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FISH AS FOOD: PROJECTIONS TO 2020 UNDER DIFFERENT SCENARIOS

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ABSTRACT

This paper reports results of incorporating fish into IMPACT, a global model of food supply and demand that estimates market-clearing prices to 2020 for 32 commodities in 36 regions. It summarizes results for production, consumption, net exports and real price changes for 10 economic categories of fisheries items, disaggregated into 15 geographic regions of the world. Under the medium-variant scenario for the uncertain capture fisheries sectors, global production of food fish is projected to rise by 1.5% annually through 2020, with two-thirds of this from aquaculture, whose share in total food fish production rises to 41%. Global per capita fish consumption is projected to be 17.1 kg in 2020, with sensitivity analysis indicating a margin of 2 kg/capita either way based on extreme scenarios for capture and aquaculture. Most growth will occur in developing countries, which will account for 79% of food fish production in 2020. China's share of world production will continue to expand, while that of Japan, the EU, and former USSR will continue to contract. Real fish prices will rise 4 to 16% by 2020, while meat prices will fall 3%. Fishmeal and oil prices will rise 18%; use of these commodities will increasingly be concentrated in carnivorous aquaculture. Growing domestic demand will dampen fish exports from developing countries. Sensitivity analysis incorporating a very pessimistic view of capture fisheries leads to escalating food fish prices (+69% for high-value finfish) and soaring fishmeal prices (+134%), whereas an optimistic view of increased investment in aquaculture lowers real prices of low value food fish (-12%), and raises fishmeal prices (+42%).

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Siet Meijer,[5] and Mahfuzuddin Ahmed[6]

1. INTRODUCTION

Fish constitutes the fastest growing source of food in the developing world. Fish consumption will have a significant impact on the food security, nutrition, diets, and income of poor people in developing countries during the next two decades. This impact, along with aquaculture's relation to global trade, the environment, public health, and technology, needs to be studied systematically. With capture fisheries stagnating and aquaculture booming, large questions loom about the future of the world's fish supply and the ability of the poor to afford fisheries products. Quantitative simulation of the relation of fisheries to other components of world food supply and prices has not been done at the global level to date. Many of the methodological difficulties inherent in the task were discussed in Delgado and Courbois (2000). The present paper reports results of the projections to 2020 for ten major economic categories of fisheries items, disaggregated into 15 geographic regions of the world.

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[1] An earlier and shorter version of this paper was presented at the biennial meetings of the International Institute of Fisheries Economics and Trade, August 20, 2002, Wellington, New Zealand. A book-length report with much greater detail and analysis of implications for major policy issues is forthcoming.
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One aspect of fisheries that has deterred formal inquiry of this type up to now is the state of data at the global level. All policy analysts wishing to examine the price interactions between disaggregated food sectors at the global level have to use national-level data from FAO, which in turn are based on submissions from national statistical agencies. Fishermen the world over tend to under-report catches, and some governments, particularly in countries where administrative advancement depends on production levels claimed, tend to over-report them. Recent work by ecologists concerned with fisheries, for example, suggests that China in recent years has exaggerated the size of its marine fisheries landings (Watson and Pauly 2001). They suggest that the size of the exaggeration, based on comparison of results from biophysical modeling, may be enough to mask fundamental and negative trends in world fisheries. Although not investigated by Watson and Pauly, the same perverse system of incentives could apply to reporting on aquaculture.

Nonetheless, estimates of world fisheries production also need to be consistent with the best available economic data drawn from a wide variety of independent sources, including trade statistics on fish and fish feeds, micro-studies on fish-feed use and aquaculture production, and household studies of fish consumption. A variety of sources in China, for example, show a rapid rise in fish consumption in the 1990s (Huang *et al.*). This would be consistent with growth in catch. However, detailed household surveys of fish consumption in urban and rural areas that are truly independent of national-level production data have not to our knowledge yet been used to confirm or refute the production estimates. Work at the level of country-specific global food models cannot fully resolve these issues, but it can illustrate the consistency of myriad assumptions and results, or the lack thereof.

