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International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

science for global insight

An Integrated Economic Model of Global Fisheries, Aquaculture, and Agriculture

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Introduction: IIASA and the GLOBIOM Model

- International Institute for Applied Systems Analysis (IIASA)
  - International scientific institute with 23 member countries
  - Research on global environmental, scientific, and technological challenges using integrated systems approaches

- Global Biosphere Management Model (GLOBIOM)
  - Used for agricultural/environmental policy analysis (EU, Brazil)
    - Climate mitigation, adaptation, biofuels, deforestation, LULUC, etc…
  - PE economic model with strong biophysical foundation
  - Global integrated model of the land-based sectors
    - Agriculture, livestock, forestry, bioenergy
  - Next step to integrate fisheries and aquaculture
    - Food security, feed markets, biodiversity, environmental trade-offs

Population, GDP, consumer preferences

Demand

Seafood | Food | Fibers | Energy | Industry

Markets

MARKET, TRADE, PRICES

MARKET & TRADE: EU + WORLD → **PRICES**

Production

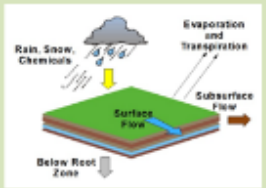
FEED | FEEDSTOCK | FEED | BIOMASS

TBD
Fish model

→ **Feed efficiency**
→ **Feed formulation**
→ **Feed production**
→ **GHG emissions**

FEED

EPIC
Crop model



RUMINANT
Digestibility model

→ Feed intake
→ Animal production
→ GHG emissions

BIOENERGY
Processing

→ MJ biofuel
→ MJ bioelectric
→ Coproducts

G4M
Global Forest model

→ Harvestable wood
→ Harvesting costs

Land use

Worldwide:
10 commodities
21 production systems

Capture/Aquaculture
Fresh/Brackish/Marine
Intensive/Non-Fed

Worldwide:
18 crops (FAO + SPAM)
Management systems:
low/high input & irrigated

EU28:
9 additional crops,
crop rotations.
Management options:
fertilizer, irrigation & tillage

7 animals
(FAO + Gridded livestock)

Cattle & Buffalo
Sheep & Goat
Pig
Poultry

8 different systems

Perennial crops
Short rotation coppice

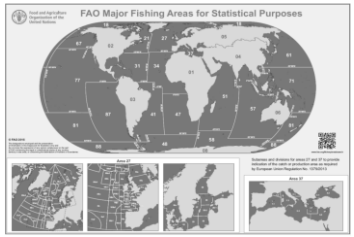
Conversion technologies
First generation biofuels
Second generation biofuels
Biomass power plants

