process max TAN	Process avg TAN
quarantine	0.18	0.11	0.18	0.11
nursery	0.49	0.35	0.24	0.17
growout	1.29	0.97	0.30	0.19
depurate	0.08	0.08	0.08	0.08

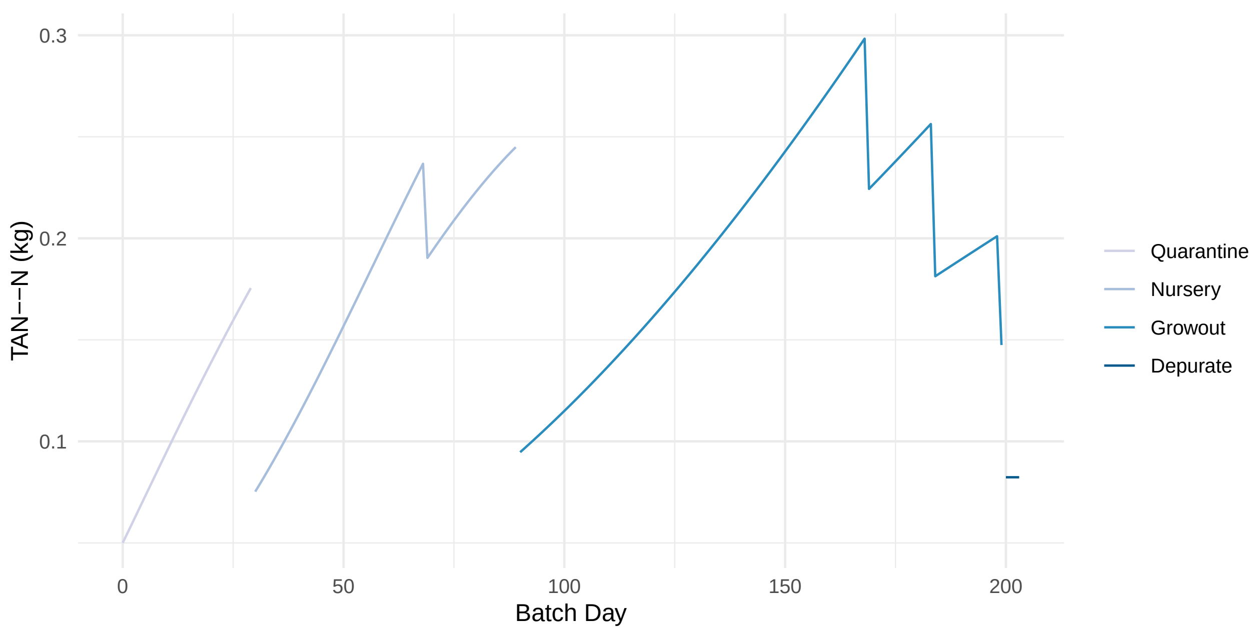

Figure 14: $95^{th} st$. 2023 process/ tank TAN–N profile.

Table 9: $101^{st}st.$ 2024 TAN–N system and process loading summary.

System	System max TAN	System avg TAN	Process max TAN A	Process avg TAN A	Process max TAN B
quarantine	0.27	0.14	0.18	0.11	0.27
nursery	0.85	0.46	0.26	0.19	0.42
growout	2.19	1.51	0.28	0.19	0.28
depurate	0.08	0.08	0.08	0.08	0.08

