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Valuing seafood: The Peruvian fisheries sector ☆

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ABSTRACT

There are tradeoffs in managing fisheries, and ideally such tradeoffs should be known when setting fisheries policies. An aspect of this, which is rarely considered, is the spin-off effect of different fisheries: the economic and social benefits that fisheries generate through processing through distribution and on to the end consumer. This study evaluated the benefits generated in the Peruvian marine fisheries sector through a comprehensive value chain analysis, based on a newly-developed combined ecosystem-economic modeling approach, which was integrated in the widely-used Ecopath with Ecosim approach and software. The value chain was parameterized by extensive data collection through 35 enterprise types covering the marine fisheries sector in Peru, including the world's biggest single-species fishery for anchoveta. While anchoveta is what is known about Peruvian fisheries, the study finds that anchoveta accounts for only 31% of the sector contribution to GDP and for only 23% of the employment. Thus, while anchoveta indeed is the fundamental fish species in the Peruvian ecosystem, there are other fisheries to be considered for management. The study indicates that the economic multipliers for Peruvian fisheries were 2.9 on average over the industry, and that these varied surprisingly little between fleets and between seafood categories indicating that the multipliers can be used beyond Peru to generalize the spin-off effect of the value chain. Employment multipliers vary much more across types of fisheries, but also around an average of 2.9; here it was clear that longer value chains result in more employment.

1. Introduction

Peruvians love seafood, and this is nothing new. In 1908 at the 4th International Fishery Congress in Washington DC, Dr Robert E. Coker, Fishery Expert to the Government of Peru, described the Peruvian fisheries, and stated “no people could be more highly or more generally appreciative of fish food” [1]. Dr Coker's description is one of highly diverse fisheries and, as he expressed it, “[d]oubtless the fishes and the fishery resources of no country represented at this congress are less known to the world than are those of Peru.”

As can be expected, anchoveta (*Engraulis ringens*, Peruvian anchovy), the central species in the world's most productive ecosystem formed part of Coker's description. “[S]triking … are the immense schools of small fishes, the “anchobetas“ (*Engraulis ringens* Jenyns), which are followed by numbers of bonitos and other fishes and by sea lions, while at the same time they are preyed upon by the flocks of cormorants, pelicans, gannets, and other abundant sea birds. It is these birds, however, that offer the most impressive sight. The long files of pelicans, the low-moving black clouds of cormorants, or the rain-storms of plunging gannets probably can not be equaled in any other part of the world. These birds feed chiefly, almost exclusively, upon the anchobetas. The anchobeta, then, is not only an article of diet to a large number of Peruvians, and the food of the larger fishes, but, as the food of the birds, it is the source from which is derived each year probably a score of thousands of tons of high-grade bird guano. It is therefore to be regarded as the most valuable resource of the waters of Peru.”

Anchoveta fisheries were at the time, i.e. a century ago, minor, though “[t]he anchobetas (*Engraulis*) are favored by the indigenous Peruvians. Large quantities are preserved in the crudest way by mixing with salt and spreading on the ground to dry in the sun.” Dr Coker, though, raised “a very significant practical question to what extent Peru should continue to depend upon the birds for the production of nitrogenous guano, or whether the direct manufacture of fertilizer from the fishes should be undertaken in order to supplement the present available supply.”

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Peru did make this change, encouraged by optimistic estimates of sustainable yield for anchoveta [1,2], to develop the world's largest single-species fishery of the industrial era with catches of 285 million tons during 1950–2006 [3]. As can be expected, anchoveta fishery has become what is known to the world about Peruvian fisheries, but there is far more to Peruvian fisheries than anchoveta.

Peruvians, as express by Coker, love seafood – there are more than 12,000 ‘cevicherias’ in Lima alone, to illustrate this. The contributions these and other parts of the more informal fisheries sector make to the economy of Peru is not well accounted for in the official economy, which at present is focused on the industrial fisheries and fisheries exports.

Peru is one of the world's fastest growing economies with the 2011 GDP estimated to be US$177 billion (B), doubling in only six years as reported by the World Bank [4]. FAO evaluated the fisheries GDP to be US$0.6B in 2005, while the gross value of the fisheries exports were estimated to US$2.4B in 2008 [5]. The contribution of the fisheries sector to the GDP has, however, up to now been based on export values with very little or no consideration for the value of the seafood production that is consumed within Peru. This is especially important for the small-scale fisheries sector [6].

