



Fish In - Fish Out (FIFO) Ratios explained

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One of the long continued debates in aquaculture is the use of fishmeal and fish oil in feeds and the amount of wild fish it takes to produce farmed fish. This debate has particularly raged around the use of fish oil and fishmeal in salmon diets and a lot of different figures have been quoted for the number of tonnes of wild fish it takes to produce a tonne of farmed salmon (FIFO ratio). These quoted figures range from 3:1 to 10:1; the most recent figure published comes from Tacon & Metian (2008) who gave the figure for Salmon in 2006 as 4.9:1, meaning it takes 4.9 tonnes of wild fish to produce 1 tonne of salmon.

It can be easily demonstrated how they came up with this figure. If we take 1 tonne (1000 kg) of wild fish, they assume that this would yield 225 kg of fishmeal and 50 kg of fish oil.

In 2006 they say that on average salmon diets contained 30% fishmeal and 20% fish oil. This means that one could produce 250kg of salmon feed by using up all of the 50 kg of fish oil. Salmon then have a feed conversion ratio (FCR) of 1.25 which therefore gives a harvest volume of 200 kg of salmon. So our starting 1000kg of wild fish have been turned into 200 kg of salmon which is a Fish in - Fish out (FIFO) ratio of 5:1 (1000:200), which compares well with Tacon & Metian's global figure of 4.9:1.

SALMON

Wt of pelagic fish at start kg	1000
Wt of Fishmeal kg	225
Wt of fish oil kg	50
How much salmon do I produce?	
Fish oil in the diet %	20
Fishmeal in the diet %	30
Requirement of oil kg	50
Requirement of fishmeal kg	75
Amount of feed that can be produced kg	250
FCR	1.25
Salmon Produced kg	200
FIFO	5.0
Fishmeal left over kg	150

Assumptions from Tacon & Metian highlighted

However, it can be seen from the table that while all the fish oil was used to produce the salmon feed, there was 150kg of fishmeal left over; this cannot be used as there is no more oil. In their calculation this is just thrown away and wasted.

Let us now turn our attention to the production of shrimp, the other major global user of fishmeal; in this case Tacon & Metian give a FIFO ratio of 1.4:1. Again we can do a worked example using the same starting point of 1 tonne of wild fish.

SHRIMP	
Wt of pelagic fish at start kg	1000
Wt of Fishmeal kg	225
Wt of fish oil kg	50
How much shrimp do I produce?	
Fish oil in the diet %	2
Fishmeal in the diet %	20
Requirement of oil kg	22.5
Requirement of fishmeal kg	225
Amount of feed that can be produced kg	1125
FCR	1.7
Shrimp Produced kg	662
FIFO	1.5
Fish Oil left over kg	28

In this case the diets from shrimp require much more fishmeal than fish oil, so all the 225kg of fishmeal is used to produce 1125 kg of shrimp feed, which with an FCR of 1.7, produces 662kg of harvestable shrimp and a FIFO ratio of 1.5:1 (1000/662). This is virtually the same as the Tacon & Metian figure of 1.4:1. On this occasion it can be seen that there is 28kg of surplus fish oil which it is assumed is discarded.

It can therefore be clearly seen that with salmon production there is surplus fishmeal and with shrimp production there is surplus fish oil, so that a combination of the two should be more efficient.

SALMON	PLUS	SHRIMP
Wt of pelagic fish at start kg	1000	
Wt of Fishmeal kg	225	
Wt of fish oil kg	50	
How much salmon do I produce?		How much shrimp do I produce?
Fish oil in the diet %	20	Fish oil in the diet % 2
Fishmeal in the diet %	30	Fishmeal in the diet % 20
Requirement of oil kg	35	Requirement of oil kg 15
Requirement of fishmeal kg	53	Requirement of fishmeal kg 150
Amount of feed that can be produced kg	175	Amount of feed that can be produced kg 750
FCR	1.25	FCR 1.7
Salmon Produced kg	140	Shrimp Produced kg 441
Total Weight Produced	581	
FIFO	1.7	
Fishmeal left over kg	23	
Fish Oil left over kg	0	

In this case if we use most of the oil (35kg from the available 50kg) for the salmon, we can produce 175 kg of salmon feed and this produces 140 kg of salmon. This would also use 53 kg of the available 225kg of fishmeal. If we use the remaining 15 kg of fish oil for shrimp feed and combine this with 150

kg of fishmeal we could produce 750kg of shrimp feed, which would yield 441kg of shrimp. The combined FIFO ratio is now 1.7:1 (1000:581) and there is still 23kg of fishmeal left over.

So let us go one more step and combine our salmon and shrimp production with some carp production, which does not use any fish oil.