To mobilize the resources necessary to model price tradeoffs over the long term among fisheries commodities and between fisheries commodities and other food items, the International Food Policy Research Institute (IFPRI), the World Fish Center (ICLARM), and the Food and Agriculture Organization (FAO), collaborated to incorporate fish into IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) global food model. The project is an attempt to place fisheries issues into broader national and global debates about food and agriculture while providing consistent, quantitative estimates of future fish supply, demand, and trade.

2. MODELING FISH TO 2020 WITHIN A GLOBAL MODEL OF FOOD SUPPLY AND DEMAND

Besides providing a framework for assessing the consistency of assumptions about fish production, feed requirements, consumption, and trade, the main contribution of economics as a discipline to forecasting fishery outcomes is to explicitly allow for the fact that producers, traders, input suppliers, and consumers all react to changes in relative prices, and choose among alternate inputs and outputs--including non-fisheries alternatives-- based on perceptions of changing relative costs and benefits. Thus projections of massive long-term changes in relative prices for specific fisheries items need to be treated with caution, since over time people in the real world are likely to find a better way of achieving their goals as consumers or producers before those massive relative price changes actually occur.

The tool of choice for taking into account the impact of price changes on production, consumption, and trade trends is a supply and demand model that takes differing demand and production outcomes for different commodities and locations into account, and estimates an equilibrium set of prices and trade flows that allow all food markets (including food items used as feeds) in all locations to match local demand with local availability (production plus net trade). Furthermore, the model needs to take into account the main non-price drivers of change, such as changing demographics and income levels. Finally, it should be iterative in the sense that producers, consumers, and traders in the model should have a chance to refine their strategies periodically in light of changing conditions (once a year in the case of a long-term model), as do actors in the real world.

IFPRI's IMPACT model, developed and maintained by a team led by Mark Rosegrant, meets these conditions (Rosegrant *et al*. 2001). IMPACT is specified as a set of country or regional sub-models, within each of which supply, demand, and prices for agricultural commodities are determined. The present version of IMPACT (July 2002) covers 36 countries and regions (which account for virtually all of world food production and consumption), and 22 non-fish commodities, including all cereals, soybeans, roots and tubers, four meats, milk, eggs, oils, oilcakes, meals, sweeteners, fruits, and vegetables. In addition, the new version of the model includes eight categories of fish output (low value finfish such as herring and carp, high value finfish such as salmon and tuna, crustaceans such as prawns and crabs, and mollusks such as clams, oysters, and squid; each distinguished by origin from capture or culture), in addition to fishmeal and fish oil. It collapses aquaculture and capture-produced items on the consumption side to six categories whose supply and demand will produce equilibrium prices: high-value finfish, low-value finfish, crustaceans, mollusks, fishmeal, and fish oil.

The problems involved in going from biologically defined fisheries categories of aggregation (“pelagic”, “demersal”, etc.) to economically defined aggregations (for example, “similar demand and supply elasticities and similar value-to-weight attributes”) are legion. They are explored in Delgado *et al.* (2000), and have been a major impediment to this type of work up to now.

IMPACT uses a system of supply and demand elasticities, different for each of the 36 markets and incorporated into a series of linear and nonlinear equations, to approximate the underlying supply and demand functions. Cross-price elasticities and intermediate demands (such as feed grains for livestock production) ensure the interlinkage of markets within each of the 36 country groupings. Demand within each of the 36 country-group markets is a function of prices, income, and population growth specific to that market. Growth in crop production in each country-group is determined by crop prices and an exogenous rate of productivity growth specific to that group.

Prices are endogenous in the system. Domestic prices consist of world prices modified by country- and commodity-specific price wedges. The effects of country-group specific price policies are expressed in terms of producer subsidy equivalents (PSE), consumer subsidy equivalents (CSE), and marketing margins. PSE and CSE measure the implicit level of taxation or subsidy borne by producers or consumers relative to world prices and account for the wedge between domestic and world prices. Marketing margins reflect factors such as transport costs.