Similarly, the employment in the fisheries sector (including aquaculture) was estimated to be 121,123 jobs in 2007 for the primary sector with an additional 24,109 employed in the secondary sector for a total of just over 145,000 jobs [5]. These estimates include employment in marine and freshwater fisheries as well as in aquaculture production, and they include part-time employees (not corrected for part time employment). The employment estimates are focused on the more industrialized fisheries and processing parts of the industry, and do not cover the more informal part of the sector or secondary employment, such as in, e.g., retail.

Through this study, it is intended to change the general perception that Peruvian fisheries are all about anchoveta. This is done by bottom-up derived estimation of the contribution that the entire marine fisheries sector makes to the Peruvian economy and society. The findings are important to set the stage for evaluating trade-offs in management as individual fisheries impact not just their target species, but, through food web interactions, also fish stocks targeted by other fisheries [7].

2. Methods

The value chain module of the Ecopath with Ecosim (EwE) software system [8] as developed by Christensen et al. [9] served as the structuring element for the analysis. The value chain module was used to describe the flow of seafood products from

Table 1
Production (t), revenue (10^3 US$), cost ($10^3$ US$), and employment for 2009 by Peruvian fisheries sector enterprise types. ‘F’ is producer (fishing fleet), ‘P’ is processor, ‘D’ is distributor, ‘W’ is wholesaler, ‘R’ is retailer, ‘C’ is consumer, and ‘B’ is broker. ‘art’ is artisanal, ‘dom’ is domestic, ‘dist’ is distributors, ‘ind’ is industrial.

Name	Type	Production	Revenue	Cost	Jobs		
					Female	Male	Total
Steel purse seiners	F	5,043,916	683,444	514,984	–	10,744	10,744
Fishmeal plants	P	1,617,497	1,675,995	1,136,332	751	11,799	12,550
Wooden purse seiners	F	939,588	115,356	86,226	–	6361	6361
Artisanal purse seiners	F	494,893	199,012	102,711	–	10,353	10,353
Freezing plants	P	439,851	810,063	663,176	8305	9961	18,267
Squid boats	F	414,016	171,817	57,556	–	8496	8496
Middlemen freezing	D	352,312	307,716	263,402	95	377	472
Fresh seafood	W	308,080	558,106	468,971	1031	4943	5974
Local markets	R	302,998	979,569	699,932	7790	5193	12,983
Canning plants	P	191,177	248,965	155,112	8480	7583	16,063
Fishmeal exporters	D,B	141,639	708	234	10	10	20
Fishmeal residues	P	136,585	148,266	63,217	48	556	604
Fish restaurants	R	85,399	889,020	663,144	46,615	35,079	81,694
Longliners	F	65,839	95,441	61,881	–	6575	6575
Gillnets	F	47,333	61,185	36,849	–	14,893	14,893
Trawlers	F	43,984	64,532	25,758	–	1534	1534
Compressed air divers	F	37,198	97,668	40,745		7124	7124
Dom dist canned	D	30,166	121,049	102,763		175	184
Supermarkets	R	29,177	165,677	90,940	324	294	618
Fish oil exporters	D,B	26,782	134	63	2	2	4
Agrorural	F	20,213	7099	7099	10	413	423
Dom dist frozen	D	17,652	76,774	71,344	7	157	164
Semi-intensive aquaculture	F	16,047	58,604	45,974	–	4132	4132
Shore fishers	F	13,993	18,997	6963	–	1900	1900
Intensive aquaculture	F	13,425	122,570	49,545	–	2359	2359
Hook and lines	F	12,739	16,442	10,725	–	4200	4200
Middlemen canning	D	11,459	15,778	11,774	6	23	28
Traps	F	11,104	16,491	5159	–	367	367
Ind curing	P	9772	26,579	13,208	1875	640	2515
Frozen wholesaler	W	9002	45,282	38,810	52	234	285
Artisanal curing	P	3450	13,370	8815	162	176	338
Dom dist art cured	D	3450	15,375	13,679	–	76	76
Macroalgae drying	P	1561	12,955	8020	12	41	53
Guano exporters	D,B	1440	783	535	1	2	3
Dom dist cured	D	519	7890	2649	–	3	3
Rural farmer	C	–	–	–	–	–	–
Other sectors	C	–	–	–	–	–	–
Pronaa	C	–	–	–	–	–	–
Peruvians	C	–	–	–	–	–	–
Foreign markets	C	–	–	–	–	–	–

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fishing fleets through the various enterprises of the fisheries sector and on through to the ultimate consumer. For each step this involved an evaluation of the revenue, cost, employment, and salaries per unit weight of production, in order to obtain overall estimates for contribution of the entire fisheries sector to the economy of and employment in Peru. The study was based on information about the fisheries sector collected for 2009 or averaged over the period 2009–2012.

