Aquaculture

Standard Operating Procedures

Feeding Practices and Feed Management

Selecting the proper feeds and feeding methods is an important aspect of fish growth. Feed considerations are therefore a fundamental part of indoor recirculating aquaculture. Unlike pond culture, the only source of nutrition for aquaculture fish is in the feed they are given. Complete fish feed pellets, which contain all necessary nutrition, are essential. Feed ingredients are chosen for their digestibility of protein, fat, and carbohydrate components, as well as their buoyancy characteristics and price and accessibility for feed mills. Most of these complete feeds contain fish meal, which provides the proper amino acid profile and healthy omega-3 fatty acids needed for fish nutrition. Sustainability of aquaculture, however, will require feeds that reduce the fish meal needed, decreasing ocean fishing pressure in the name of aquaculture. Replacing fish meal with other proteins can negatively change the fatty acid profile from heart-healthy omega-3 fatty acids to saturated fats and trans fats, making fish products less healthy for human consumption. Thus feed ingredients must be carefully selected.

Various fish feeds

METHODS (How to, How often, When, Where)

Feeding

1. Measure water chemistry and monitor fish behavior prior to feeding the fish.
2. Visually inspect the fish for external signs of disease (lesions, discolored skin, erratic swimming behavior, etc.).
3. If the water quality falls within the optimal range and fish behave normally and appear to be disease free, the farmer should begin hand feeding a small portion (1 handful) of the feed that the fish have been rationed.
4. If fish are slow to eat and leave feed floating on the surface of the water, feeding should cease and the uneaten feed should be removed from the water. If the fish are feeding very aggressively and consume the feed quickly, more feed should be added.
5. Feeding should continue to satiation, or until the fish cease eating and leave a small amount of feed floating. The typical method for gauging satiation in fish is to feed the fish as much feed as they will consume in 15 minutes.
6. Excess feed should still be removed.
7. The amount of feed fed and the feeding response should be recorded to help predict the amount of feed the fish will require in the future.

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FEED CALCULATIONS

Feeding Schedules – A feeding schedule is a prediction of the amount of feed that should be fed to the fish at any given point during the growth cycle. It is based on a percentage of the total biomass, or combined weight of all fish in the system. A typical feed schedule may call for a feed ration that equals 40% of the fish biomass on a daily basis as fry or juveniles, then 10% of biomass as fingerlings, then 2%-3% of the fish biomass as adults. A daily growth increment should additionally be considered in the biomass estimate between samplings. (An example feed schedule can be seen in Appendix A.)

1. Gather biomass estimate data during the grading process.
2. Use previous production data to estimate daily growth rates for the age of fish.
3. Add the appropriate weight estimate to the previous biomass estimate for the number of fish in the tank.
4. Multiply the estimated biomass by the appropriate percentage for the age class of the fish (larvae: 20%-40%; fingerling: 5%-15%; adults: 2%-3%)to achieve the daily feed ration for the fish.
5. Divide the feed ration into the desired number of feedings to be given throughout the day.

Feed Conversion Ratio (FCR) – Feed conversion ratio refers to the weight of feed fed per weight of fish weight increase throughout the growth cycle. A realistic FCR for a novice farmer is about 1.5 to 2.5, but an experienced aquaculturist can achieve an FCR of 0.8 to 1.0. Gather biomass estimate data during the grading process.

1. Subtract the current biomass estimate from the previous sampling period's biomass estimate.
2. Sum the total amount of feed fed for the period between the current and previous sampling.
3. Divide the amount of feed fed by the amount of biomass gained using the same mass units.
4. Calculate the FCR and record it.

$$\text{FCR} = \frac{\text{Mass of Feed Fed}}{\text{Biomass of Fish Gained}}$$

Automated fish feeder

Estimated Population Biomass = Estimated Daily Growth Rate × Age (days) × Estimated Number of Fish

Daily Feed Ration = Estimated Population Biomass × Feeding Rate (% of Biomass)

$$\text{Single Feed Ration} = \frac{\text{Daily Feed Ration}}{\text{Number of Feedings per Day}}$$

FEED MANAGEMENT

Fish feed has an expiration date because of its organic components. It must be stored and managed properly to get the maximum value. Record keeping is very important to tracking incoming and outgoing feed to ensure that it is the correct feed (size, nutritional content, floating *vs.* sinking) being fed to the correct fish (size and species) in the correct tanks (prevent over or under feeding) at the correct time (feeding frequency and use of degraded feeds).