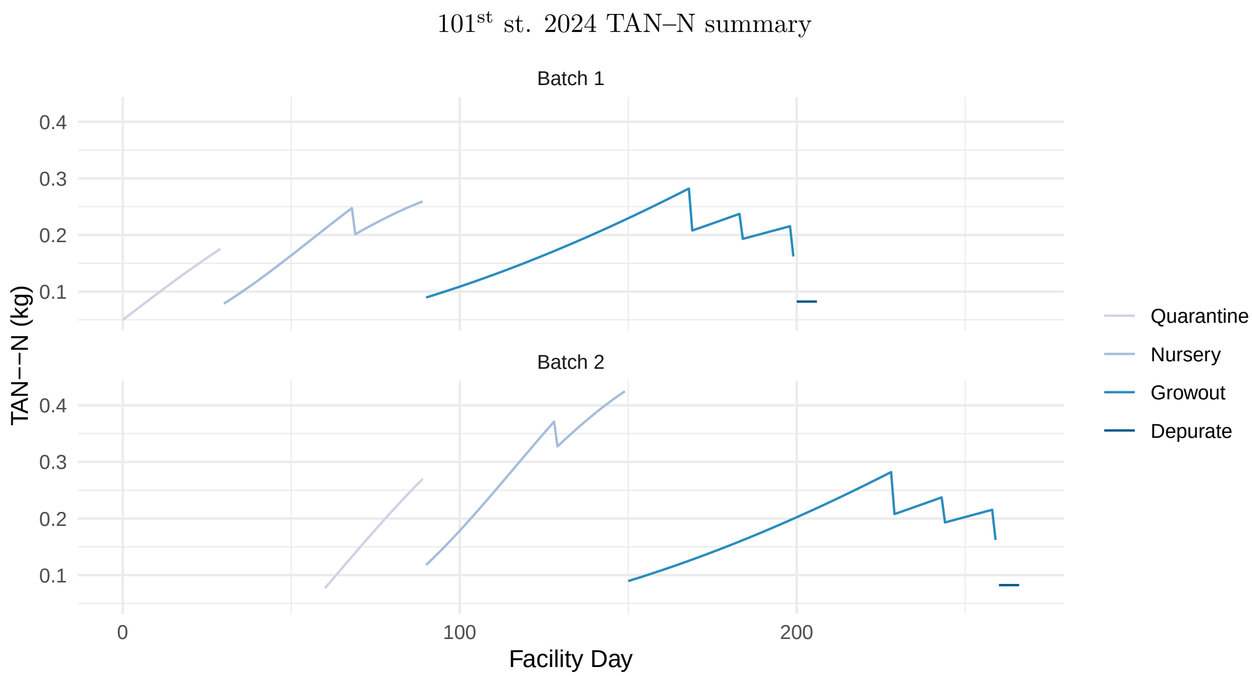

Figure 15: $101^{th}st.$ 2024 process/ tank TAN–N profile.

Ammonia removal from intensive aquaculture production can be managed by three distinct pathways:

- Photoautotrophic (algal)
- Autotrophic (bacterial)
- Heterotrophic (bacterial)

Of relevance in the production process at SyAqua Americas are autotrophic (quarantine and depuration/ purging) and heterotrophic (nursery, juvenile and grow-out) pathways.

Chemoautotrophic pathway (simplified) $NH_4^+ + O_2$ + alkalinity $\rightarrow NO_2^- \rightarrow NO_3^- + CO_2$ + small amount of bacterial biomass

Heterotrophic pathway (simplified) $NH_4^+ + O_2$ + alkalinity + organic C $\rightarrow$ large amount of bacterial biomass + CO_2

The carbon/ nitrogen ratio influences the relative proportion of autotrophic/ heterotrophic bacterial community and therefore may be used as a management tool for determination of nitrogen removal pathway.

Stoichiometric equations predict that for every g of ammonia-nitrogen converted to microbial biomass (by heterotrophic bacteria), 15.17 g of carbohydrates or 6.07 g of organic carbon is consumed. Organic carbon can be made available from livestock feed constituents and supplementary carbohydrate additions e.g. molasses or other source.

$NH_4^+ - N$ within the quarantine systems would typically be removed primarily by the chemoautotrophic pathway, utilising a fixed film moving-bed bioreactor. The volume of the biomedia would be dictated by the surface area and the maximum potential daily $NH_4^+ - N$ loading.