The 36 country-group sub-models for each commodity are interlinked through trade with a separate, unique "world market" for each commodity, a specification that highlights the interdependence of commodity prices across countries and commodities in global agricultural markets. Commodity trade by country-group is the difference between domestic production and excess demand for that commodity in that country-group. Countries with positive trade are net exporters, while those with negative values are net importers. This specification does not permit a separate identification of countries that are both importers and exporters of a particular commodity.

The world price of a commodity is the equilibrating mechanism such that when an exogenous shock is introduced in the model, the world price will adjust and each adjustment is passed back to the effective producer and consumer prices via price transmission equations. Changes in domestic prices subsequently affect commodity supply and demand of the commodity concerned and of complements and substitutes for that commodity, necessitating myriad iterative readjustments for all commodities and regions until world supply and demand balance, and world net trade is again equal to zero. World agricultural commodity prices are thus determined annually at levels that clear world and regional markets.[7]

[7] The model is written in the General Algebraic Modeling System (GAMS) programming language. The solution of the system of equations is achieved by using the Gauss-Seidel algorithm. This procedure minimizes the sum of net trade flows at the international level and seeks a world market price for a commodity that satisfies the market-clearing condition that all country-group level excess demands for a given commodity sum to zero, and that this condition holds simultaneously for all commodities. Technical issues concerning model mechanics are most properly raised with its proprietor, Mark Rosegrant.

3. PROJECTIONS TO 2020 BY GEOGRAPHIC REGION

There is substantial evidence that population numbers and average sizes for many stocks of wild fish have declined over the past century, at least in many traditional fisheries (FAO 2000). However, precise estimates of fish stocks are extraordinarily difficult to calculate, in contrast with the comparatively easier task of estimating global stocks of livestock such as pigs and poultry. This presents a series of problems for geographically disaggregated projections of a number of fisheries commodities. Our approach is to piece together a reasonable but generally conservative scenario for capture fisheries, using exogenous growth rates that represent the extrapolation of recent past trends at declining rates. This scenario is our "baseline;" actual projections in the baseline depend not only on exogenous trend factors, but also on responses across all sectors to endogenous price changes.

It is not necessary to agree with the assumptions of the baseline to derive value from the simulations; the approach is useful for examining the implications of the baseline assumptions for fisheries outcomes when modified over time and across sectors by price-induced changes. The main point of modeling capture fisheries in this effort is to include its relationship with aquaculture through prices and substitution relationships; sensitivity of results to assumptions will be assessed below. We first present the baseline results, which represent our best guess, and define a series of optimistic and pessimistic scenarios for fisheries on either side of it. Table 1 outlines briefly the scenarios reported here.

Table 1— Description of IMPACT projection scenarios
"Baseline": Judged to be most plausible set of assumptions.
"Faster aquaculture expansion": Production growth trends (not including supply response to price change) for all aquaculture commodities increased by 50% relative to baseline.
"Lower China production": Chinese capture fisheries production reduced by 4.6 mmt in base year 1996-98 (Watson and Pauly 2001) and demand was reduced an identical amount. Reductions were spread proportionately among fish commodities. Income demand elasticities, production growth trends, and feed conversion ratios were adjusted downward.
"Fishmeal and oil efficiency": Feed conversion efficiency for fishmeal and fish oil improves at a rate double to that specified in the baseline.
"Slower aquaculture expansion": Production growth trends (not including supply response to price change) for all aquaculture commodities decreased by 50% relative to baseline.
"Ecological collapse": -1% annual growth trends in production (not including supply response to price change) for all capture fisheries commodities, including fishmeal and fish oil.
Note: The exogenous growth trends capture the effects of technological change and other non-price effects.

PRODUCTION

Production levels and trends for food fish from the baseline projections are shown in Table 2. A snapshot of world fisheries in the late 1990s can be derived from the figures in the table. The developed countries accounted for 27 percent of the world's food fish, with the remainder fairly evenly split between China and the rest of the developing world. Worldwide, the share of aquaculture in total food fish in 1996/98 was under 31 percent, but the share in China was over 58 percent, with other developing countries producing 17 percent of their food fish from aquaculture. Low value species accounted for about 48 percent of food fish worldwide, but for only 19 percent in the developed countries. Thus capture fisheries in the late 1990s accounted for more than two-thirds of the world's food fish, China accounted for the large majority of aquaculture, and low value species accounted for just under half the fish used as food.