SALMON	PLUS	SHRIMP	PLUS	CARP	
Wt of pelagic fish at start kg	1000				
Wt of Fishmeal kg	225				
Wt of fish oil kg	50				
How much salmon do I produce?		How much shrimp do I produce?		How much carp do I produce?	
Fish oil in the diet %	20	Fish oil in the diet %	2	Fish oil in the diet %	0
Fishmeal in the diet %	30	Fishmeal in the diet %	20	Fishmeal in the diet %	5
Requirement of oil kg	35	Requirement of oil kg	15	Requirement of oil kg	0
Requirement of fishmeal kg	53	Requirement of fishmeal kg	150	Requirement of fishmeal kg	23
Amount of feed that can be produced kg	175	Amount of feed that can be produced kg	750	Amount of feed that can be produced kg	450
FCR	1.25	FCR	1.7	FCR	1.8
Salmon Produced kg	140	Shrimp Produced kg	441	Carp Produced kg	250
Total Weight Produced	831				
FIFO	1.2				
Fishmeal left over kg	0				
Fish Oil left over kg	0				

Now we can see that if we use the extra 23kg of fishmeal, we could produce 250kg of carp and reduce further the FIFO ratio to 1.2:1 and now everything is being used and there is no wastage.

From these worked examples it can be seen that calculating the FIFO ratio based on just one type of farming does not give the correct picture and that the reality is that one should only use in the FIFO ratio calculation what is actually used and not “discard” anything. In the real world all the fishmeal and fish oil is used and therefore we need a method of calculation that correctly attributes the wild fish caught to their final use.

Let us therefore use the following formula :

$$\text{FIFO Ratio} = \frac{\text{Level of fishmeal in the diet} + \text{Level of fish oil in the diet}}{\text{Yield of fishmeal from wild fish} + \text{Yield of fish oil from wild fish}} \times \text{FCR}$$

So for Salmon we calculate:

$$\text{Salmon FIFO Ratio} = \frac{30 + 20}{22.5 + 5.0} \times 1.25 = 2.27$$

To check whether this is giving us the correct answer we can use it to recalculate how much wild fish was used in our worked example to produce our 140, 441 and 250 kg of salmon, shrimp and carp:

	Salmon	Shrimp	Carp
FIFO calculated using formula	2.27	1.36	0.33
Total of farmed production kg	140	441	250
Amount of wild fish used kg (Production x FIFO)	318	600	82
Total amount of wild fish used kg	1000		

We can therefore see that the total requirement of wild fish to produce these different amounts of salmon, shrimp and carp was 1000kg, our agreed start number. We can therefore assume that this method of calculating the FIFO ratio correctly attributes volumes of wild caught fish to their correct final use. Let us therefore turn from just one tonne of wild caught fish to the 20.2 million tonnes of raw material that was used for the production of fishmeal and fish oil in 2006 according to the FAO (FAO SOFIA 2008).

Tacon & Metian in their recent paper gave the results of their global survey of aquaculture feeds and reported the following :

Data presented by Tacon & Metian with Wild Fish Used calculated using their method								
Species	Volumes ,000 t	Fish Production	Feed Used	World FCR	FM Used	FO Used	FIFO Ratio	Wild Fish Used
Salmon		1465	1831	1.25	549	361	4.9	7220
Trout		632	790	1.25	237	109	3.4	2180
Eel		266	379	1.42	209	19	3.5	927
Marine Fish		1536	2072	1.35	663	166	2.2	3316
Shrimp		3164	4948	1.56	990	99	1.4	4399
FW Crustaceans		1066	1030	0.97	155	15	0.6	687
Tilapia		2326	3203	1.38	192	16	0.4	854
Catfish		1809	1927	1.07	193	33	0.5	856
Milkfish		585	468	0.80	14	5	0.2	94
Carp		10225	8466	0.83	423	0	0.2	1881
Misc FW Carn. Fish		777	249	0.32	100	12	0.6	442
Total Fed farmed fish & shellfish		23851	25363		3724	835		22856

We can see all the groupings of aquaculture species that make use of fishmeal and fish oil and their calculated FIFO Ratios including those for salmon and shrimp as already discussed. However, in the final column one can see the tonnage of wild fish required in the production of each group and this agrees with their reported FIFO ratios. We can see that, as in our small scale example, the method produces very high levels of wild fish usage to the point where if we add them up we reach a total global figure of nearly 23 million tonnes of wild fish. This is in excess of the FAO figure for total world catch of wild fish rendered for fishmeal and oil production (20.2 million) and the calculation does not consider fishmeal and fish oil used in pig and poultry production.