Suggested minimum quarantine biomedia surface areas are as follows (based on a 24 hr metabolic period):

95th st. 2022; 236m^2
95th st. 2023; 439m^2
101st st. 2024; 675m^2

$NH_4^+ - N$ within the depuration/ purging systems would typically be managed by water exchange and minimal nitrification/ ammonia sequestration from bacteria present in the sand filter/ water column.

The charts below indicate theoretical carbohydrate additions required to supplement organic carbon supplied in feed (nursery/ juvenile/ grow-out stages only).

Calculations based upon:

TAN produced * bacterial carbohydrate demand - carbohydrate in feed

Feed input * protein proportion * 0.144 * 15.17 - (feed input * 0.1089 / 0.4)

95th st. 2022

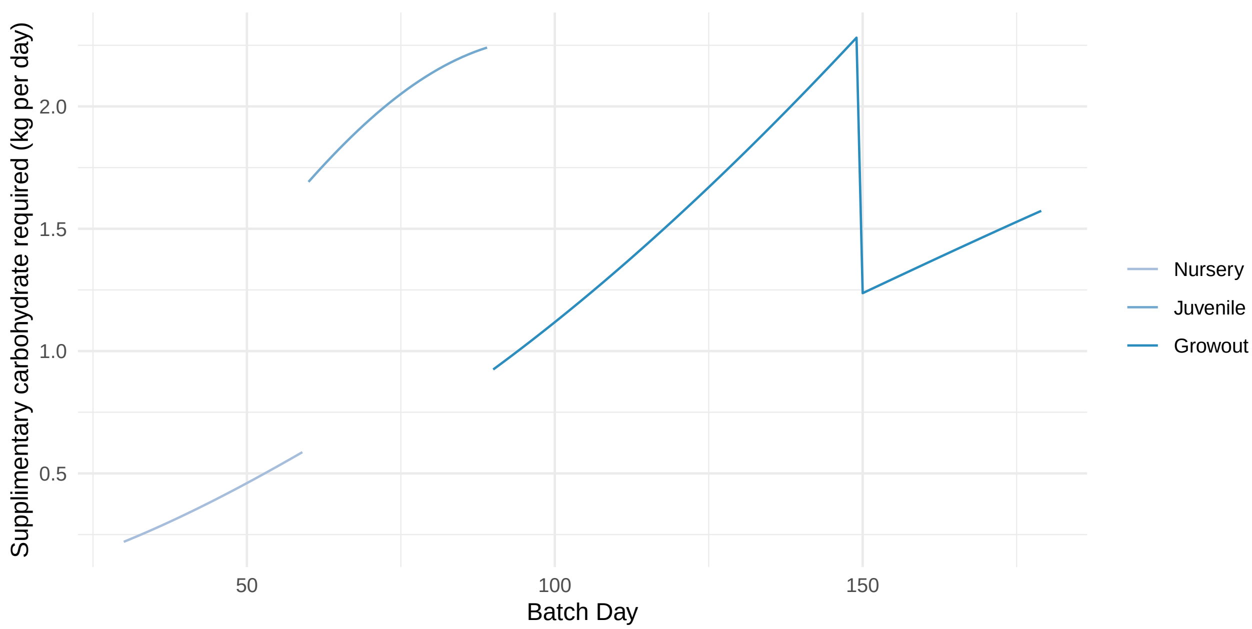

Figure 16: $95^{th} st.$ 2022 Theoretical supplimentary carbohydrate requirement (per tank).

95th st. 2023

101st st. 2024

Solids Management

Solids within the production process will be comprised of uneaten feed, faeces and bacterial biomass.

The literature indicates a total suspended solids (TSS) concentration of 200-300 mg/l is typical within biofloc operation, and levels of up to 500 mg/l may be acceptable without reduction of welfare or growth of shrimp.

Solids concentration will increase in zero exchange systems and active management techniques may be required to maintain optimal levels of TSS.