Downscaled FAO FRA at grid level

Area
Carbon stock
Age
Tree size
Species
Rotation time
Thinning

Land cover

Water surface



FAO Fishing Areas

Cropland | **Grassland** | **Short rotation plantations** | **Managed forest**

Natural forest

Other natural land

Gridded representation of world land use

Model Structure and Data Sources

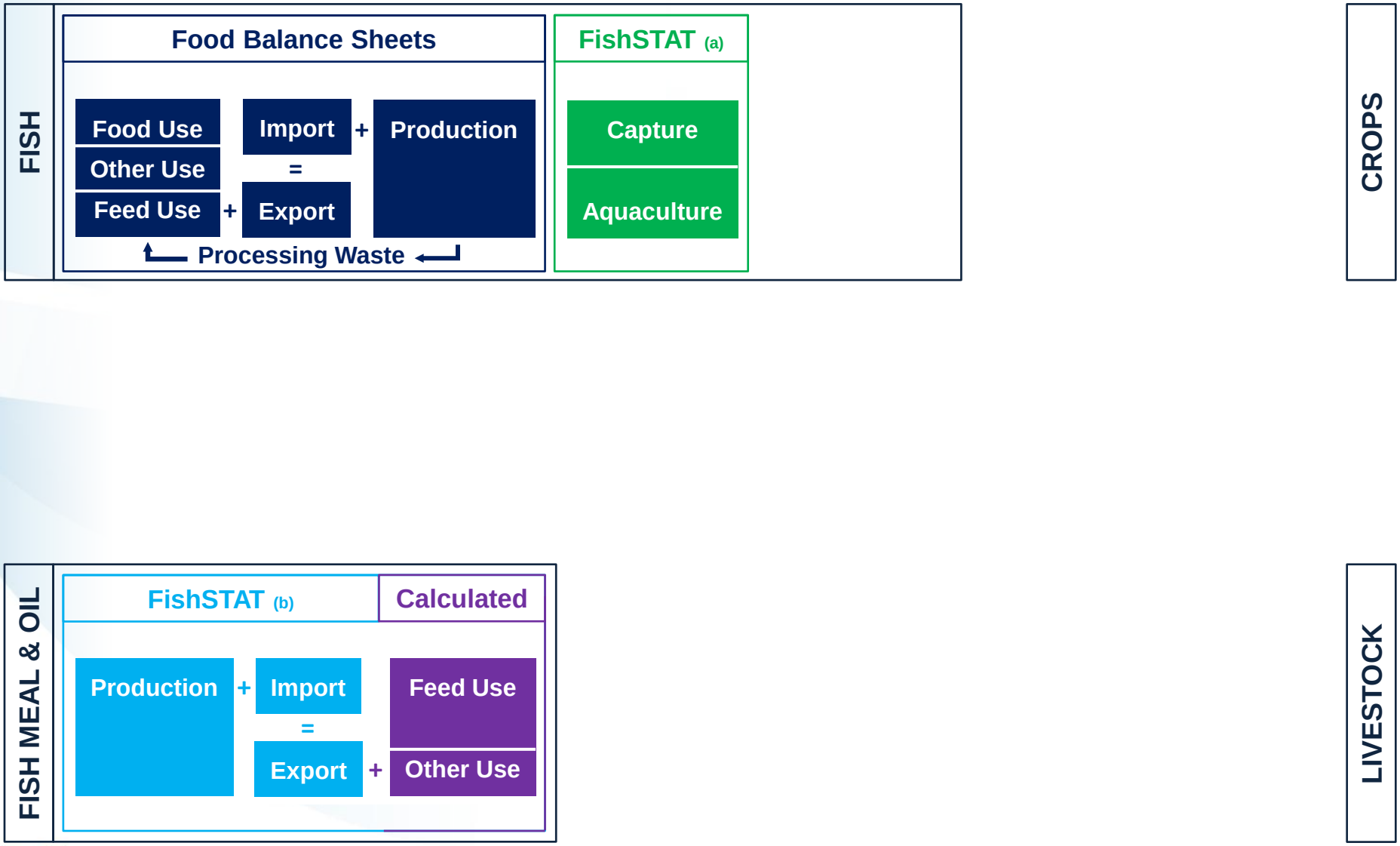
FISH

CROPS

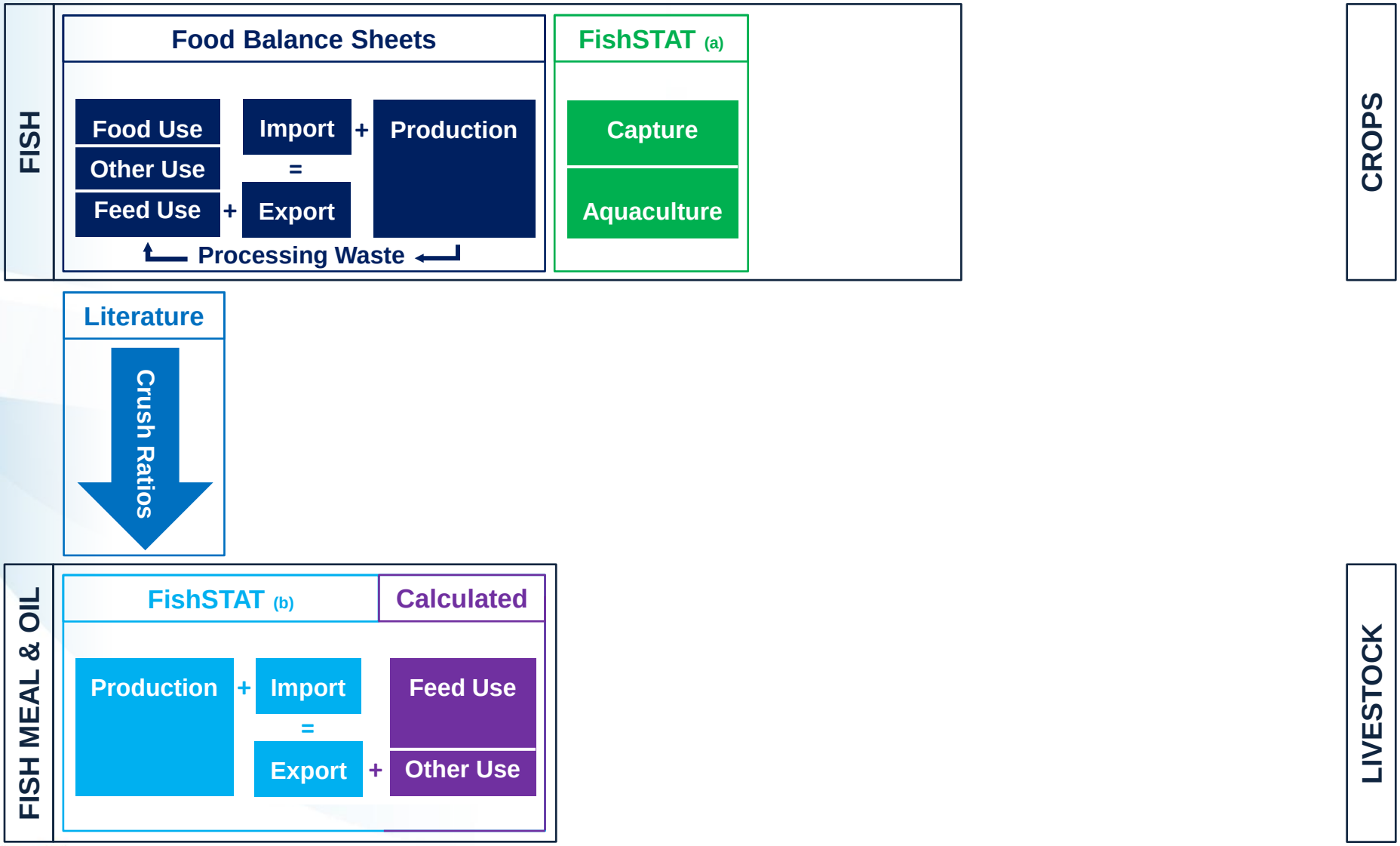
FISH MEAL & OIL

LIVESTOCK

Model Structure and Data Sources



Model Structure and Data Sources



Balancing Fish Meal and Oil Production

FISH

Food Use

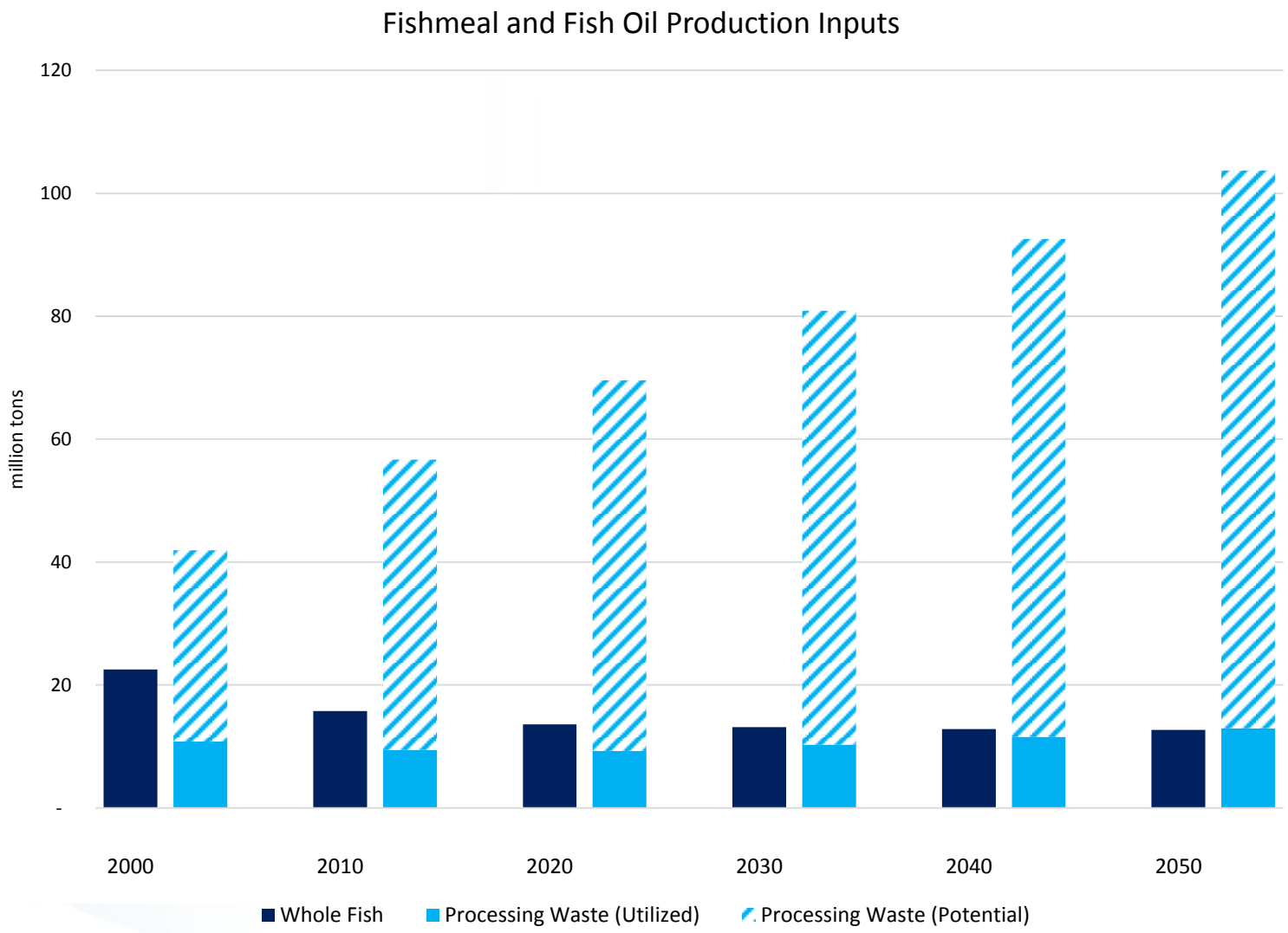
Other Use

Feed Use

Crush Ratios

FISH MEAL & OIL

Production



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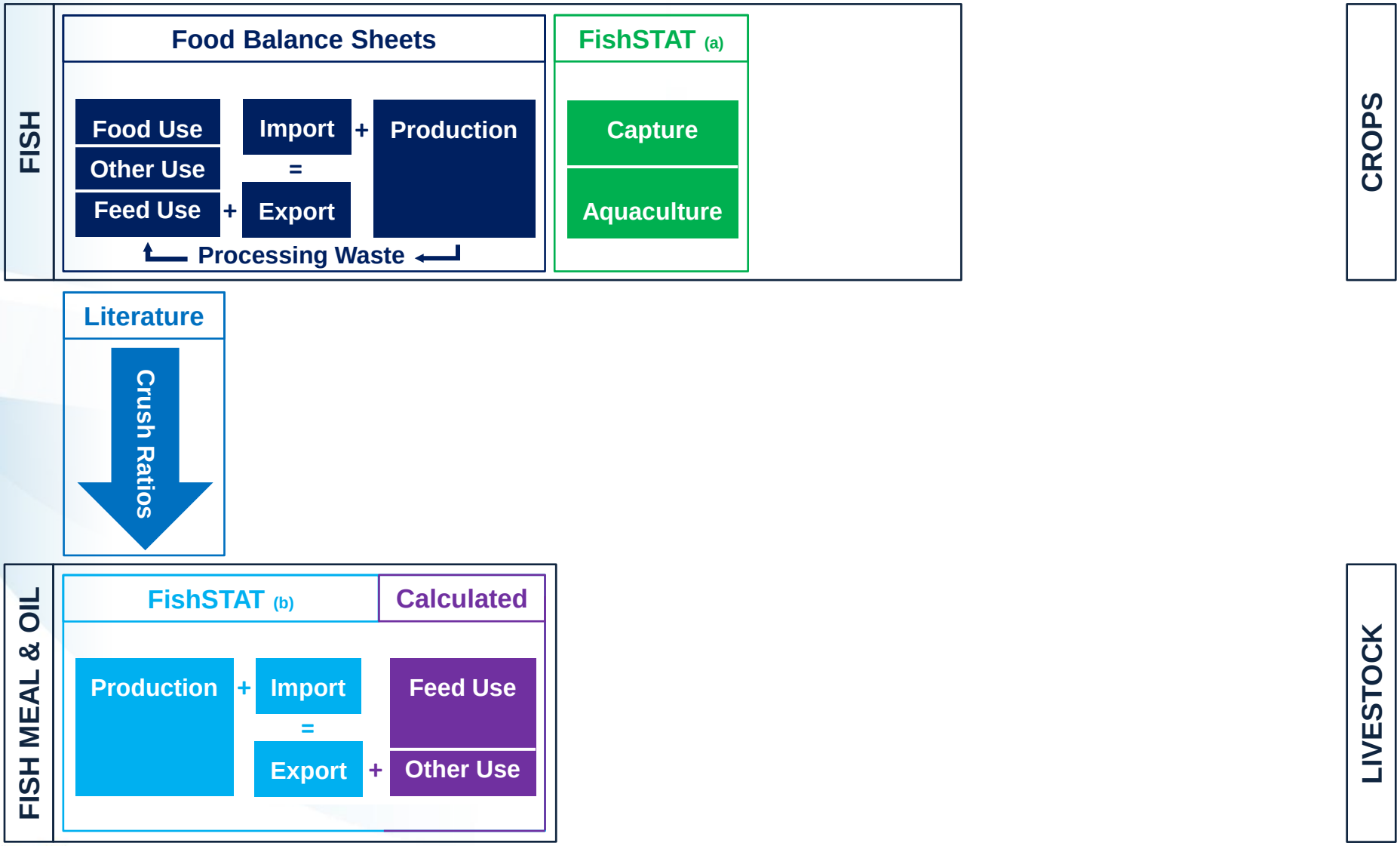