Table 2 shows a projected growth in total food fish production to 2020 of 40 percent, equivalent to an annual rate of increase of 1.5 percent from 1996/98 onwards. Over two-thirds of this growth is projected to come from aquaculture (not shown in table). Table 2 shows that aquaculture growth trends projected to 2020 are almost twice as high as for capture fisheries in most of the world. China is a notable exception; capture fisheries are projected to grow at 2 percent per annum through 2020 in China, partially in substitution of the fishing effort of other nations. It should be noted that capture fisheries projections in IMPACT are largely influenced by (conservative) assumptions about non-price factors driving capture fisheries[8], whereas aquaculture growth rates are more influenced by relative prices and thus have a higher endogenous component in the modeling.

The picture that emerges of changes to 2020 on the production side for food fish can be summarized into three sets of points. First, the production share of the developing countries rises from 73 percent in 1996/98 to 79 percent in 2020, and about 5 of the 6 percent increase in share is accounted for by China. Second, the share of aquaculture worldwide is projected to increase from 31 to 41 percent in 2020. While China's share of food fish production from aquaculture increases from 59 to 66 percent, other developing countries' share of production from aquaculture increases from 17 to 27

[8] Based on historical trends, other information as available and with changes allowed every five years forward, permitting curvature in forecast exogenous trends, modified annually by price-endogenous factors.

percent, a larger relative change. The share of aquaculture will increase worldwide, but especially in the developing countries, and not just in China. Third, the share of low value fish in total food fish is remarkably stable, at about 48 percent. The overall shares in total food fish production of high and low value finfish capture species fall (by 4 and 6 percent of total production, respectively), but the production shares of low value finfish and (high value) mollusks and crustaceans from aquaculture rise enough by 2020 to compensate for this.

Table 2—Production of total food fish, 1997 (actual) and 2020 (projected)

Region	1997		2020		Annual % growth, 1997-2020	
	('000 mt)	(% from aq.)	('000 mt)	(% from aq.)	(total)	(aquaculture)
China	33,339	58	53,074	66	2.0	2.6
Southeast Asia	12,632	18	17,521	29	1.4	3.6
India	4,768	40	7,985	55	2.3	3.7
Other South Asia	2,056	23	2,999	39	1.7	4.0
Latin America	6,380	10	8,807	16	1.4	3.5
WANA	2,248	9	2,776	16	0.9	3.6
SSA	3,738	1	6,015	2	2.1	5.8
United States	4,423	10	4,927	16	0.5	2.7
Japan	5,188	15	5,172	20	0.0	1.2
EU-15	5,926	21	6,716	29	0.5	2.1
E. Europe & former USSR	4,896	4	5,024	4	0.1	0.4
Other developed	4,761	12	5,779	20	0.8	2.9
Developing world	67,973	37	102,495	47	1.8	2.8
Developing world excl. China	34,634	17	49,421	27	1.6	3.6
Developed world	25,194	13	27,618	19	0.4	2.1
World	93,167	31	130,112	41	1.5	2.8

Sources: 1997 data are three-year averages centered on 1997, calculated from FAOSTAT (2000). Projections for 2020 are from IFPRI's IMPACT model (July 2002

Notes: Growth rates are exponential growth rates compounded annually using three-year averages as endpoints.

AGGREGATE CONSUMPTION AND NET TRADE

Aggregate consumption trends (Table 3) largely mirror production trends in terms of composition and region, except that annual rates of growth of consumption in developing countries outstrip rates of growth of production by 0.2 percent per annum through 2020 (0.3 percent, excluding China), suggesting decreasing net exports of food fish from the developing to the developed countries, driven by increasing domestic demand in the former. Aggregate consumption of both high and low value finfish is increasing rapidly in the developing world, at 2.3 and 1.6 percent respectively, whereas it is static in the developed world. The rates hardly change if China is removed from the calculation, suggesting that this is a widespread structural phenomenon driven by population growth, urbanization, and income growth.