Metric ton (t) of fish was used as the fundamental unit throughout the analysis. Employment was estimated based on the number of people employed per t processed per day, scaled to annual employment based on annual production figures. All revenue and cost figures were expressed in US$.

The first step of the value chain analysis was to define the various enterprises that form part of the sector, (see Table 1 for an overview). For each enterprise, the revenue, cost of operation, and employment was then evaluated in considerable detail.

A data file with the combined ecosystem model and value chain data is available on request from the corresponding author.

2.1. Fish landings

All estimates for landings, processing (seafood input destined for reduction, curing, freezing, and canning, as well as output), internal consumption (by type of product; e.g., cans of fish, fresh fish) and exports (by product) were obtained from the official statistics of the Peruvian Ministry of Production (PRODUCE).

Landings per fishing gear/fleet were reconstructed from the official data of Instituto del Mar del Perú (IMARPE) data for the artisanal fleets, and the official data from PRODUCE data for the industrial fleets.

2.2. Employment

2.2.1. Producers

The number of fishers was estimated as the product of the number of vessels per fleet and the average crew size. The number of vessels was obtained from PRODUCE, IMARPE, and Estrella et al. [10]. The average crew size was estimated based on: (i) interviews with artisanal fishermen ($n=60$) and vessel owners ($n=25$) along the coast; (ii) direct observations; and (iii) literature including, Alfaro-Shigueto et al. [11] and Estrella et al. [10]. Gender ratios for all enterprises was based on direct observations.

In order to estimate employment in fishmeal and fish oil processing plants, the number of factories that were operating in 2009 were divided in four groups based on processing capacity. The number of people employed in each group was estimated using information gathered in interviews with fishmeal entrepreneurs, fishmeal plant owners and workers, and other key informants. Large plants (>70 t/h) on the average employed 119 people (including surveillance staff, secretary, operators, etc.), medium large plants (30–70 t/h) employed 94 people, medium plants (10–30 t/h) employed 74 people, and small plants (0–10 t/h) employed 20 people. Residual fishmeal plants were included with the smallest subset.

Employment at plants that process fish for direct human consumption was estimated based on (i) visits to the plants of different types [freezing ($n=5$), canning ($n=4$), industrial curing ($n=2$) and artisanal curing ($n=3$)] and locations along the Peruvian coast (Piura to Ica – no plants were visited in Tumbes, Arequipa, Moquegua and Tacna); (ii) structured interviews with company owners and other key informants ($n=15$); (iii) the number of plants working in 2009 (PRODUCE official data); and (iv) the volume of fish processed and produced per plant and per type of plant (PRODUCE official data). It is important to note that plant-processing capacity for direct human consumption is not necessarily a good indicator of the size of the plant in terms of employment, as it is the case for reduction fisheries.

Employment in the guano industry was derived from interviews with staff at the Programa de Desarrollo Productivo Agrario Rural (AGRORURAL) of the Peruvian Ministry of Agriculture, and site visits to Punta San Juan and Balletas Islands during guano extraction. The limiting factors for extraction are in the short term more related to logistic and operational capacities rather than guano production, the anchoveta biomass, or others. Based on this it was estimated that a total number of 250 people were employed during the extractive phase of the process. An additional 50 people were employed with other aspects of this guano processing, which also takes place at the extraction sites.

For aquaculture, only mariculture was considered, and employment was estimated based on the assumption that scallops were produced in semi-intensive systems and that shrimps were produced in intensive systems. Estimates of employment per hectare for scallops were obtained from Alcazar and Mendo [12] and for shrimp from Berger et al. [13]. The total number of scallops and shrimp aquaculture concessions on the coast was obtained from official PRODUCE data, and from the same source also the total 2009 aquaculture production of these species in Peru. The total number of people employed per ton was then calculated from the total number of tons produced per hectare.