If however we use the same data as presented by Tacon & Metian but use the alternative method of calculating the FIFO ratio, as outlined earlier, we obtain the following:

Alternative Method for Calculating FIFO Ratios

Species	FM in Diet %	FO in Diet %	Yield of FM from wild fish %	Yield of FO from wild fish %	FIFO Ratio	Wild Fish used ,000 t
Salmon	30	20	22.5	5	2.3	3329
Trout	30	15	22.5	5	2.0	1293
Eel	55	5	22.5	5	3.1	827
Marine Fish	32	8	22.5	5	2.0	3014
Shrimp	20	2	22.5	5	1.3	3958
FW Crustaceans	15	1.5	22.5	5	0.6	618
Tilapia	6	0.5	22.5	5	0.3	757
Catfish	10	1.7	22.5	5	0.5	820
Milkfish	3	1	22.5	5	0.1	68
Carp	5	0	22.5	5	0.2	1539
Misc FW Carn. Fish	40	5	22.5	5	0.5	407
Total of Fed farmed fish & shellfish						16631

Now with this new method we have a different set of FIFO ratios, with salmon still the highest at 2.3:1, but now the total amount of wild fish used in aquaculture production is 16.6 million. The remainder is used in pig and poultry production.

So if we follow the same system to try and get an idea of the global picture using FAO STAT data for pig and poultry production we can estimate the following:

Table showing the calculated FIFO for Aquaculture, Pigs and Poultry

	FM in Diet %	FO in Diet %	Yield of FM %	Yield of FO %	FCR	FIFO FIPO	World Production ,000 t	Use of Wild Fish ,000 t
Aquaculture						0.7	23851	16696
Pigs	0.25	0	22.5	5.0	3.9	0.04	141222	5007
Poultry	0.3	0	22.5	5.0	2	0.02	76245	1664
Total						0.10	241318	23366

Pigs and poultry make very little use of fish oil and fishmeal is used mostly in the early stages but has been largely removed from most adult grower diets. So the inclusion figure in the above table is very low over the whole growing cycle.

This gives us a total raw material use for fishmeal and fish oil production of 23.3 million tonnes for these three major categories. We therefore feel that this method of calculating the Fish in - Fish out ratios for aquaculture gives a truer representation of situation than previously used methods. But, as already mentioned, the FAO estimated 20.2 million tonnes of wild fish being rendered down for fishmeal and fish oil in 2006.

One reason for this is that the assumed yield figure of fishmeal from whole fish used by Tacon and Metian was 22.5%. Over the last decade improved processing equipment has ensured a greater protein recovery from the whole fish and the latest data IFFO has on this is that yield figures for the industry range from 23.5-24.5%. So if instead of 22.5%, we use a fishmeal yield figure of 24% we get the following:

Summary of FIFO Ratios as calculated by IFFO

Species	FM in Diet %	FO in Diet %	Yield of FM from wild fish %	Yield of FO from wild fish %	FIFO Ratio	Wild Fish used ,000 t
Salmon	30	20	24	5	2.2	3157
Trout	30	15	24	5	1.9	1226
Eel	55	5	24	5	2.9	784
Marine Fish	32	8	24	5	1.9	2858
Shrimp	20	2	24	5	1.2	3754
FW Crustaceans	15	1.5	24	5	0.5	586
Tilapia	6	0.5	24	5	0.3	718
Catfish	10	1.7	24	5	0.4	777
Milkfish	3	1	24	5	0.1	65
Carp	5	0	24	5	0.1	1460
Misc FW Carn. Fish	40	5	24	5	0.5	386
Total of Fed farmed fish & shellfish					0.66	15770
Pigs	0.25	0	24	5	0.03	4748
Poultry	0.3	0	24	5	0.02	1577
Total					0.09	22096

This reduces the total weight of wild fish used to 22.1 million tonnes (down from 23.3 million) which is closer to the FAO figure of 20.2. The annual global production of fishmeal in 2006 according to IFFO statistics was 5.2 million tonnes which at a 24% yield would require 21.7 million tonnes of raw material. The figures are therefore all consistent.

One final consideration is that more and more of the world's fishmeal and oil is derived from fisheries by-products such as heads, guts and filleting waste. The differentiation between by-product fishmeal and whole fish fishmeal has not been well captured in world statistics; this goes for both IFFO and FAO data. In a recent study conducted by IFFO we calculated that around 22% of fishmeal was derived from by-products rather than whole fish.

If we use this assumption the whole wild fish in - whole farmed fish out ratio obviously falls:

Table showing the calculated FIFO for Aquaculture, Pigs and Poultry excluding fisheries by-products

	World Production ,000 t	Use of Fish ,000 t	% Coming from fishery by-products	Use of whole wild fish ,000 t	FIFO /FIPO
Aquaculture	23851	15770	22	12301	0.52
Pigs	141222	4748	22	3703	0.03
Poultry	76245	1577	22	1230	0.02
Total	241318	22096	22	17235	0.07
Salmon	1465	3157	22	2462	1.68

In this case the Fish in - Fish out ratio for all aquaculture falls to 0.52. That is for every tonne of whole wild fish caught, aquaculture produces 1.92 tonnes of harvestable product. Salmon is still the highest user with a FIFO ratio of 1.68, meaning that for every tonne of whole wild fish used there is 0.595 tonnes of salmon produced. If one looks at the whole of the fishmeal and fish oil industry, for every 1 tonne of whole wild fish converted into fishmeal and fish oil, the food producing industries which use these products produce around 14 tonnes of farmed produce.