Developing countries went from being net importers of food fish in the mid-1980s (not shown) to significant net exporters in the late 1990s (4 million metric tons (MMT)). As shown in Table 4, India, China, and Latin America are projected to continue net exports in the absolute sense to 2020 (at 0.4, 0.5 and 3.0 MMT, respectively). But among developing regions, only Latin America is projected to export a significant share of total production (net exports from the region are projected to be 35 percent of total production in the region) through 2020. In other developing regions, demand will continue to outstrip growing supply. Whereas net exports of food fish were more than 11 percent of food fish production in developing countries excluding China in the late 1990s, they are projected to be less than 5 percent in 2020.

Table 3—Consumption of total food fish, 1997 (actual) and 2020 (projected)

Region	1997	2020	Annual percent
	(thousand metric tons)		growth (1997-2020)
China	33,151	52,520	2.0
Southeast Asia	11,288	16,736	1.7
India	4,547	7,377	2.1
Other South Asia	1,975	3,154	2.1
Latin America	3,844	5,612	1.7
WANA	2,140	3,223	1.8
SSA	3,704	6,357	2.4
United States	5,352	6,251	0.7
Japan	7,893	7,439	-0.3
EU-15	8,829	8,807	0.0
E. Europe & former USSR	4,385	4,827	0.4
Other developed	1,605	1,870	0.7
Developing world	63,207	98,583	2.0
Developing world excl. China	30,056	46,063	1.9
Developed world	28,064	29,192	0.2
World	91,271	127,776	1.5

Sources: 1997 data are three-year averages centered on 1997, calculated from FAOSTAT (2000). Projections for 2020 are from IFPRI's IMPACT model (July 2002).

Table 4—Net exports of total food fish, 1997 (actual) and 2020 (projected)

Region	1997	2020	Annual percent
	('000 mt)		growth (1997-2020)
China	181	543	5
Southeast Asia	1,131	482	-4
India	122	426	6
Other South Asia	84	-157	-5
Latin America	2,435	3,047	1
WANA	50	-538	-11
SSA	-54	-492	-10
United States	-1,106	-1,528	-1
Japan	-3,112	-2,663	1
EU-15	-3,251	-2,443	1
E. Europe & former USSR	507	189	-4
Other developed	2,919	3,631	1
Developing world	4,045	2,813	-2
Developing world excl. China	3,864	2,270	-2
Developed world	-4,045	-2,813	2

Sources: 1997 data are three-year averages centered on 1997, calculated from FAOSTAT (2000). Projections for 2020 are from IFPRI's IMPACT model (July 2002), baseline scenario.

Notes: (a) Negative numbers indicate net imports.
(b) Growth rates are exponential growth rates compounded annually using three-year averages as endpoints.

SENSITIVITY ANALYSIS: EFFECTS ON PER CAPITA CONSUMPTION IN 2020

The model was re-run under a variety of assumptions. A selection of results is given in Table 5, which illustrates the results in terms of projected per capita food fish consumption in different regions in 2020. The leftmost column is the "most likely" baseline scenario reported above. The scenarios are outlined in Table 1. The direst assumptions about the future of capture fisheries are built into an "ecological collapse" scenario in which the exogenous growth rate of capture fisheries production is set to be –1.0% per year. The latter would have the effect of cutting world capture fisheries production by more than half through 2020 if price factors did not play a part. Yet projected global per capita consumption in 2020 under this scenario only declines to 14.2 kg/capita/year from 17.1 under the baseline. The comparable figure from FAOStat for 1996/98 is 15.7 kg/capita/year. The absence of a larger per capita decline in food fish consumption is due to the sharp price increases under this scenario that slow the decline of production growth in capture fisheries, and induce increased aquaculture output, in addition to reducing demand pressure.