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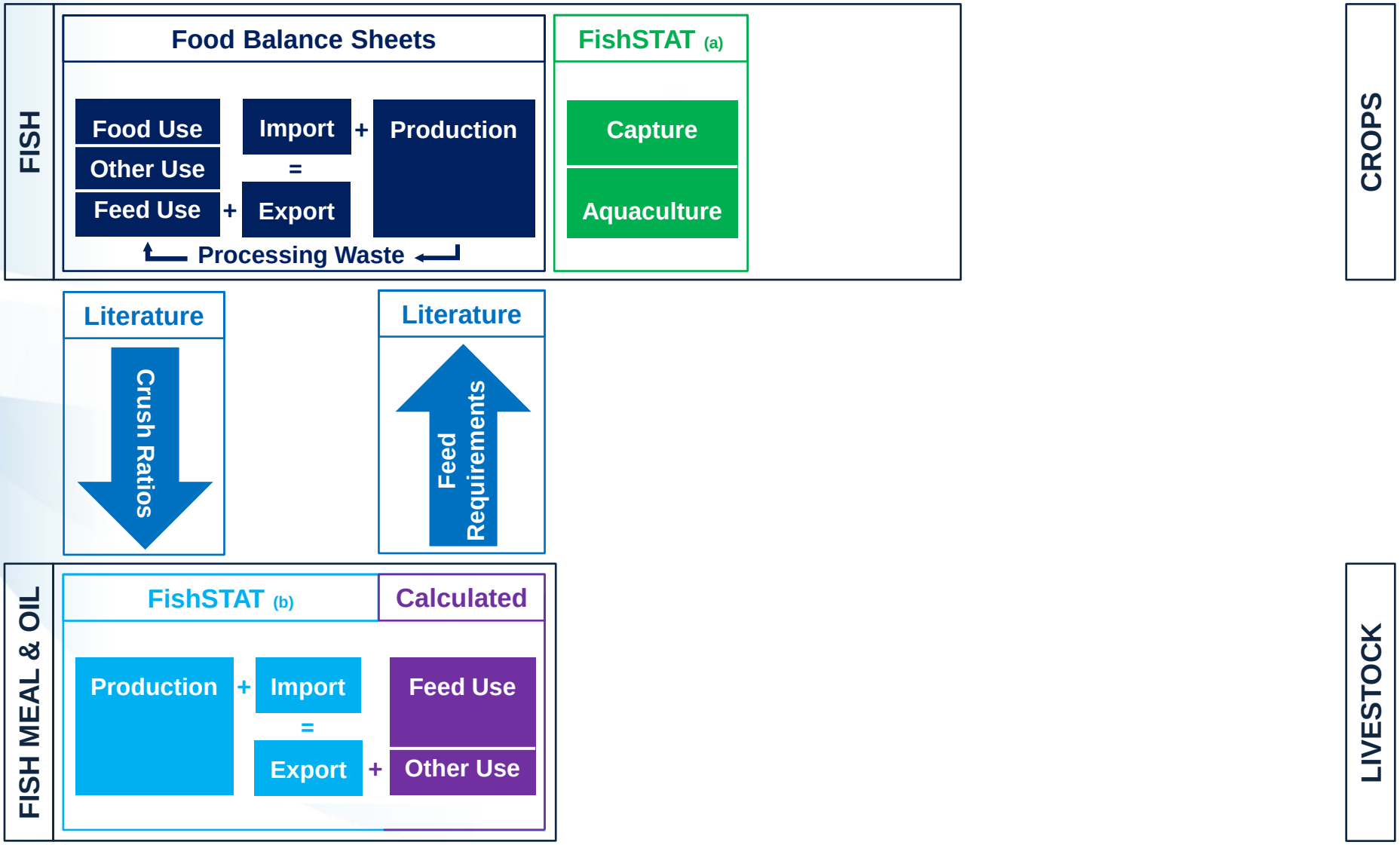


Model Commodity Disaggregation

FISH

Production

Feed Requirements

FISH MEAL & OIL

Feed Use

Other Use

FAOSTAT Groups	GLOBIOM Model Commodities	GLOBIOM Model Production Systems
Freshwater and Diadromous	Filter Carps	Filter Carps
	Salmon and Trout	Salmon
		Trout
	Other Freshwater and Diadromous	Tilapia
		Catfish
		Milkfish
		Chinese Carps
		Freshwater Carnivores
		Eel
		Other Freshwater
Demersal	Demersal	Mullet
		Selected Demersal*
		Other Demersal
Pelagic	Tuna	Tuna
	Other Pelagic	Selected Pelagic*
		Other Pelagic
Marine, Other	Other Marine	Other Marine
Crustaceans	Shrimp	Shrimp
		Freshwater Prawns
	Other Crustaceans	Other Crustaceans
Cephalopods	Molluscs	Molluscs
Molluscs, Other		