2.2.2. Distribution

In Peru, seafood is either landed at the beach, at docks and piers, or directly to processing plants. Seafood landed directly at beaches and taken to homes, restaurants, or local markets are not accounted for in the landing statistics of PRODUCE or IMARPE. There are therefore no estimates for them for 2009, and they are not included in the calculations. An estimate for 2012–2113 (unpublished study) of these landings amounts to around 8–10% of the reported landings for direct human consumption, but was not considered in the present study. By not including the beach landings, the overall employment in the present study is likely to be underestimated.

Information was obtained from Fondo Nacional de Desarrollo Pesquero (FONDEPES), IMARPE, PRODUCE and the various Direcciones Regionales de la Producción (DIREPRO) for all seafood-landing places with piers and docks in Peru with official monitoring by the government. From this, the employment was estimated based on (i) the total number of landing sites; (ii) their size; (iii) the amount of seafood landed; and (iv) the destination of the landed seafood (fresh markets, curing facilities, canning plants, etc.) Places with little to no infrastructure only employ people that take the seafood from the vessel and load it into trucks. Places with more infrastructure also employ cleaning staff, secretaries, administrative staff, surveillance staff, operators, etc. Employment by productive destination (canning, freezing, curing, fresh, etc.) was estimated based on the total number of people employed and the percentage of the overall landings that went to each productive process. As an example, if 30% of the landings went to curing plants, it was assumed that they employed 30% of the people working there. Fish is transported from the vessel to the truck using ‘landing squads’, and it was assumed based on direct observations and Clemente [14] that landing squads consist of 10 people.

The canning and freezing industries in addition to direct landings at the plants obtain seafood from other landing sites through intermediaries. The total number of intermediaries was estimated based on interviews and observations, and the number of plants per productive process and their locations.

Some freezing and canning plants use landing barges with pumping systems to transport the fish directly from the vessels' holding area to the plants' storage containers. These were not included in the calculations, as fish landed directly at the plants does not employ additional personnel (employment is already considered in the processing segment).

2.2.3. Seafood transport

Employment in the seafood transport sector was estimated based on standardized truck units, in terms of capacity (tonnage), productive process, and the resources that they transport. The number of trips per year was based on interviews with truck drivers and company owners and divided by the volume of fish transported by the trucks per productive process. From this was obtained, the number of trucks required to move the fish per productive process. Moreover, it was assumed (based on interviews) that each truck employed one driver and that in 20% of the cases they had a helper or copilot.

Employment in transport of seafood from landing site to wholesalers was included with the wholesaler employment. For this, it was assumed that the combined employment in the major wholesale markets of Ventanilla (Callao), Villa María del Triunfo (Lima) and Santa Rosa (Chiclayo) account for 50% of the total employment (as well as for the amount of seafood marketed) at fresh seafood wholesale markets in Peru. Site visits to the wholesale markets in Lima, Callao, and Chiclayo were conducted regularly throughout this study to estimate employment, and interview staff, supervisors, and managers. This information was complemented through the study of Clemente (2009), from which it was obtained that each wholesaler had one or more trucks, and that each truck employed 4 people for the sale. This employment was added to a total pool of people in cleaning, surveillance, administration, transportation (stevedores), and quality controls, among others. For each site visit, the number of people working was counted, and that number was used as denominator to the total volume of fish (tons) that was marketed on the given day based on official PRODUCE data. From this the total employment per ton was obtained.

2.2.4. Distribution of products

People employed to export products from fishing plants were included in the staff of the plants (for instance for fishmeal and fish oil plants). In the case of reduction fisheries, only a very small amount of the overall production was exported using brokers. In this case, a broker only employed a secretary. The same was true for guano exporters. The export by such brokers was estimated, and from this the employment per t of product as well as their fees per t of product.

Similar calculations were made for the distribution of seafood products such as artisanally cured products, cured products, frozen products, and cans.

Further, official PRODUCE data was used for local consumption of marine fish and invertebrates for 2009. Using 'typical truck' units based on capacity (tonnage), the products they transport, and the distance traveled, the total number of trips per year per truck (based on interviews with truck drivers and company owners) and the volume of fish transported by the trucks per productive process, gave the number of trucks required to move the products per productive process to their destination. It was assumed that each truck employed one driver and that in 20% of the cases they had a helper or copilot. When transporting cans and cured products, trucks are rarely filled only with one product, (e.g., also with other cans, milk, juices, eggs, or beans), but for the calculation of the total employment per ton transported it was assumed that only fish were transported. In the calculations, the office and administrative staff for the companies that distribute cured, canned, and frozen products across Peru was also considered. These were estimated from interviews.