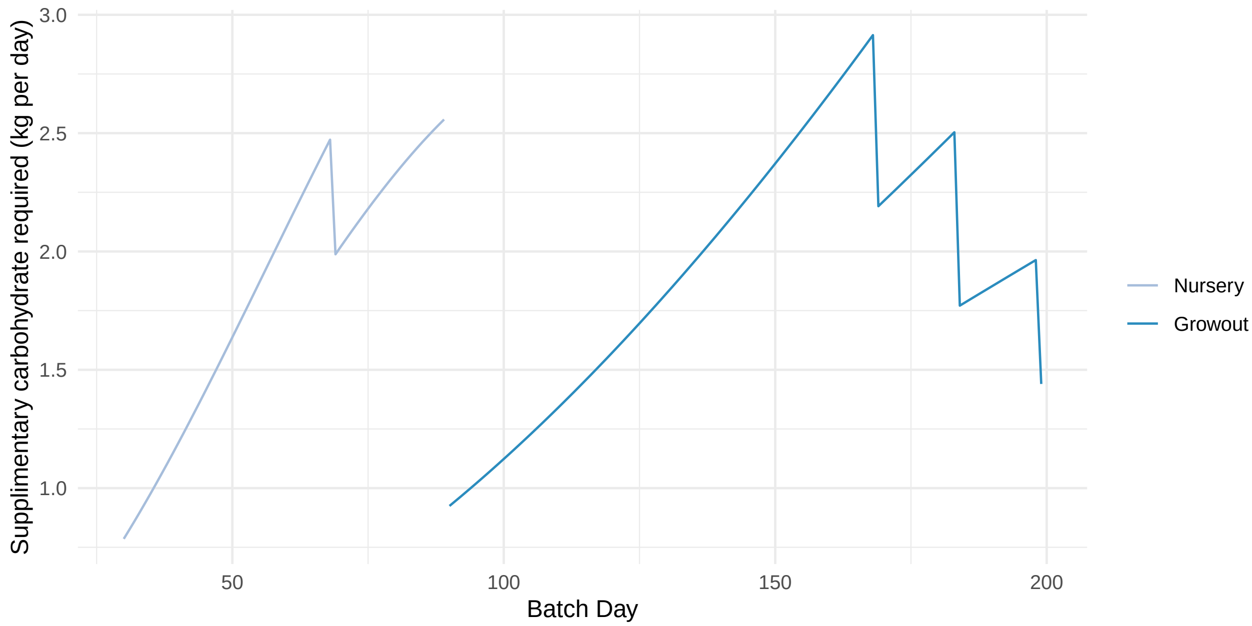

Figure 17: $95^{th}st$. 2023 Theoretical supplimentary carbohydrate requirement (per tank).