1. Newly received feed shipments should be marked by date and cataloged.
2. Feeds should be stored in a dry place and refrigerated or put in a cool storage unit.
3. Feed must be used in the order in which it is received, unless feed quality is compromised.
4. Feed being used in the facility must be kept in a secondary container with a lid to protect it from pests and water damage. Larger facilities may use warehouse style storage and must continuously manage for pests.
5. Spilled feed should be swept up daily. Spilled feed may attract pests and present safety hazards for employees as they may slip and fall.
6. Feed must constantly be monitored for evidence of mold and other degradation. Degraded feeds are not to be fed to fish.
7. Spilled and degraded feeds are to be composted.

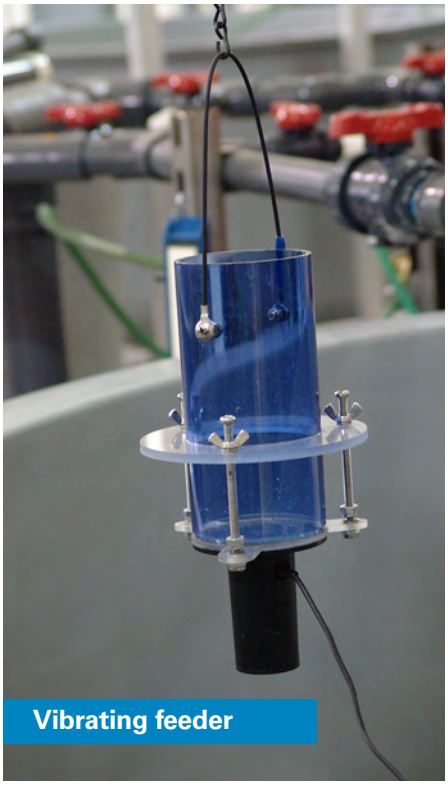
Drop style automated fish feeder

FREQUENCY OF FEED MANAGEMENT PRACTICES

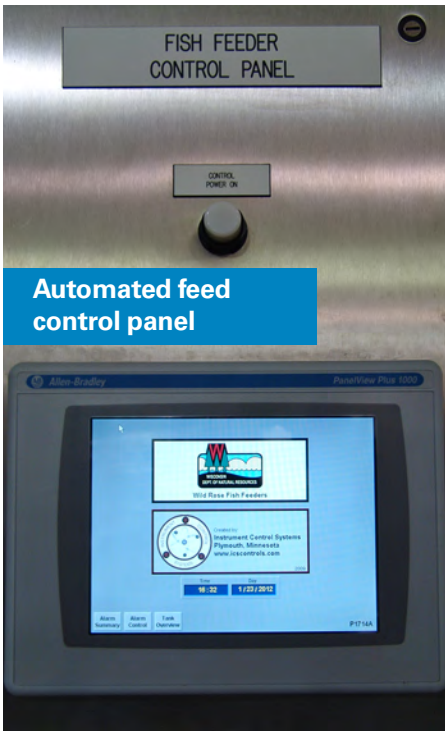
Feeding	Multiple times daily
Recording feed usage	Daily
Monitoring and recording feeding behavior	Multiple times daily
Monitoring and recording fish health	Multiple times daily
Cleaning spilled feed	Daily
Feed cataloging	As new feed shipments arrive