For the frozen seafood wholesalers, the total amount of frozen seafood that was not distributed to local markets throughout Peru, (which mainly is to the highlands) was estimated. People who buy products from freezing plants and domestic distributer's storage facilities and transport them to frozen wholesaler markets were also considered, as were people who sell products at the frozen wholesaler markets, including administrative and surveillance staff. The employment per ton was obtained from the ratio of the total number of tons sold at the market and the total employment.

2.2.5. Retailers

The total number of people employed with seafood in fish restaurants in Peru was obtained by first excluding all restaurants that were selling other products than seafood. Seafood thus had to be the only source of animal protein sold in a restaurant for it to be included. This means that employment in this sector was underestimated significantly, as many (or most) restaurants sell seafood as only a component of their assortment. The total number of seafood restaurants was obtained from Ipsos Apoyo [15] and Arellano Marketing [16], and the restaurants were ranked in terms of size (number of tables). Based on this, 'typical restaurants' were defined with a fixed number of employees per restaurant size. From field observations and interviews with members of the Peruvian Gastronomic Association (APEGA) and restaurant owners, the 'typical consumption of fish' per fish restaurant was then derived, and via a weighted average estimated the overall employment per ton of seafood sold. All types of jobs in the restaurants were considered – from waiters to security guards.

The total number of supermarkets across Peru in 2009 was obtained from official web pages and by interviews with brand managers in Lima (Supermercados Peruanos, Wong, and TOTUS). It was assumed that there were 1–2 people employed full time in the fresh fish section (depending on the supermarket brand and size) and that there were 1–2 people employed full time arranging and selling canned, cured, and frozen fish products in each supermarket, as well as 1–2 people involved with storing and distributing fish to the supermarkets from the wholesaler markets. Although many of the people that are employed in supermarkets move, organize and sell fish products at any given time, only a minor fraction of their salaries come from this exchange. Therefore, the employment per ton of seafood sold, was estimated based on the number of full time jobs per ton rather than fractions of a job per ton. Supermarket employees validated these numbers.

The total number of local retail markets (whether organized by a municipality, district, privately, or publicly) was enumerated in 1996 [17] and here extrapolated to account for their growth, assuming an overall increase of 10% by 2009. Based on field observations, it was estimated that 20 percentage of stands sold fresh fish out of the total number of stands at markets at the coast, highlands, and jungle. It was also assumed (based on observations and interviews) that 80% of the fresh seafood was sold commercially through local markets at the coast and that the remaining 20% was sold commercially in the highlands and jungle. Freshwater fish (both wild caught and aquaculture produced) is significantly more frequent in the Andean and Amazonian markets as compared to seafood, and this was considered in the calculations, though only marine products are included in the results here. Estimates of the total number of stores (small scale bodegas, etc.) throughout the coast was also obtained [15], and the proportion of their revenue that comes from selling canned fish was estimated. These estimates were pooled to obtain the total number of people employed per ton of seafood in the local markets.

2.2.6. Consumers

Peruvians, and foreign markets were considered end consumers in the study, and these did therefore not include employment or cost of operation. Similarly, rural farmers, other sectors, and the national food security program, El Programa Nacional de Asistencia Alimentaria (Pronaa), were also considered end consumers, and there is therefore no account of the derived benefits from the use of fish products from these groups, including of the employment they provide.

2.3. Cost of operation

Cost structures were reconstructed from structured interviews of key stakeholders involved with each step of the value chain. Some cost structures for the industrial anchoveta fleet were updated and developed based on estimates in De la Puente et al. [18] and calculations for the artisanal fleet were updated based on estimates in Estrella et al. [10], Alfaro-Shigueto et al. [11]; Estrella and Swartzman [19]. The majority of the cost estimates, however, came from interviews and fieldwork that were undertaken as part of the present study.

Included import taxes for materials (e.g., tin cans) were not considered, nor were value added taxes in the costs. This is to some extent countered by not considering the export subsidies that enterprises may get to compensate for the import taxes they have paid.

2.4. Contribution to GDP

The contribution of the fisheries sector to the Gross Domestic Product (GDP) of Peru was estimated based on the income approach [20] by evaluating the following sum for each enterprise type in the fisheries sector as well as for each seafood commodity,

$$GDP = C_e + I_p + C_t + C_o - I_s \quad (1)$$

where C_e is the total cost of compensations, I_p is the gross operating profit, C_t is total taxes, C_o cost for management, royalties, certification, and monitoring, and I_s is the income from subsidies.