Calibrating Feed Requirements: Fishmeal

FISH

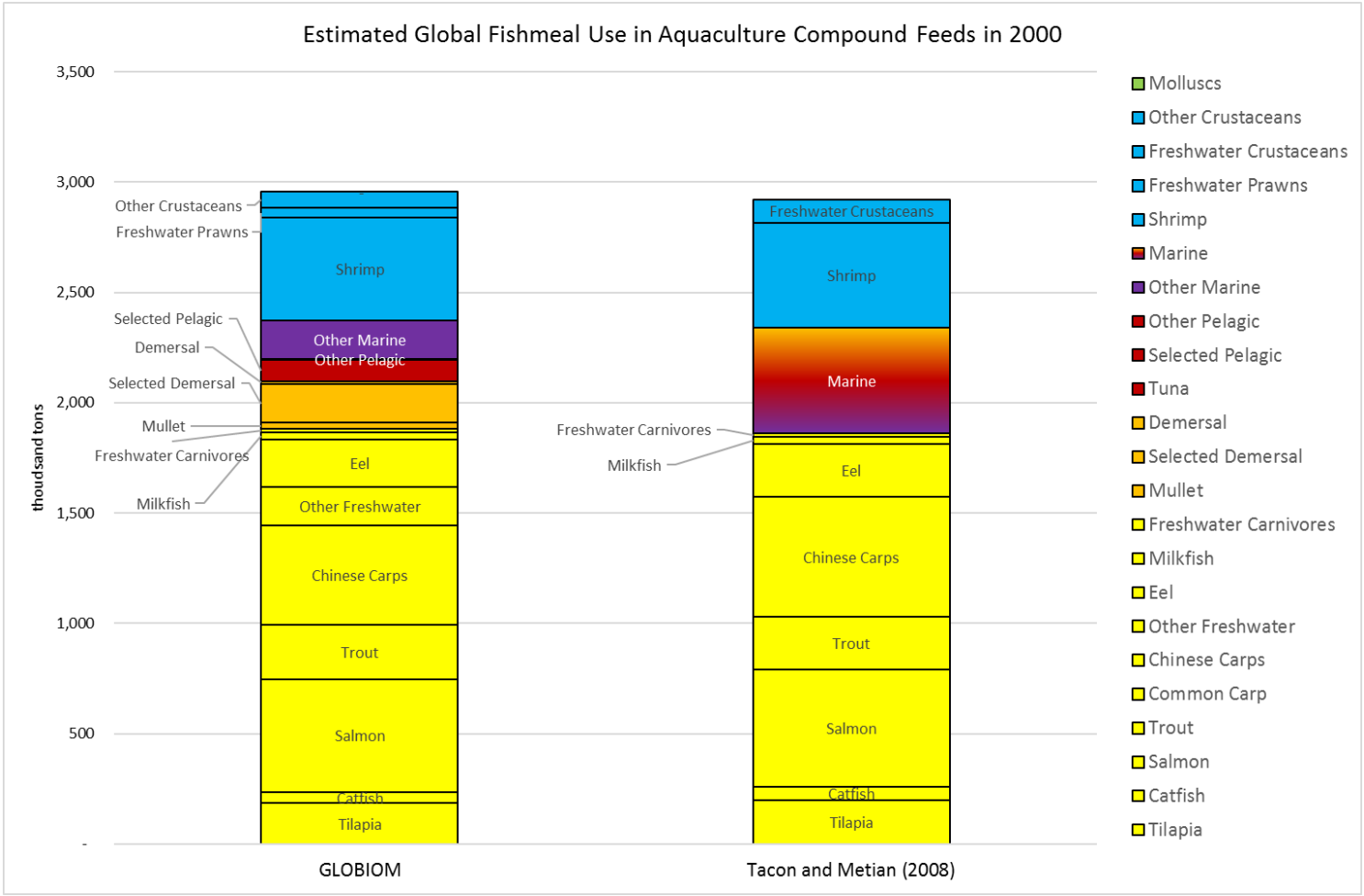
Production

Feed Requirements

FISH MEAL & OIL

Feed Use

Other Use



Calibrating Feed Requirements: Fish Oil

FISH

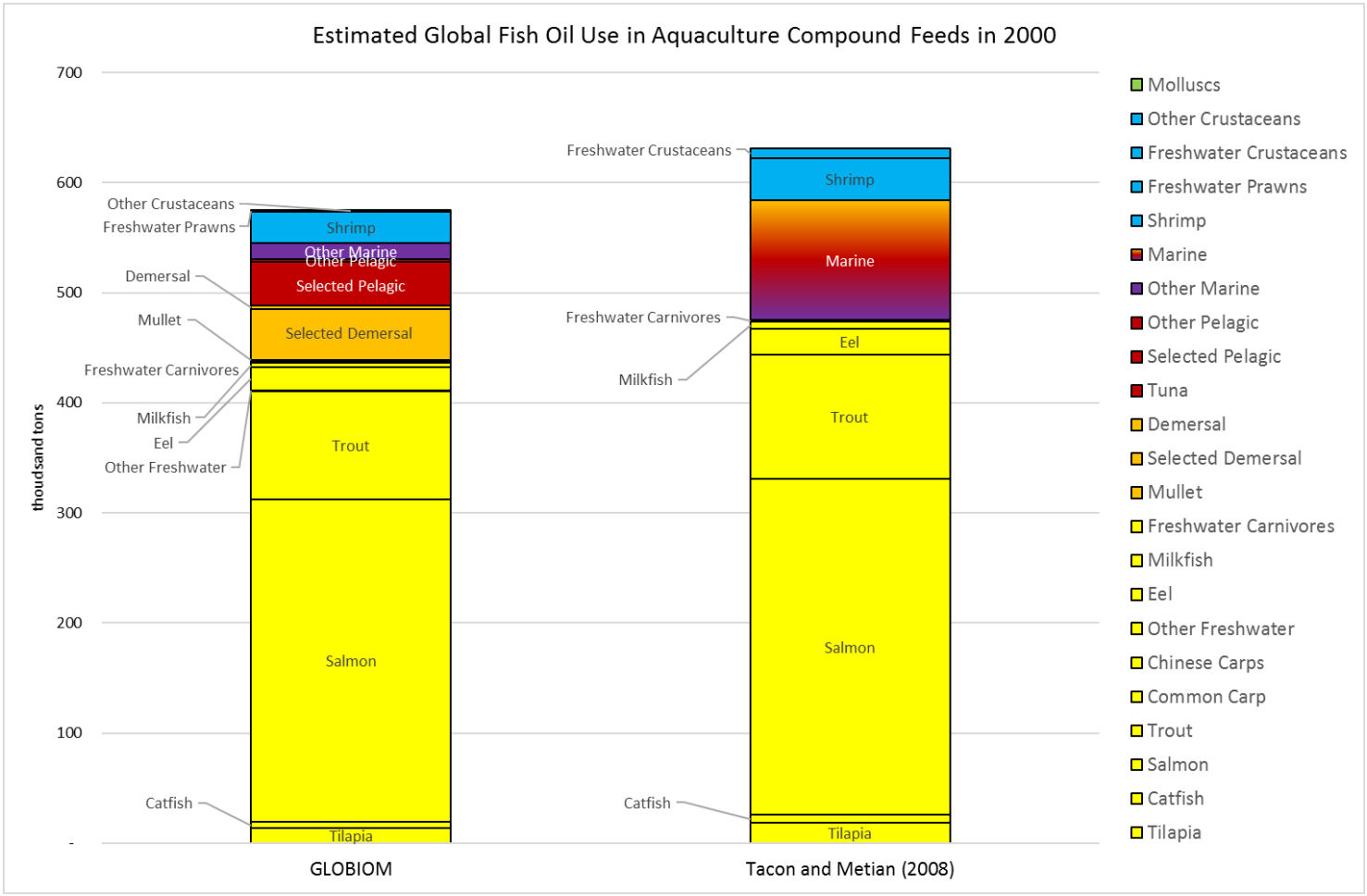
Production

Feed Requirements

FISH MEAL & OIL

Feed Use

Other Use



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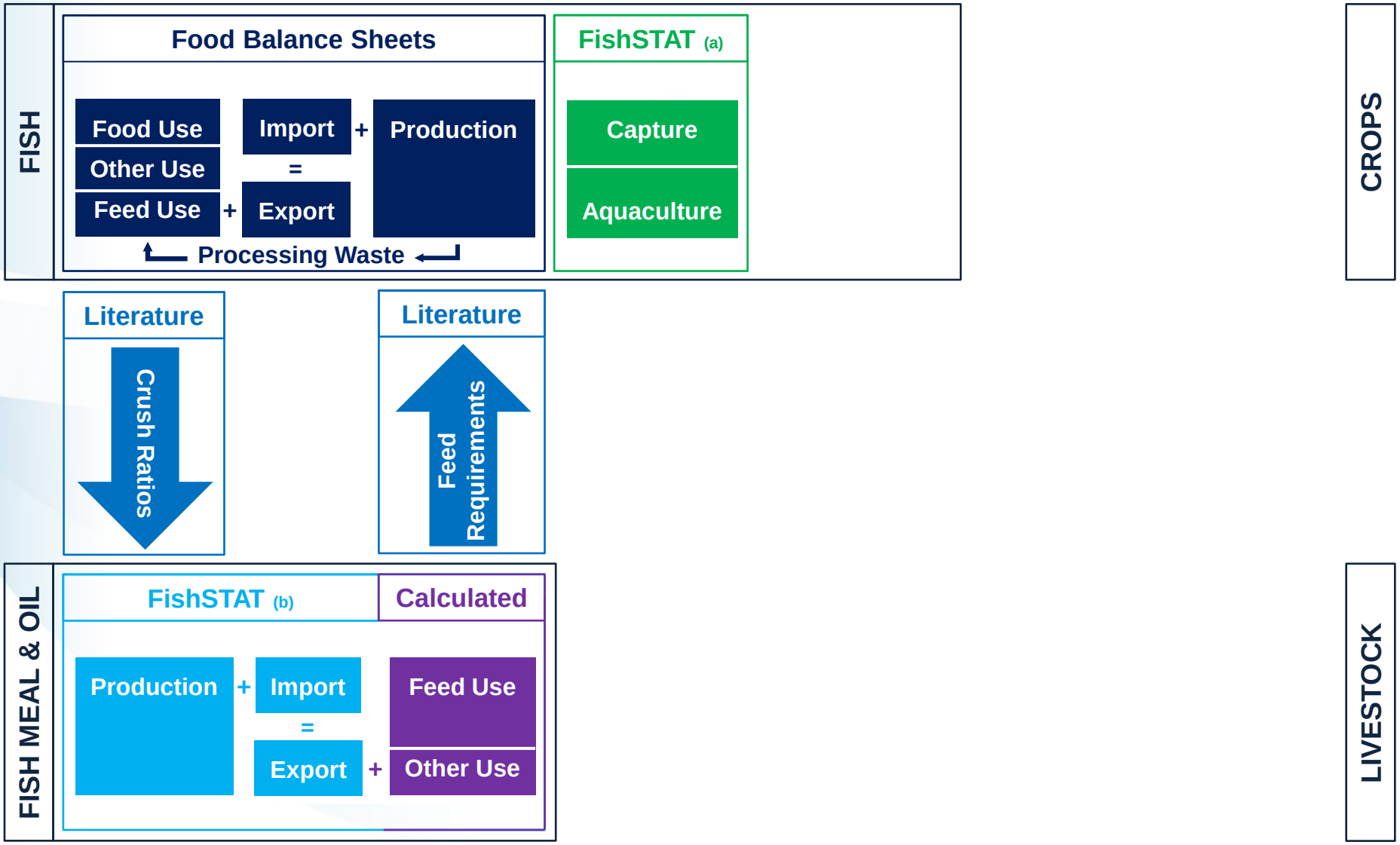

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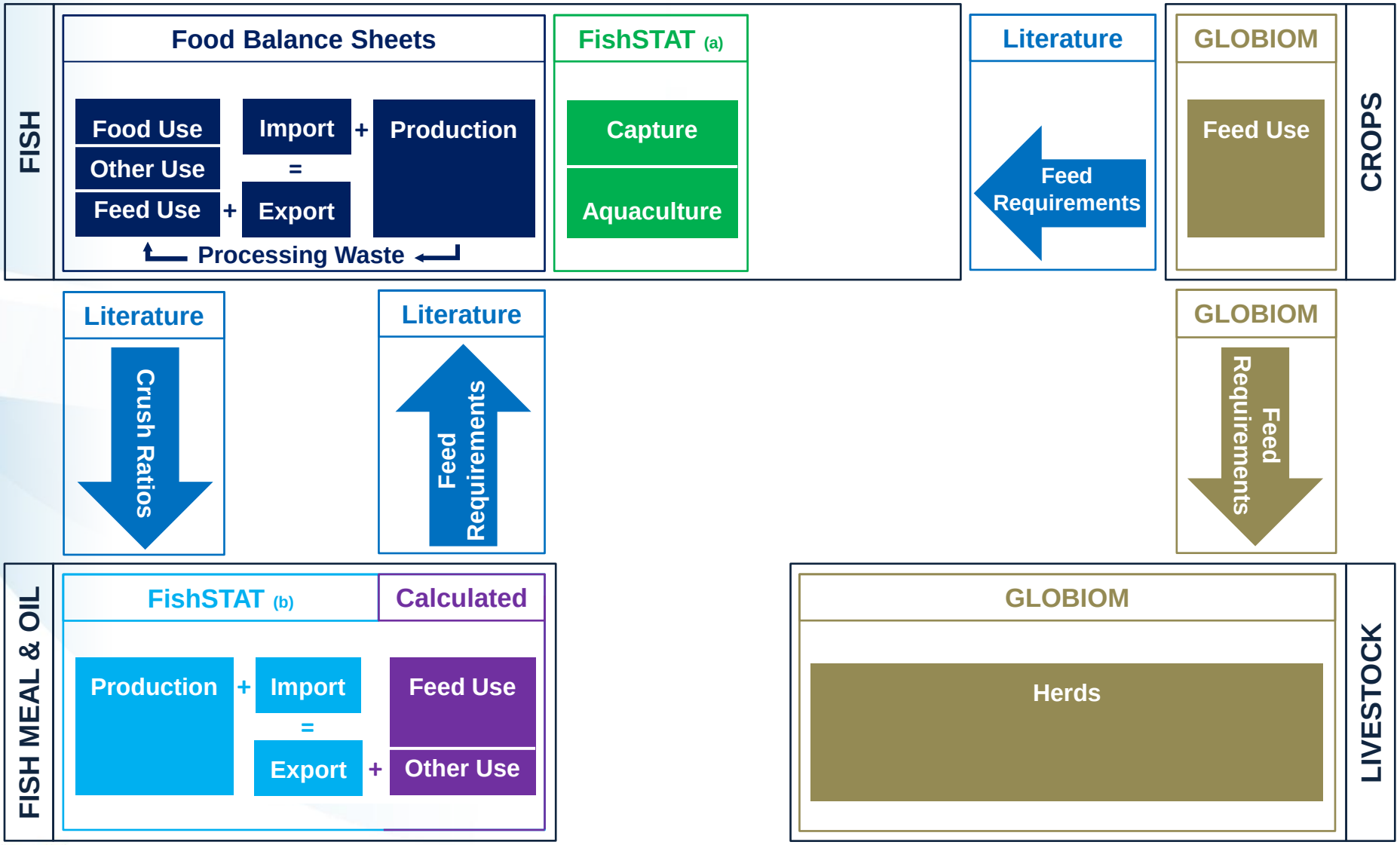