TROUBLESHOOTING ACTION PLAN

Fish will not eat the feed	1. Do not feed the fish. 2. Record the feeding behavior. 3. Alert the facility manager and fish health professional. 4. Remove any excess feed. 5. Monitor closely for abnormal behavior and sick fish. This may require temporarily shutting off aeration to help see the fish. 6. Collect a sick fish (if applicable) for pathology and preserve it according to the sample collection protocols. 7. Collect water quality data and perform the appropriate actions to deal with the water quality issue.
Water quality is outside the acceptable range	1. Do not feed the fish. 2. Alert the facility manager and fish health professional. 3. Perform the appropriate actions to deal with the water quality issue.
Fish are showing signs of stress or disease	1. Do not feed the fish. 2. Alert the facility manager and fish health professional. 3. Collect a sick fish for pathology and preserve it according to the sample collection protocols. 4. Collect water quality data and perform the appropriate actions to deal with the water quality issue.
Feed is moldy	1. Do not use. Open a different bag of feed. 2. Order more feed if necessary. 3. Record the moldy feed bag. 4. If large batches of feed are moldy, it may be necessary to purge the system and begin fresh.
Feed is expired	1. Do not feed expired feed. Refrigerated or frozen feed may exceed the manufacturer's shelf life specifications. 2. Order more feed.
Ran out of feed	1. Order more feed. 2. Inform the facility manager and record the new order.
Feed sinks when it should float	1. Attempt to feed with close monitoring. Remove any uneaten feed. 2. Order the proper feed. 3. Inform the facility manager and record the new order.
Feed floats when it should sink	1. Crush feed down to the proper size that will sink and sift off the fines. 2. Attempt to feed with close monitoring. Remove any uneaten feed. 3. Order the proper feed. 4. Inform the facility manager and record the new order.
Feed is too large for the fish	1. Crush feed down to the proper size and sift off the fines. 2. Attempt to feed with close monitoring. Remove any uneaten feed. 3. Order the proper feed. 4. Inform the facility manager and record the new order.
Feed is too small for the fish	1. Attempt to feed with close monitoring. Remove any uneaten feed. 2. Order the proper feed. 3. Inform the facility manager and record the new order.
Feed is wet	1. Do not use. Open a different bag of feed. 2. Dispose of wet feed. 3. Inform the facility manager and record the wet feed.
Manufacturer sent the wrong feed	1. Contact the feed company and have them send the correct feed. 2. Inform the facility manager and record the new order.
Feed has excessive fines in it	1. Contact the feed company and have them send the correct feed. 2. Sift off fines and attempt to feed with close monitoring. Remove any uneaten feed. 3. Inform the facility manager and record the new order.



Vibrating feeder



Automated feed control panel

Species	Month	Phase	Age (days)	Average Individual Weight (g)	Daily Growth Rate (g/day)	% of Biomass Fed	Individual Daily Feed Ration (g)	Stocking Density (lbs/gal)	Tank Size (gal)	Estimated # of Fish per Tank	Grading Number	Total Daily Feed Ration (lbs)
Barramundi	1	Hatchery	0	0.001	-	40%	0.0004	0.05	250	5700000	1	5.0
Barramundi	1	Hatchery	5	0.101	0.02	40%	0.0404	0.05	250	56000	2	5.0
Barramundi	1	Hatchery	10	1.10	0.2	30%	0.3303	0.1	250	10000	3	7.3
Barramundi	1	Nursery	15	2.60	0.3	30%	0.7803	0.1	250	4500	4	7.7
Barramundi	1	Nursery	20	4.60	0.4	20%	0.9202	0.2	250	4500		9.1
Barramundi	1	Nursery	25	7.10	0.5	20%	1.4202	0.2	250	3500	5	10.9
Barramundi	1	Nursery	30	9.60	0.5	20%	1.9202	0.3	250	3500		14.8
Barramundi	2	Nursery	35	12.1	0.5	10%	1.2101	0.4	250	3500		9.3
Barramundi	2	Nursery	40	17.1	1	10%	1.7101	0.4	250	2400	6	9.0
Barramundi	2	Nursery	45	24.6	1.5	10%	2.4601	0.5	250	2400		13.0
Barramundi	2	Nursery	50	32.1	1.5	10%	3.2101	0.5	250	1400	7	9.9
Barramundi	2	Nursery	55	42.1	2	10%	4.2101	0.5	250	1400		13.0
Barramundi	2	Nursery	60	52.1	2	10%	5.2101	0.5	250	1400		16.1
Barramundi	3	Growout	65	62.1	2	5%	3.10505	0.5	10000	30000	8	205.2
Barramundi	3	Growout	70	72.1	2	5%	3.60505	0.5	10000	30000		238.2
Barramundi	3	Growout	75	82.1	2	5%	4.10505	0.5	10000	30000		271.3
Barramundi	3	Growout	80	92.1	2	5%	4.60505	0.5	10000	20000	9	202.9
Barramundi	3	Growout	85	102	2.5	5%	5.10505	0.5	10000	20000		224.9
Barramundi	3	Growout	90	115	2.5	5%	5.73005	0.5	10000	20000		252.4
Barramundi	4	Growout	95	127	2.5	5%	6.35505	0.5	10000	15000	10	210.0
Barramundi	4	Growout	100	140	2.5	5%	6.98005	0.5	10000	15000		230.6
Barramundi	4	Growout	105	152	2.5	3%	4.56303	0.5	10000	15000		150.8
Barramundi	4	Growout	110	165	3	3%	4.93803	0.5	10000	12000	11	130.5
Barramundi	4	Growout	115	180	3	3%	5.38803	0.5	10000	12000		142.4
Barramundi	4	Growout	120	195	3	3%	5.83803	0.5	10000	12000		154.3
Barramundi	5	Growout	125	210	3	3%	6.28803	0.5	10000	10000	12	138.5
Barramundi	5	Growout	130	225	3.5	3%	6.73803	0.5	10000	10000		148.4
Barramundi	5	Growout	135	242	3.5	3%	7.26303	0.5	10000	10000		160.0
Barramundi	5	Growout	140	260	3.5	3%	7.78803	0.5	10000	10000		171.5
Barramundi	5	Growout	145	277	4.5	2%	5.54202	0.5	10000	10000	13	122.1
Barramundi	5	Growout	150	300	4.5	2%	5.99202	0.5	10000	7000		92.4
Barramundi	6	Growout	155	322	4.5	2%	6.44202	0.5	10000	7000		99.3