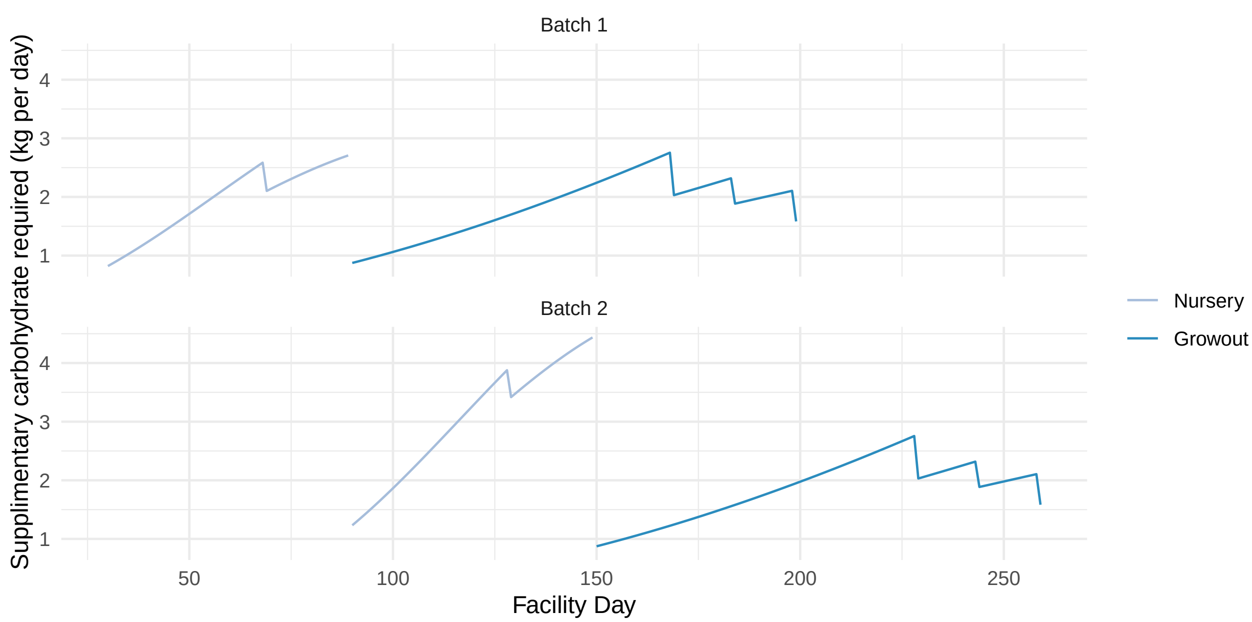

Figure 18: $101^{st}st$. 2024 Theoretical supplimentary carbohydrate requirement (per tank).

Table 10: $95^{th}st.$ 2022 TSS system and process loading summary.

System	System max TSS	System avg TSS	Process max TSS	Process avg TSS
quarantine	0.33	0.21	0.33	0.21
nursery	2.09	1.40	0.70	0.47
juvenile	2.66	2.38	2.66	2.38
growout	8.28	4.86	3.04	2.01
depurate	0.02	0.02	0.02	0.02

Table 11: $95^{th}st.$ 2023 TSS system and process loading summary.

System	System max TSS	System avg TSS	Process max TSS	Process avg TSS
quarantine	0.61	0.40	0.61	0.40
nursery	6.08	4.30	3.04	2.15
growout	16.84	12.70	3.89	2.49
depurate	0.02	0.02	0.02	0.02

TSS accumulation can be modelled according to system management based on feed input for chemoautotrophic-managed nitrogen pathways or feed input and bacterial biomass synthesised for heterotrophic-managed nitrogen pathways.

Solids input

95^{th} st. 2022

95^{th} st. 2023

101^{st} st. 2024

A cumulative TSS sum may give an indication of the timing within the production run that the desired TSS will be achieved. From this point onwards, solids will require either continuous or periodic removal to maintain TSS within acceptable limits.

Calculations based upon full tanks:

- Nursery 15 m^3
- Juvenile (95^{th} 2022) 90 m^3
- Growout 90 m^3

95^{th} st. 2022

95^{th} st. 2023

101^{st} st. 2024

Table 12: $101^{st}st.$ 2024 TSS system and process loading summary.

System	System max TSS	System avg TSS	Process max TSS A	Process avg TSS A	Process max TSS B	Pr
quarantine	0.94	0.49	0.61	0.40	0.94	
nursery	10.54	5.71	3.22	2.30	5.27	
growout	28.58	19.73	3.68	2.44	3.68	
depurate	0.02	0.02	0.02	0.02	0.02	