The "Lower China Production" scenario does lead to a 1 kg/capita/year decrease in global projected food fish consumption in 2020, but mostly though its effects on estimated Chinese consumption. In a consistency framework, reducing estimates of China's production implies that either consumption is overestimated to the same extent, or that adjustments should be made to trade statistics. Since the latter are judged to be the most reliable of the three, we have adjusted consumption downwards an amount equivalent to the adjustment in production quantities.

Table 5—Per capita consumption of total food fish under different production scenarios, 2020

Region	Most likely (baseline)	Faster aquaculture growth	Lower China production	Fishmeal and oil efficiency	Slower aquaculture growth	Ecological collapse
			(kg/person/year)			
China	35.9	41.0	30.9	36.1	32.1	30.4
Southeast Asia	25.8	28.5	25.8	26.0	23.7	21.7
India	5.8	6.5	5.8	5.9	5.3	4.8
Other South Asia	6.1	6.8	6.1	6.2	5.6	5.2
Latin America	8.6	9.4	8.6	8.7	7.9	7.3
WANA	6.4	7.1	6.4	6.4	5.8	5.4
SSA	6.6	7.6	6.7	6.7	5.9	5.5
United States	19.7	20.8	19.6	19.8	18.8	15.2
Japan	60.2	63.3	60.0	60.3	57.8	50.9
EU-15	23.7	25.1	23.6	23.8	22.7	18.9
E. Europe & former USSR	11.6	12.0	11.5	11.7	11.3	8.6
Other developed	14.0	14.8	13.9	14.0	13.4	10.9
Developing world	16.2	18.2	15.0	16.3	14.6	13.6
Developing world excl. China	9.9	11.1	10.0	10.0	9.1	8.3
Developed world	21.5	22.6	21.3	21.5	20.6	17.0
World	17.1	19.0	16.1	17.2	15.7	14.2

Sources: Projections for 2020 are from IFPRI's IMPACT model (July 2002). Scenarios are discussed in Table 1.

The plausible scenario that has the most effect on results is the one that modifies IMPACT's conservative assumptions about the rates of technological change and other exogenous factors affecting aquaculture production. A 50 percent increase in the exogenous rates of change in aquaculture production (which, it will be recalled, is modeled primarily to be sensitive to prices) leads to an increase in forecast per capita global consumption of food fish in 2020 of 1.9 kg/capita, an increase of comparable to the declines forecast in the event of even more unfavorable ecological outcomes in capture fisheries than modeled in the baseline. Table 5 shows that the effect is twice as strong in the developing as the developed countries, although significant in both. Not surprisingly, investing in technological change in aquaculture production in a context where global markets set prices in accord with supply and demand will be critical to growing aggregate fisheries output in the future, particularly in the developing countries.

4. THE IMPORTANCE TO FISH PRICES IN 2020 OF THE OUTLOOK FOR AQUACULTURE

Forecast relative price changes are the principal insight offered by global supply and demand models such as IMPACT. The changes that are forecast are devoid of inflation and can be shown as percentage changes over the entire period relative to an actual base level in 1996/98. They provide insights into the net effect of thousands of simultaneous assumptions and parameters, adjusting over time to demographic changes, income growth, technological changes, and to changes in relative prices themselves. The latter occur though substitution effects in both consumption and production.

Consumption effects occur as consumers re-orient their consumption basket to handle price changes. Production effects occur as outputs such as fishmeal, soy, and maize, are affected by changing demands for their use as inputs to livestock products and fish.

Net forecast changes to 2020, relative to baseline price levels, are shown in Table 6. The baseline version of the model projects that long-term real prices will increase for high value finfish and crustaceans on the order of 15 percent total over 1996/98 levels (above any inflationary change). Fishmeal and fish oil prices will increase slightly more, at 18 percent. Mollusks and low value finfish are forecast to have significantly lower but positive real price appreciation (4 and 6 percent respectively). Prices for meat and eggs, on the other hand, are forecast to decline by about 3 percent in real terms, good news for a sector whose real prices are presently only half what they were twenty years ago. Thus fish will become about one-fifth more valuable relative to livestock-derived substitutes by 2020, even taking into account price-motivated substitutions by consumers. On the other hand, fishmeal and fish oil will become slightly more expensive (3 percent) relative to high value finfish, 12 percent more expensive relative to low value finfish, 19 percent more expensive relative to vegetable meals, and 20 percent more expensive relative to poultry. It does not seem far-fetched that fishmeal and oil use will disappear entirely from poultry, livestock, and non-carnivorous aquaculture uses over the next two decades.