Calibrating Feed Requirements: Crops

FISH

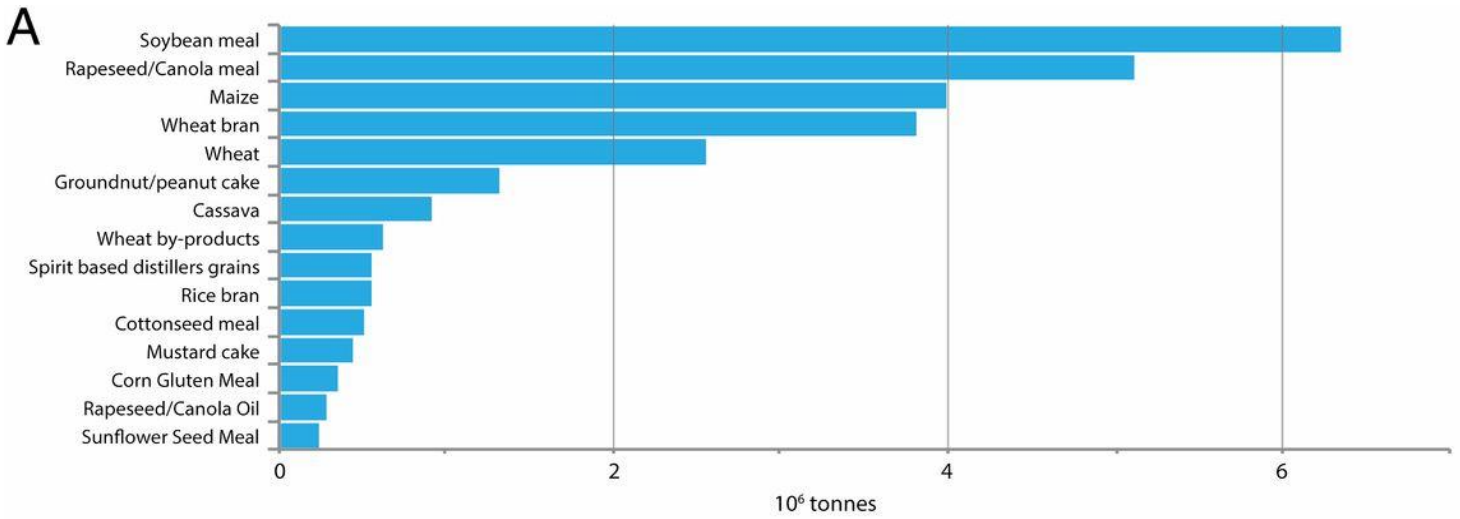
Production

Feed Requirements

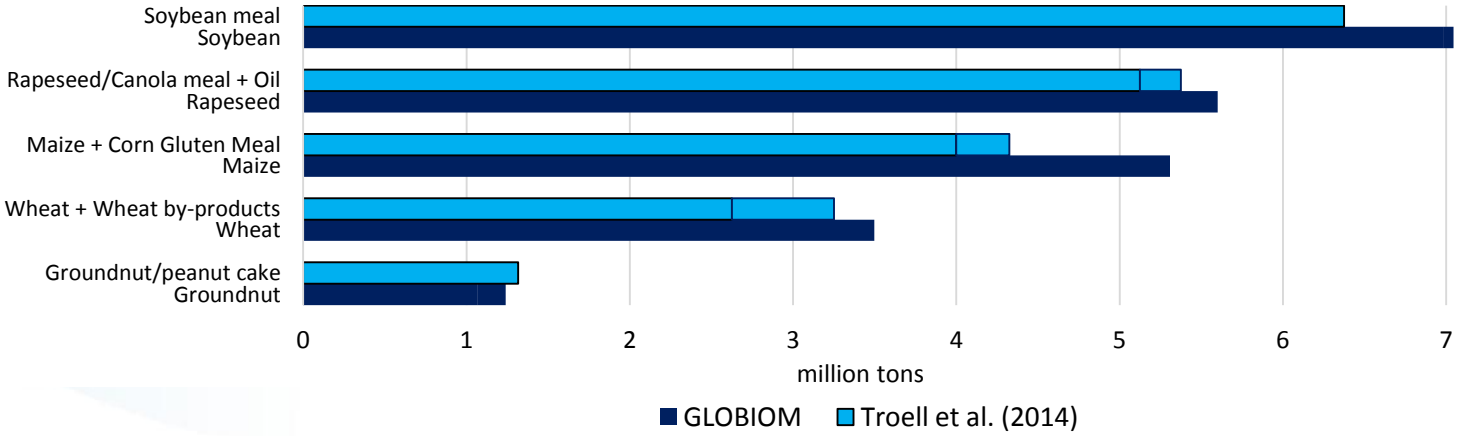
CROPS

Feed Use

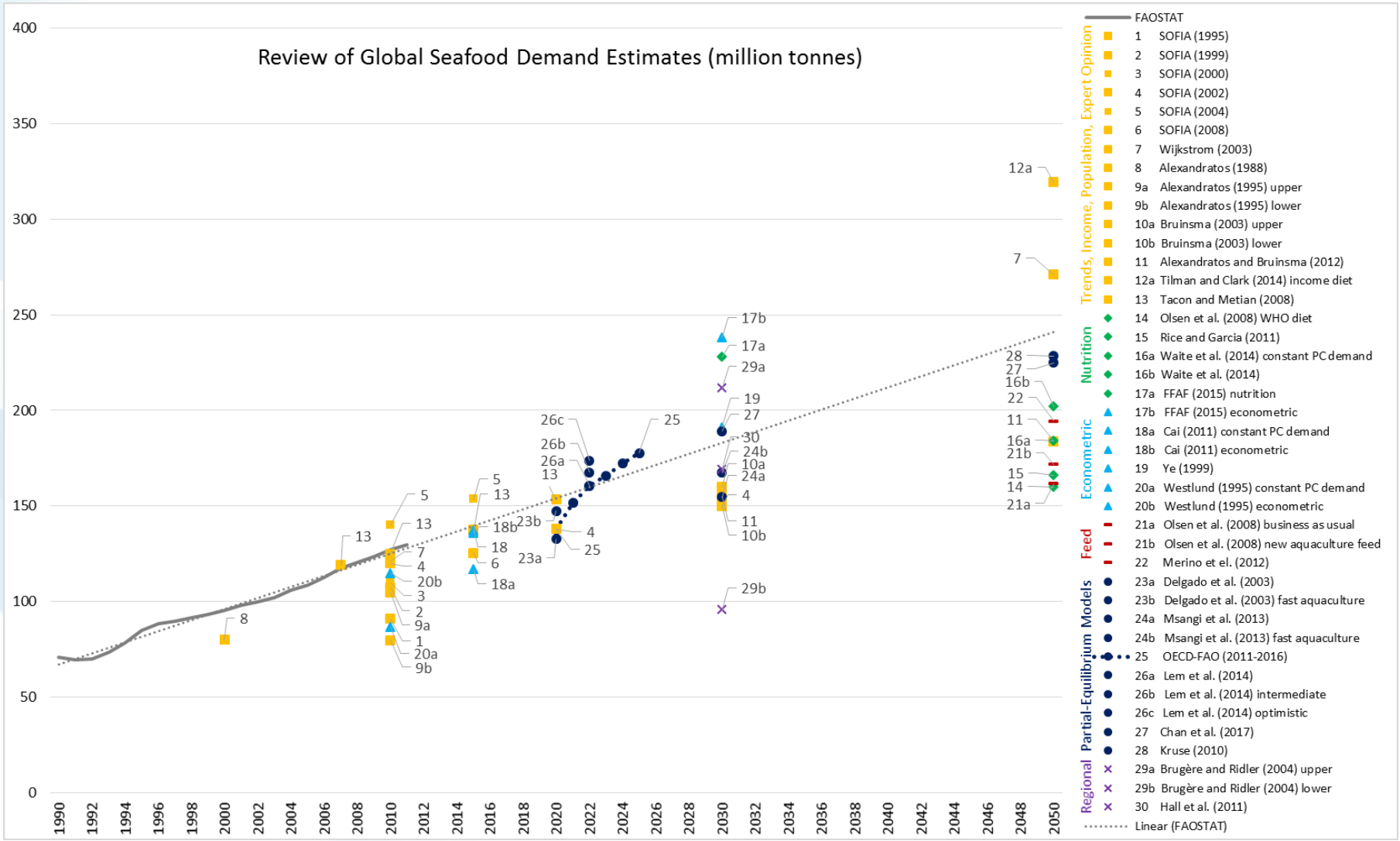
Global amount of (A) major crop feed ingredients used in aquaculture in compound feeds for fed species, (B) their relative plant equivalents (estimates from ref. 21), and (C) major agriculture products used in all terrestrial animal feeds (3). Source: Troell et al. (2014)



Global Amount of Major Crop Feed Ingredients Used in Aquaculture Compound Feeds in 2010