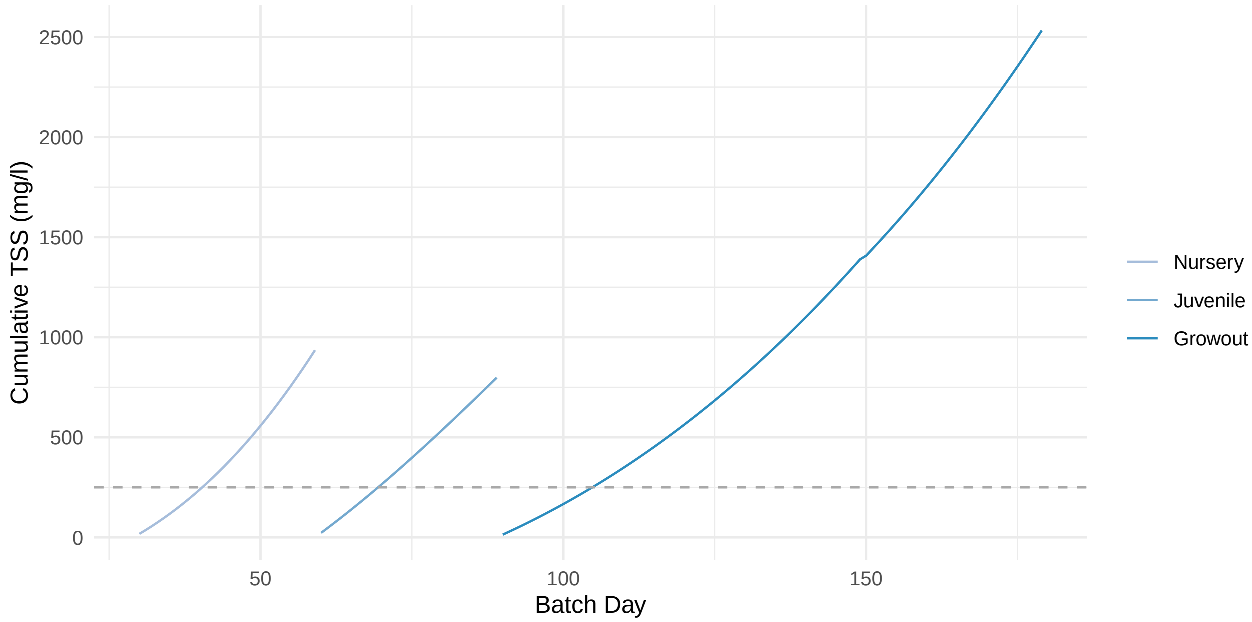

Figure 19: $95^{th}st$. 2022 Cumulative TSS accumulation - without solids management (per tank).