APPENDIX A (continued)

Species	Month	Phase	Age (days)	Average Individual Weight (g)	Daily Growth Rate (g/day)	% of Biomass Fed	Individual Daily Feed Ration (g)	Stocking Density (lbs/gal)	Tank Size (gal)	Estimated # of Fish per Tank	Grading Number	Total Daily Feed Ration (lbs)
Barramundi	6	Growout	160	345	5.5	2%	6.89202	0.5	10000	7000		106.3
Barramundi	6	Growout	165	372	5.5	2%	7.44202	0.5	10000	7000	14	114.7
Barramundi	6	Growout	170	400	5.5	2%	7.99202	0.5	10000	4000		70.4
Barramundi	6	Growout	175	427	7	2%	8.54202	0.5	10000	4000		75.3
Barramundi	6	Growout	180	462	7	2%	9.24202	0.5	10000	4000		81.4
Barramundi	7	Growout	185	497	7	2%	9.94202	0.5	10000	4000		87.6
Barramundi	7	Growout	190	532	7	2%	10.64202	0.5	10000	4000	15	93.8
Barramundi	7	Growout	195	567	9	2%	11.34202	0.5	10000	3000		74.9
Barramundi	7	Growout	200	612	9	2%	12.24202	0.5	10000	3000		80.9
Barramundi	7	Harvest	205	657	9	2%	13.14202	0.5	10000	2000	Harvest	57.9
Barramundi	7	Harvest	210	702	9	2%	14.04202	0.5	10000	1000	Harvest	30.9
Barramundi	8	Harvest	215	747	9	2%	14.94202	0.5	10000	500	Harvest	16.5
Barramundi	8	Harvest	220	792	10	2%	15.84202	0.5	10000	0	Harvest	0.0
Barramundi	8	Harvest	225	842	10	2%	16.84202	0.5	10000	0	Harvest	0.0
Barramundi	8	Harvest	230	892	10	2%	17.84202	0.5	10000	0	Harvest	0.0
Barramundi	8	Harvest	235	942	10	2%	18.84202	0.5	10000	0	Harvest	0.0
Barramundi	8	Harvest	240	992	11	2%	19.84202	0.5	10000	0	Harvest	0.0
Barramundi	9	Harvest	245	1047	11	2%	20.94202	0.5	10000	0	Harvest	0.0
Barramundi	9	Harvest	250	1102	11	2%	22.04202	0.5	10000	0	Harvest	0.0

Please note: These growth projections are based on ideal conditions. Results will vary with water quality, equipment used, and animal husbandry practices.

AUTHOR

Prepared by D. Allen Pattillo
Extension aquaculture specialist, Iowa State University Extension and Outreach
(515) 294-8616
pattillo@iastate.edu
www.extension.iastate.edu/fisheries

PHOTO CREDITS

Dave Cline, Auburn University,
Page 1.
D. Allen Pattillo, Iowa State University Extension and Outreach,
Page 2 and 3.