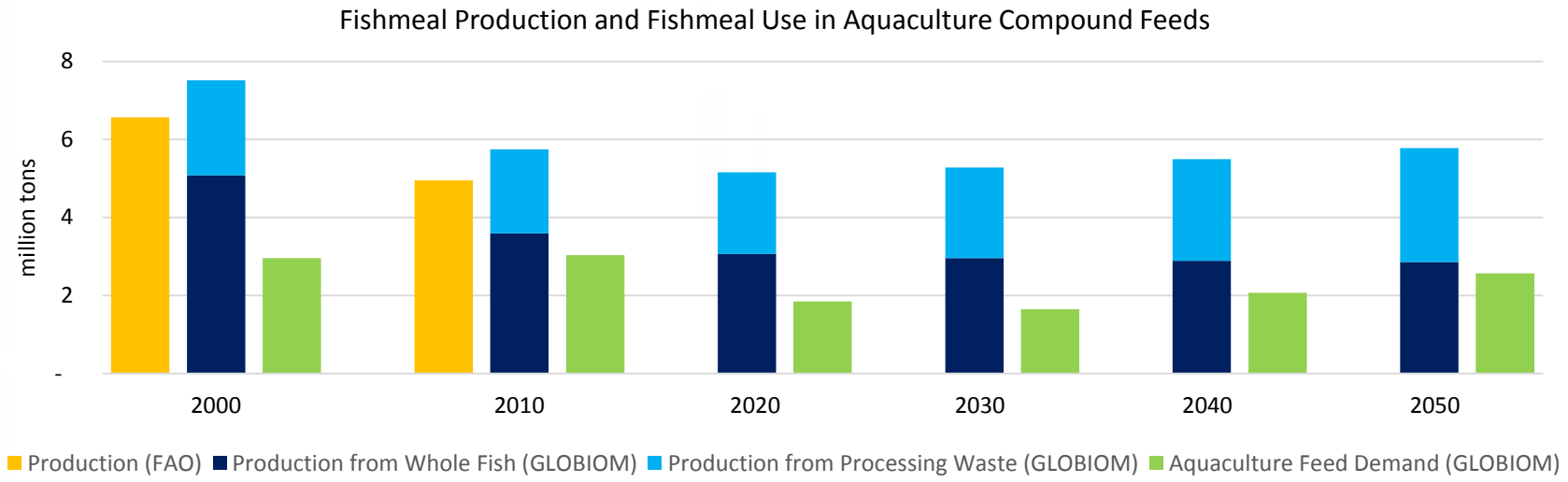


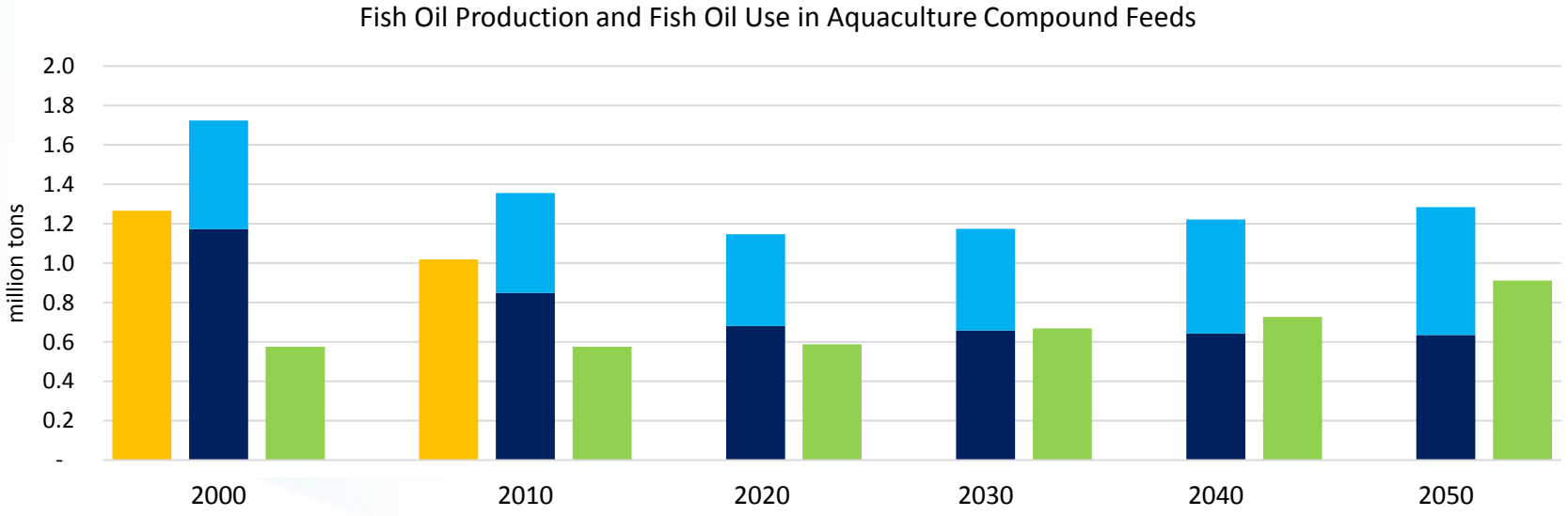
Fish Futures Outlooks: Review



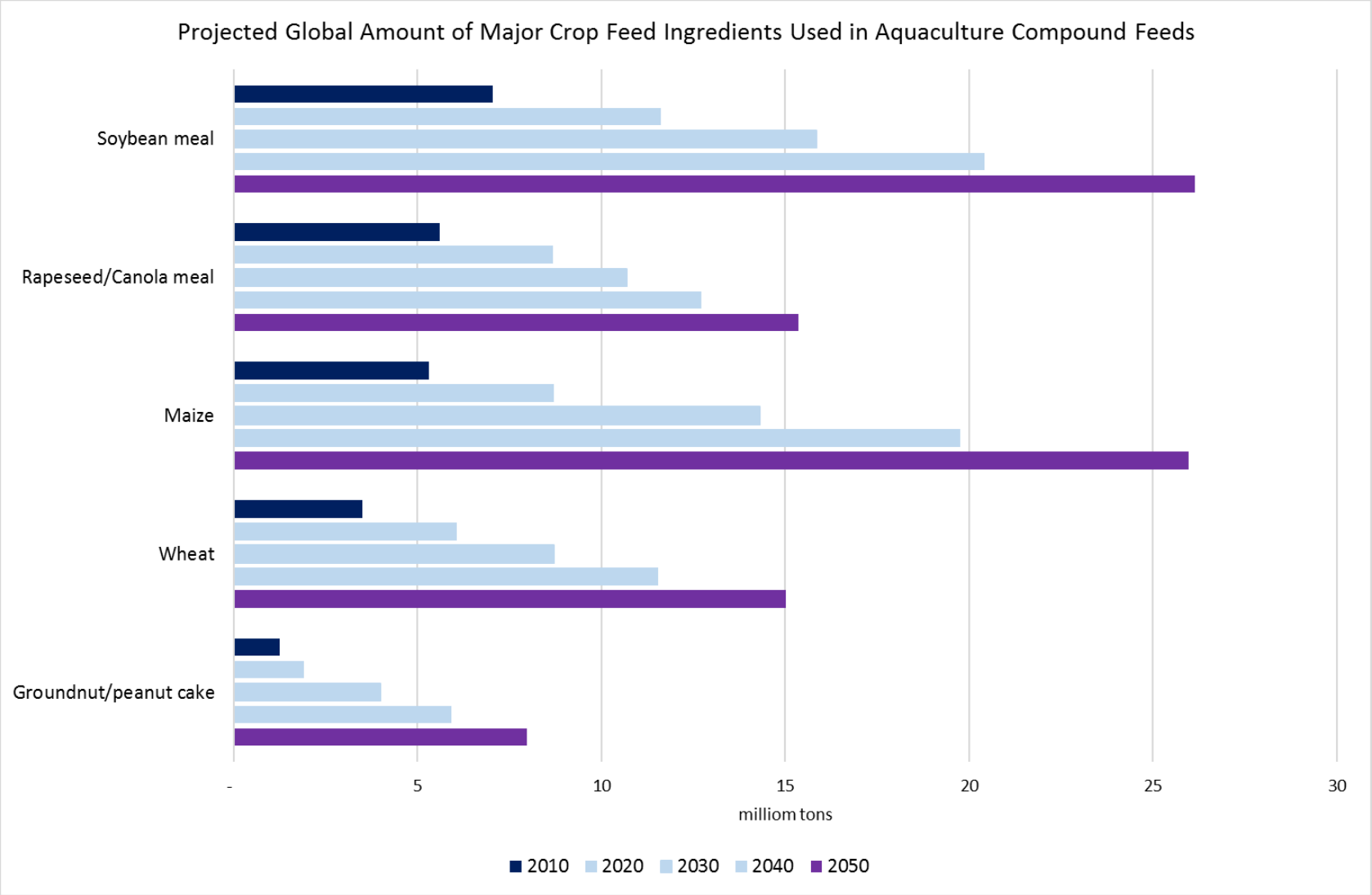
Source: IIASA

Projected Feed Use: Fish Meal and Oil

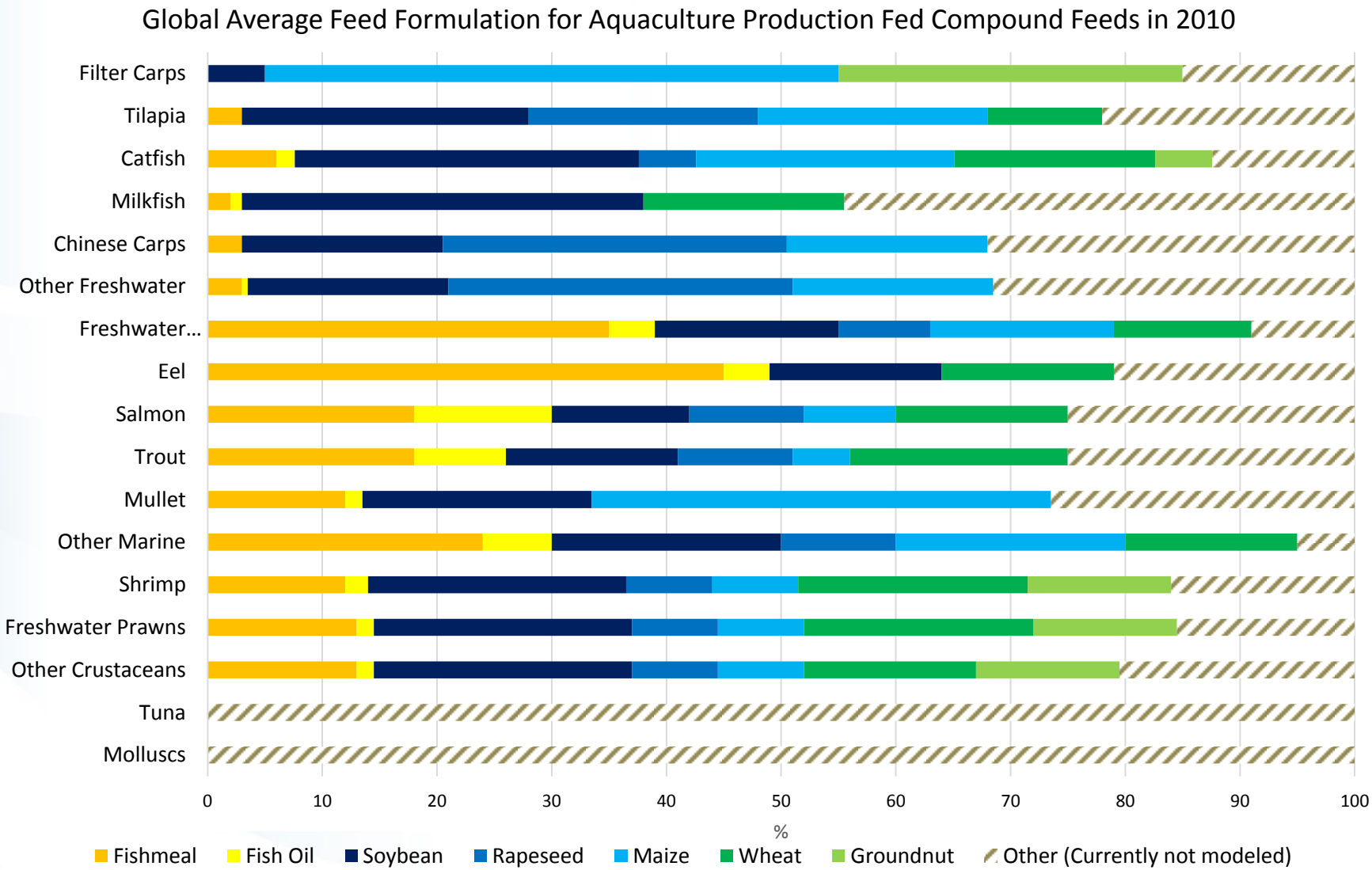




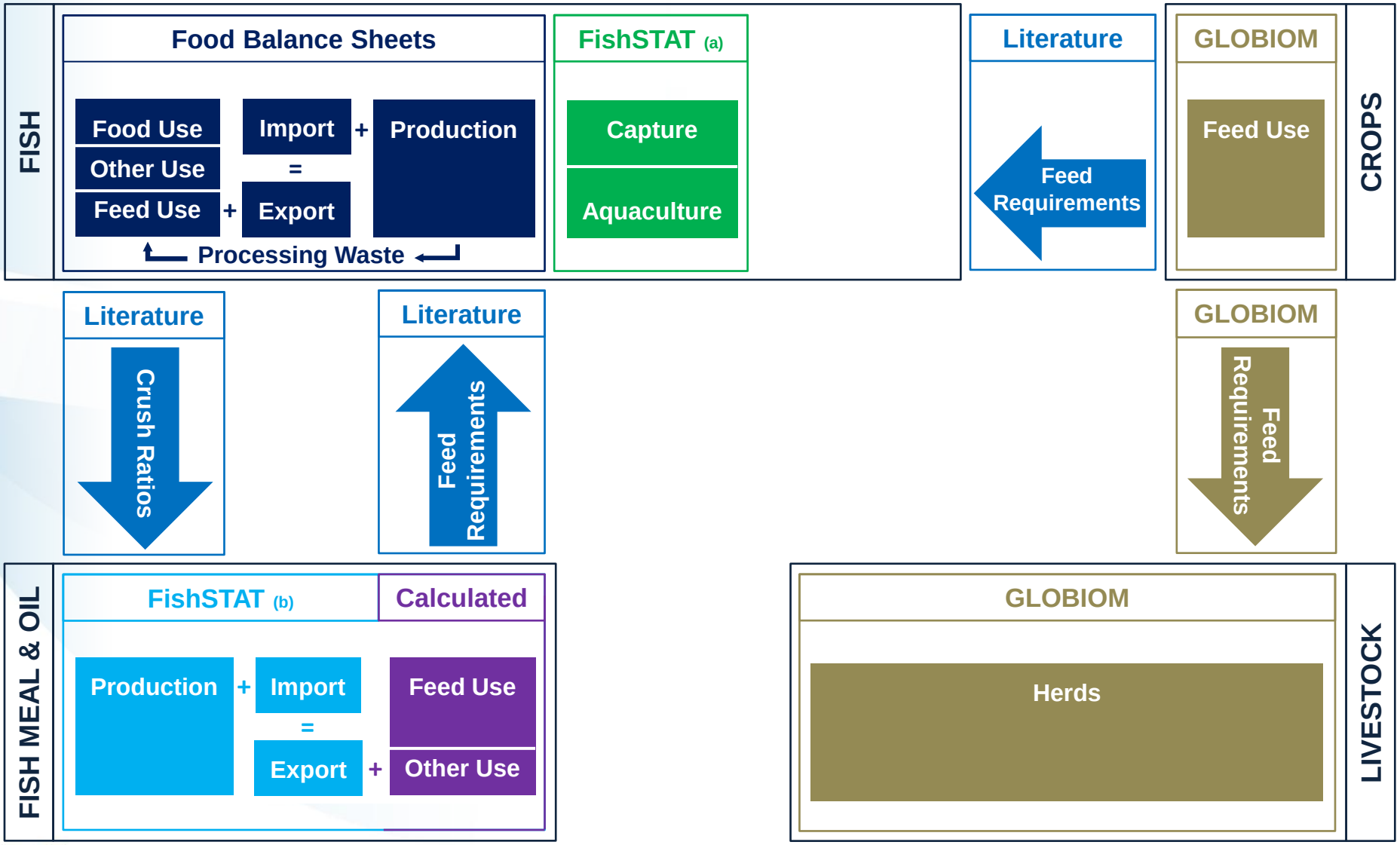