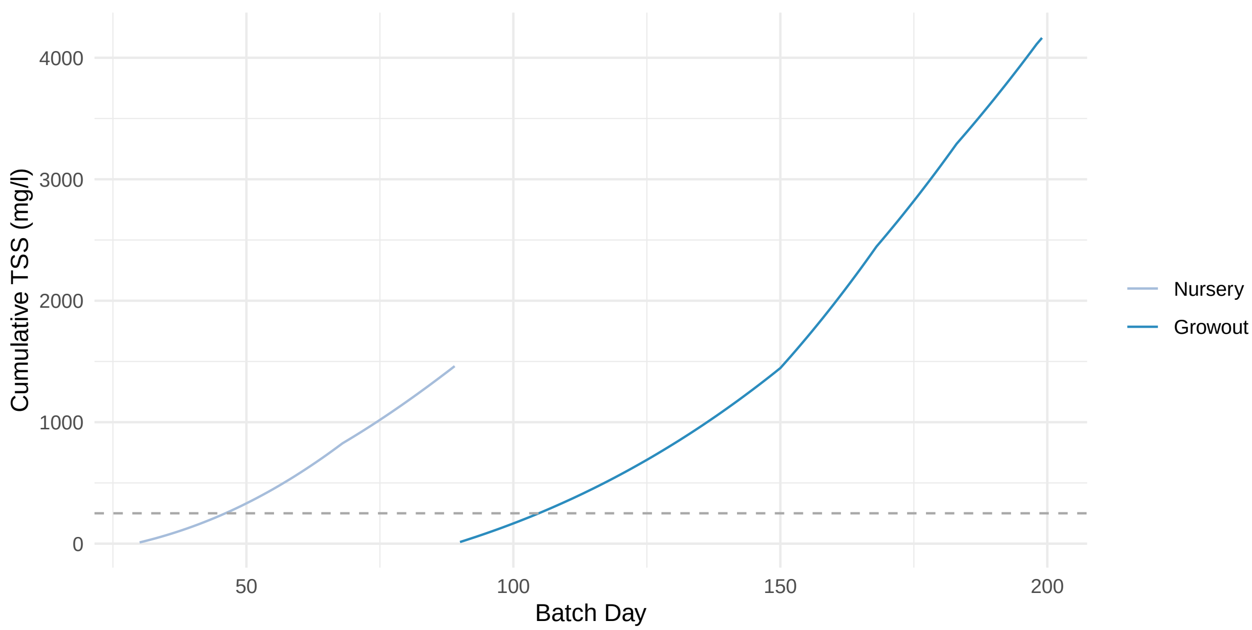

Figure 20: $95^{th}st$. 2023 Cumulative TSS accumulation - without solids management (per tank).

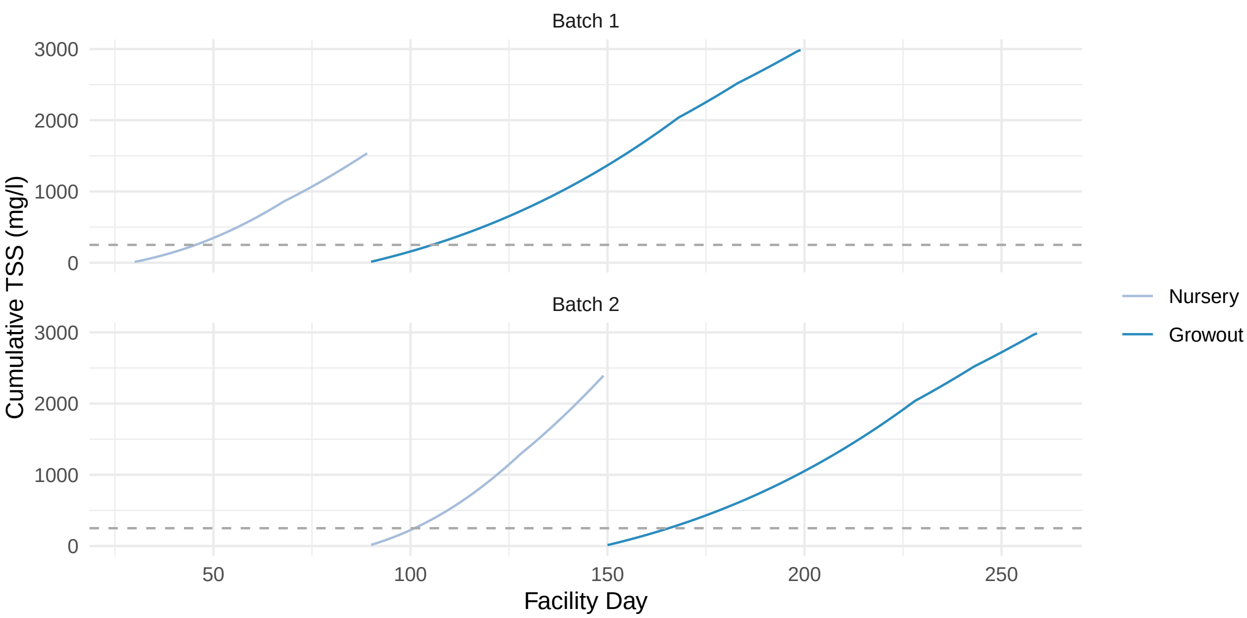

Figure 21: $101^{st}st$. 2024 Cumulative TSS accumulation - without solids management (per tank).