The model versions shown in Table 6 illustrate that fishmeal and fish oil prices are likely to shoot up under a variety of possible scenarios. The worst case would be the ecological collapse of capture fisheries, where the direct effect on fishmeal output coupled with the increased demand pressure from aquaculture would more than double current prices in 2020.[9] Even the "faster aquaculture development" scenario would put significant upward pressure on prices of fishmeal, besides hastening its departure from poultry rations. Interestingly, faster growth in aquaculture is associated with further price declines for livestock products, while ecological collapse in marine fisheries is associated with a net increase in real livestock prices by 2020. Both of these effects are due to consumers in the model substituting cheaper sources of animal protein in their diets as relative prices change.

Rapid technological progress in aquaculture embodied in higher fishmeal and oil conversion efficiency is the one scenario that leads to slightly lower real fishmeal prices. This scenario suggests the potentially high returns to the carnivorous aquaculture industry of investing in higher fishmeal and fish oil efficiency.

Finally, "the faster aquaculture investment" scenario is associated with a *decrease* in the projected real prices of low value food fish, despite a significant rise in the price of fishmeal. This is in part a result of model construction where fishmeal demand cannot be met by diverting supply of low value food fish to reduction, reflecting the qualitative literature that shows that different fisheries are involved (New and Wijkstrom 2002). However, the model result also offers the insight that aquaculture supplies a large share of the low value food fish consumed by the poor, and that investing in improving the productivity and sustainability of low value food fish aquaculture is a good way of making it more obtainable by the poor.

[9] A forecast long-term price change of this magnitude is far more significant for analytical purposes than a year-to-year change from a transitory event, such as an El Nino effect, which the system can adjust to over time.

Table 6—Projected total percentage change in prices under different production scenarios, 1997-2020

Commodity	Most likely (baseline)	Faster aquaculture growth	Lower China production	Fishmeal and oil efficiency	Slower aquaculture growth	Ecological collapse
			(percent change)			
High-value finfish	15	9	16	14	19	69
Mollusks	4	-16	3	3	25	26
Crustaceans	16	4	19	15	26	70
Low-value food fish	6	-12	6	5	25	35
Fishmeal	18	42	21	-16	0	134
Fish oil	18	50	18	-5	-4	128
Beef	-3	-5	-3	-4	-2	1
Pigmeat	-3	-4	-2	-3	-1	4
Sheepmeat	-3	-5	-3	-3	-1	2
Poultry meat	-2	-5	-2	-3	0	7
Eggs	-3	-5	-3	-4	-2	3
Milk	-8	-10	-8	-9	-8	-5
Meals	-1	3	0	-7	-4	16

Sources: Projections for 2020 are from IFPRI's IMPACT model (July 2002). Scenarios are discussed in Table 1.

5. CONCLUSIONS: THE CHANGING LOCUS AND MODE OF WORLD FOOD FISH PRODUCTION

A key aspect of “Fish to 2020” is that China’s role in world fisheries issues cannot be ignored. This is analogous to the key role China already plays in global pork and poultry markets. Even discounting China’s production estimates for the late 1990s by 20 percent (an assumption we do not make in the present study), the Chinese share of world fish production has tripled since the early 1970s, as suggested by its growth by a factor of four in Table 7. Sixty-four percent of the increase in Chinese food fish production from 1984/86 to 1996/98 shown in FAOStat originated from aquaculture; the projected share of the increase to 2020 from aquaculture is 80 percent. Even allowing large margins for error, it is clear that the rate of continued aquaculture development in China and its diffusion to other developing countries are the key variables affecting fisheries in all parts of the world.