Projected Feed Use: Crops



Feed Requirements: Composition



Model Structure and Data Sources



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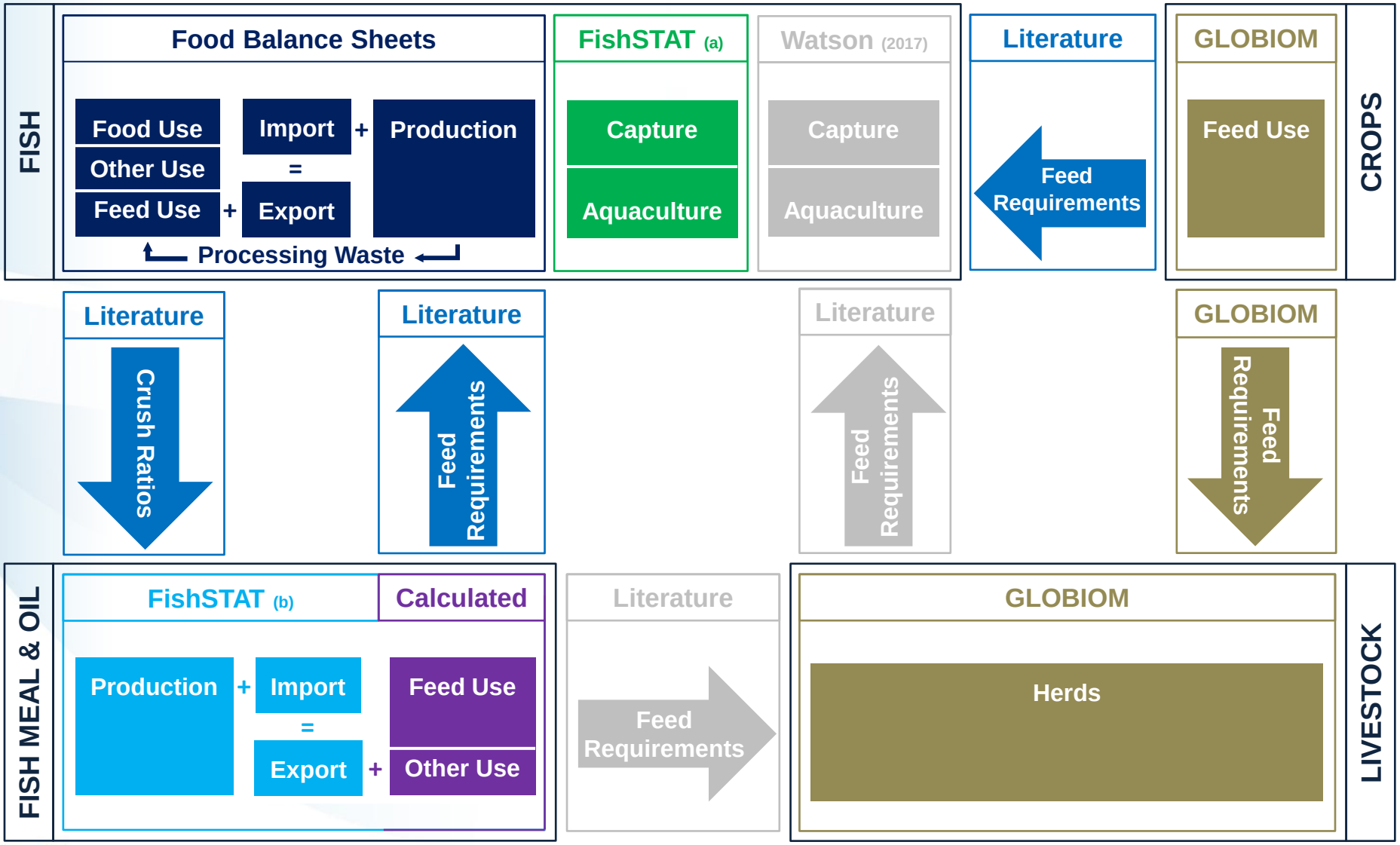

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622693 *SUSFANS*

Thank you!

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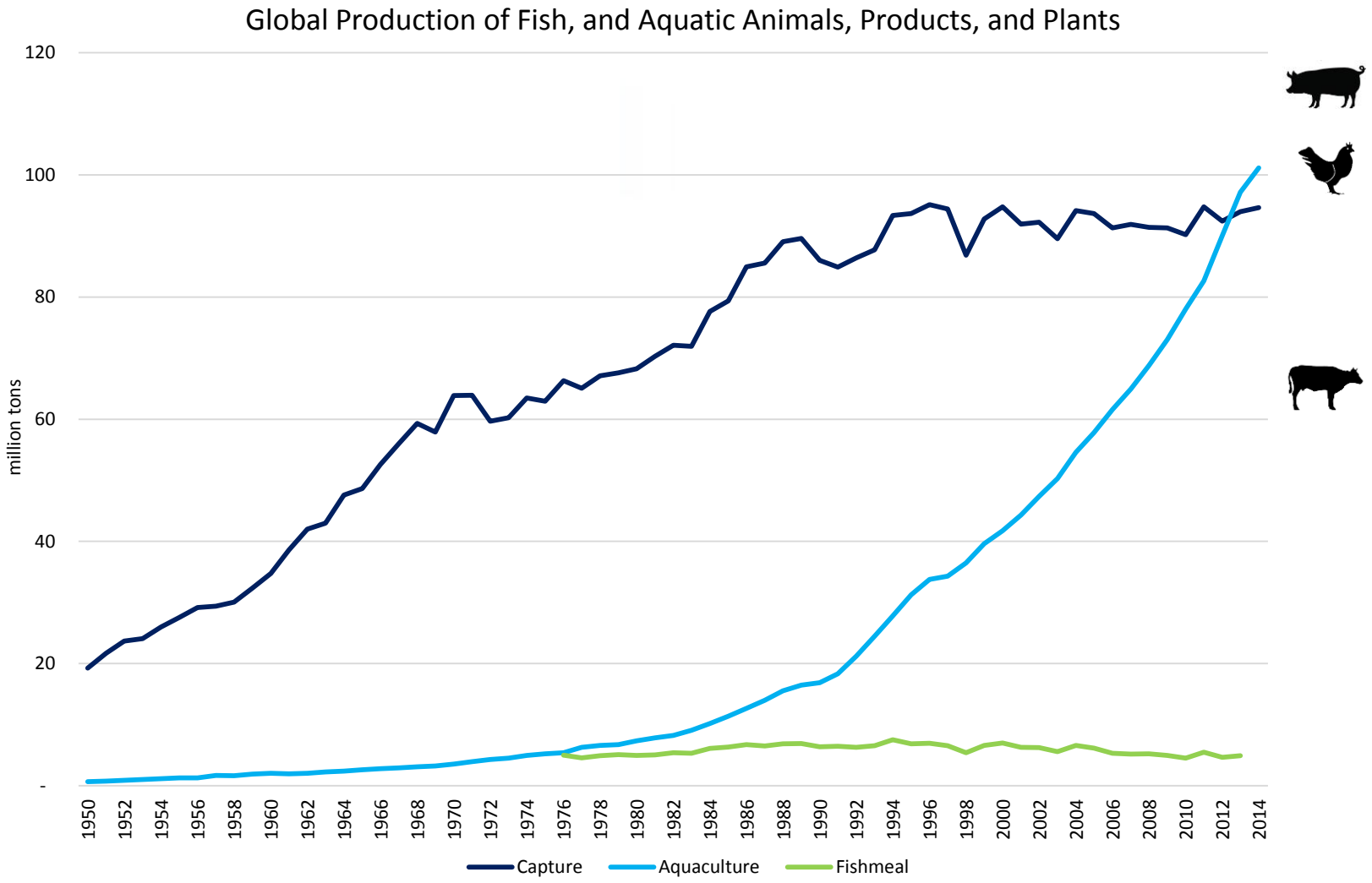
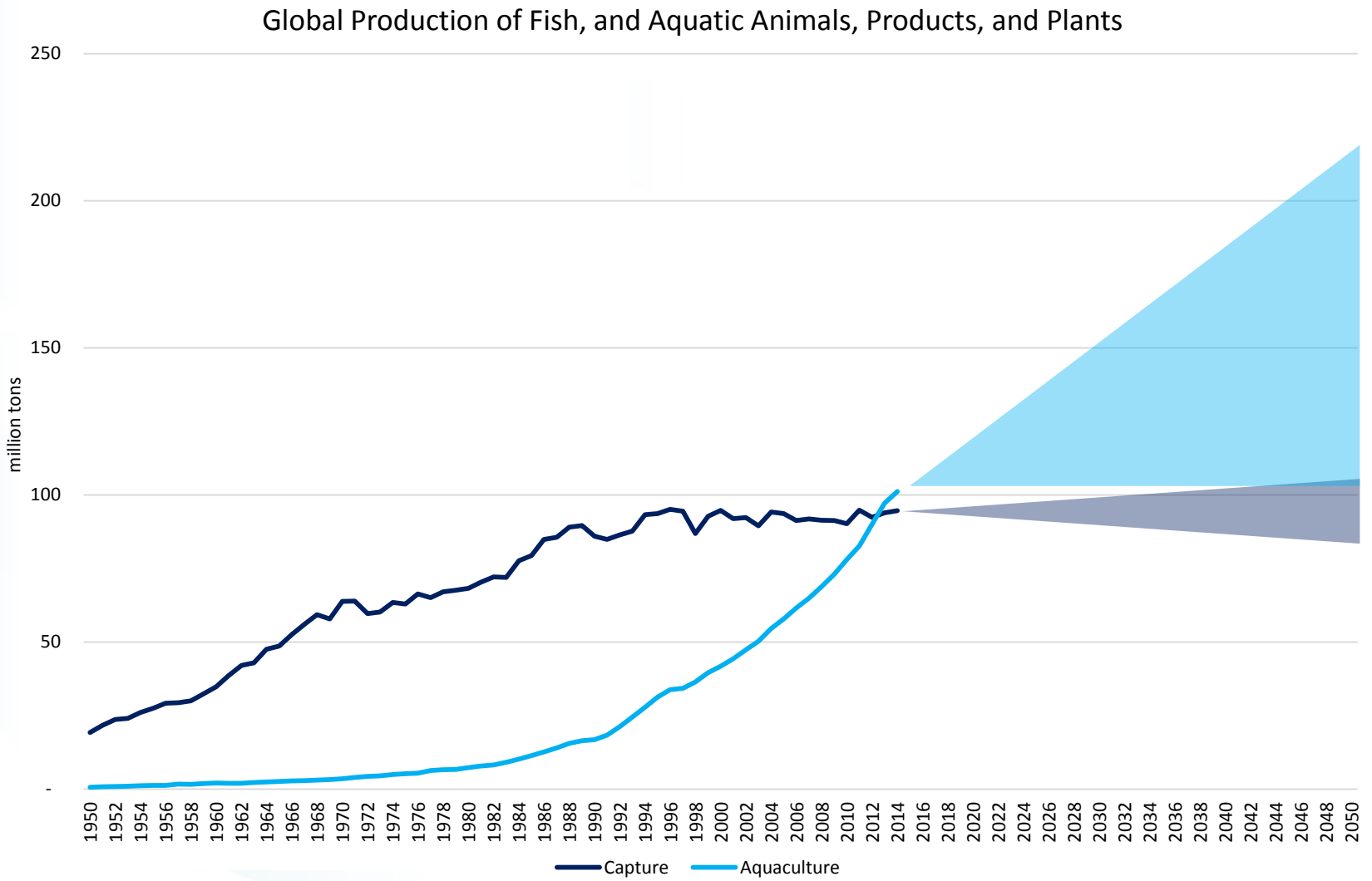
Capture, Aquaculture; Past and Present



Source: FAO Fisheries and Aquaculture Department (2017)

Capture and Aquaculture Outlook(s)



Source: FAO Fisheries and Aquaculture Department (2017) and IIASA

Feed Requirements and Aquaculture Systems Reality

FISH

Production

Feed Requirements

FISH MEAL & OIL

Feed Use

Other Use

Species	System	Feed Conversion Ratio	Feed Composition	Feed Requirement
		X	Y	Z
		A	B	C
		X	X	Z
		X	B	C
		X	Y	Z
		A	Y	C
	Fed	X	Y	Z
	Non-Fed	-	-	-
	Polyculture	X	Y	Z

Feed Requirements and Aquaculture Technological Change

FISH

Production

Feed Requirements

FISH MEAL & OIL

Feed Use

Other Use

Table 4
Estimated global use and demand (thousand tonnes) for fish meal and fish oil within compound aquafeeds 1995–2020

Species-group	Total production[a]	Growth (%/year)[b]	Percent on feeds[c]	Species EFCR[d]	Total feeds used[e]	Mean % fish meal	IFFO % fish meal estimate[f]	Mean % fish oil	IFFO % fish oil estimate	Total fish meal used	IFFO fish meal estimate	Total fish oil used	IFFO fish oil estimate
Shrimp — includes *Penaeus vannamei, P. monodon, P. merguiensis, P. japonicus, P. chinensis, P. indicus, P. stylirostris, Metapenaeus ensis*, etc…													
1995	928	5.2	75	2.0	1392	28	–	2.0	–	389.8	–	27.8	–
1996	917	−1.2	75	2.0	1376	27	–	2.0	–	371.4	–	27.5	–
1997	933	1.7	76	2.0	1418	26	–	2.0	–	368.7	–	28.4	–
1998	999	7.1	78	2.0	1558	26	–	2.0	–	405.2	–	31.2	–
1999	1068	6.9	80	2.0	1709	25	–	2.0	–	427.2	–	34.2	–
2000	1162	8.8	82	2.0	1906	25	25.0	2.0	2.0	476.4	372.0	38.1	30.0
2001	1347	15.9	83	2.0	2236	25	–	2.0	–	559.0	–	44.7	–
2002	1496	11.1	85	1.9	2416	25	24.0	2.0	2.0	604.0	545.0	48.3	45.4
2003	2129	42.3	85	1.9	3438	24	23.0	2.0	2.0	825.2	671.0	68.8	58.3
2004	2446	14.9	86	1.8	3786	24	23.0	2.0	2.0	908.7	738.0	75.7	64.1
2005	2716	9.4	89	1.8	4351	24	20.0	2.0	2.0	1044.2	722.0	87.0	72.2
2006	3164	16.5	92	1.7	4948	20	19.0	2.0	2.0	989.7	723.0	99.0	76.1
2007	3544	12.0	93	1.7	5603	18	19.0	2.0	2.0	1008.6	805.0	112.1	84.7
2010	4717	10.0	95	1.6	7170	12	16.0	2.0	2.0	860.4	823.0	143.4	102.8
2015	6930	8.0	95	1.5	9875	8	–	1.5	–	790.0	–	148.1	–
2020	9274	6.0	95	1.4	12,334	5	–	1.0	–	616.7	–	123.3	–
Chinese carp species (non-filter feeding) — includes *Ctenopharyngodon idellus, Cyprinus carpio, Carassius carassius, Parabramis pekinensis, Mylopharyngodon piceus*													
1995	4924	19.1	20	2.0	1970	10	–	0.0	–	197.0	–	0.0	–
1996	5696	15.7	25	2.0	2848	10	–	0.0	–	284.8	–	0.0	–
1997	6329	11.1	30	2.0	3797	10	–	0.0	–	379.7	–	0.0	–
1998	7010	10.8	35	2.0	4907	10	–	0.0	–	490.7	–	0.0	–
1999	7755	10.6	36	2.0	5584	9	–	0.0	–	502.5	–	0.0	–
2000	8129	4.8	37	2.0	6015	9	5.0	0.0	0.0	541.4	350.0	0.0	0.0
2001	8790	8.1	38	1.9	6346	8	–	0.0	–	507.7	–	0.0	–
2002	9226	5.0	42	1.9	7362	8	5.0	0.0	0.5	589.0	415.0	0.0	41.5
2003	9629	4.4	43	1.9	7867	8	5.0	0.0	0.5	629.4	438.0	0.0	43.8
2004	9423	−2.1	44	1.9	7878	8	5.0	0.0	1.0	630.2	460.0	0.0	91.9
2005	10,026	5.2	45	1.8	8121	8	5.0	0.0	1.0	649.7	480.0	0.0	95.9
2006	10,225	3.1	46	1.8	8466	5	5.0	0.0	1.0	423.3	515.0	0.0	103.0
2007	10,736	5.0	47	1.7	8578	5	4.0	0.0	1.0	428.9	419.0	0.0	104.7
2010	12,429	5.0	50	1.7	10,564	3	4.0	0.0	1.0	316.9	458.0	0.0	114.6
2015	15,862	5.0	55	1.6	13,959	2	–	0.0	–	279.2	–	0.0	–
2020	20,245	5.0	60	1.5	18,220	1	–	0.0	–	182.2	–	0.0	–

Source: Tacon and Metian (2008)