Although developing countries will continue to dominate world fisheries production in the future (79 percent of world food fish production in 2020, up from 73 percent in 1996/98), it should be noted that developing countries excluding China just manage to preserve their 38 percent global share of production in 2020 in the baseline scenario. China’s gain in share mirrors the loss in share from the industrialized countries, principally Eastern Europe and the former USSR, Japan, and the EU.

The most likely set of assumptions lead to global food fish production increasing slightly faster than global population through 2020. Despite this, real fish prices are expected to rise from 4 to 16 percent, depending on the commodity, while livestock product prices will decline on the order of 3 percent. Low value food fish will continue to account for a fairly constant share of 48 percent of total food fish through 2020. Aquaculture's share of aggregate finfish production will increase from 31 to 41 percent. Global increases in consumption of food fish will predominantly take place in the developing countries, where population is growing and higher incomes are allowing purchase of high value fisheries items for the first time by many people. Fishmeal and fish oil will become progressively more expensive relative to substitutes in the feeding of livestock and non-carnivorous fish. It is to be anticipated that these commodities will exit from the rations of animals other than carnivorous fish, and that fishmeal prices will become progressively de-linked from vegetable feed alternatives, such as soy meal. Historically, such de-linkage has only been transitory, at least through 1998 (Asche and Tveteras 2000).

Sensitivity analysis suggests that the key outcome for the future of fish prices, including the price of low value food fish to the poor, is the successful development and extension of sustainable aquaculture. A poverty focus would suggest concentrating on aquaculture in developing countries that produces low value food fish. However, the rosy outlook for high value aquaculture items such as crustaceans and mollusks in developing country urban markets also suggests the importance of finding ways to keep poor fishers involved in these key sectors. Finally, several of our scenarios suggest significant increases in the relative prices of fishmeal. At some point, the "trash fish" of the poor may begin to be fed to fish; pro-poor policies will focus on the aquaculture technology investments that can reduce this possibility.

Table 7—Regional shares of total food fish production, 1973-1997 (actual) and 2020 (projected)

Region	1973	1985	1997	2020
		(percent of world total)		
China	10	13	36	41
Southeast Asia	11	12	14	13
India	4	4	5	6
Other South Asia	2	2	2	2
Latin America	5	6	7	7
WANA	1	2	2	2
SSA	4	4	4	5
United States	4	6	5	4
Japan	17	14	6	4
EU-15	13	9	6	5
E. Europe & former USSR	17	14	5	4
Other developed	6	6	5	4
Developing world	44	51	73	79
Developing world excl. China	33	38	37	38
Developed world	56	49	27	21

Sources: Data for 1973-1997 are three-year averages centered on years shown, calculated from FAOSTAT (2000). Projections are from IFPRI's IMPACT model (July 2002), baseline scenario.

REFERENCES

Asche, F. and S. Tveteras. 2000. On the relationship between aquaculture and reduction fisheries. *in Microbehavior and Macroresults: Proceedings of the Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade*, Corvallis, Oregon USA, July 10-14 (CD-ROM).

Delgado, C.L. *et al*. 2000. Issues in modeling fish to 2020 within a global food model. in *Microbehavior and Macroresults: Proceedings of the Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade*, Corvallis, Oregon USA, July 10-14 (CD-ROM).

Huang, J., S. Rozelle, and M. Rosegrant. 1999. China's food economy to the twenty-first century: Supply, demand, and trade. *Economic Development and Cultural Change* 47: 737-766.

New, M. B. and U. N. Wijkstrom. 2002. *Use of fishmeal and fish oil in aquafeeds: Further thoughts on the fishmeal trap*. FAO Fisheries Circular No. 975. Rome: Food and Agriculture Organization of the United Nations.

Rosegrant, M. *et al.* 2001. *Global Food Projections to 2020.* 2002. 2020 Vision Initiative Book Series, Washington, D.C.: International Food Policy Research Institute.

Watson, R. and D. Pauly. 2001. Systematic distortions in world fisheries catch trends. *Nature* 414: 534-536.

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