2.5. Relationship to ecological model

The value chain module used here is coupled with the Ecopath and Ecosim (EwE) modeling framework, but does not rely on the EwE models for parameterization [9] apart from obtaining the landings and fleet structure from the underlying Ecopath model (and these could in principle be entered independently of the Ecopath model). All other information that was needed to develop the value chain analysis as presented in this contribution was thus derived independently of the underlying ecosystem model. The coupling with the EwE models, however, enables evaluation of the full value chain analysis as part of mass-balance modeling [21], time-dynamic simulations [22], policy optimizations [7], spatial optimizations [23], management strategy evaluations, and other analysis where social and economic factors are considered.

It is important to stress that the present study does not rely on any assumptions in the underlying Ecopath model, only in the estimates for landings and the fleet structure. The power of the coupling with the ecological model really comes from the ability to make optimization studies that builds on the entire value chain and social parameters. This makes it possible to go beyond studies that only include the primary sector in optimizations, and it also facilitates studies to evaluate fishing policies that are robust to environmental variability or climate change based on the entire fisheries sector performance.

2.6. Flow diagrams

Food webs are traditionally depicted as symbol plots with lines representing energy flows between components [24]. On such plots, the symbols representing functional groups are placed after trophic levels on one axis, so that producers and detritus groups are placed at the first trophic level, and consumers after their respective trophic levels. A similar way of depicting revenue and employment flow charts was developed for this study, where the 'trophic level' (*TL*) of any enterprise (*i*) is estimated as,

$$TLi = 1 + \sum j(TLj \cdots Iij) \quad (2)$$

where I_{ij} represents the fraction of the input of fish products to enterprise (*i*) that comes from enterprise (*j*). Producers, i.e. fishing fleets, do not have any input from other enterprises and are thus placed at *TL* 1. The *TL*s obtained this way are fractional trophic levels [25], so that, e.g., a processor that obtain half of its input from a producer (*TL* 1) and the other half from another processor (*TL* 2) will be placed at *TL* 2.5.

The size of the symbols was used to represent the total revenue or employment for a given enterprise in each flow chart. The sizes of the symbols were calculated as three-dimensional spheres with the volume being proportional to total revenue or employment by enterprise. For practical reasons, the spheres were presented here as two-dimensional circles; the third dimension will have to be imagined. The flow charts were constructed using the value chain module of EwE based on a new routine developed for this study.

3. Results

Anchoveta is the target for the world's largest single-species fishery, and is the focal species for the fisheries sector as well as in the Peruvian upwelling ecosystem. The importance for the fisheries is clear from the total landings during 1950–2006 where anchoveta contributed 80% of Peruvian landings [3], or from the numbers for 2009 as considered here where anchoveta contributed 87% of the total by weight.

In the fishing industry, anchoveta is mainly used for production of fishmeal and fish oil, though the part of the landings that are used for direct human consumption has increased in recent years, as discussed later. But anchoveta also plays an important role as forage basis for the higher trophic levels in the ecosystem – as discussed by Coker [1], and many others later e.g., [26,27].

3.1. Follow the money

For each enterprise type in the Peruvian fisheries sector, the production, revenue, cost and employment were estimated as described above and based on this the results shown in Table 1 were obtained. The largest enterprise type by production as well as by revenue comes from production of fishmeal and fish oil, which predominantly is based on processing of anchoveta. The revenue for these enterprises was estimated to US$ 1.7B, or 21% of the total revenue in the fisheries sector (Table 1). Yet, when comparing to local markets and fish restaurants, the revenue from these enterprise types combined exceeds the value from fishmeal and fish oil production, indicating the importance of the part of the sector that caters to seafood consumption.

The flow charts in this study each present, in one clear depiction, a very rare overview of the revenue and employment in an entire fisheries sector of a country. The revenue plot (Fig. 1) shows how the fishmeal plants are the biggest single enterprise type in the sector but also highlights the importance of the fish restaurants and the local markets. This is even more pronounced when examining the employment patterns in the sector where the fish restaurants are the dominant employer type followed by freezing and canning plants (Fig. 2).

The flow charts have enterprise types arranged after 'trophic levels' (TLs) on the vertical axis. Producers (fishing fleets) are

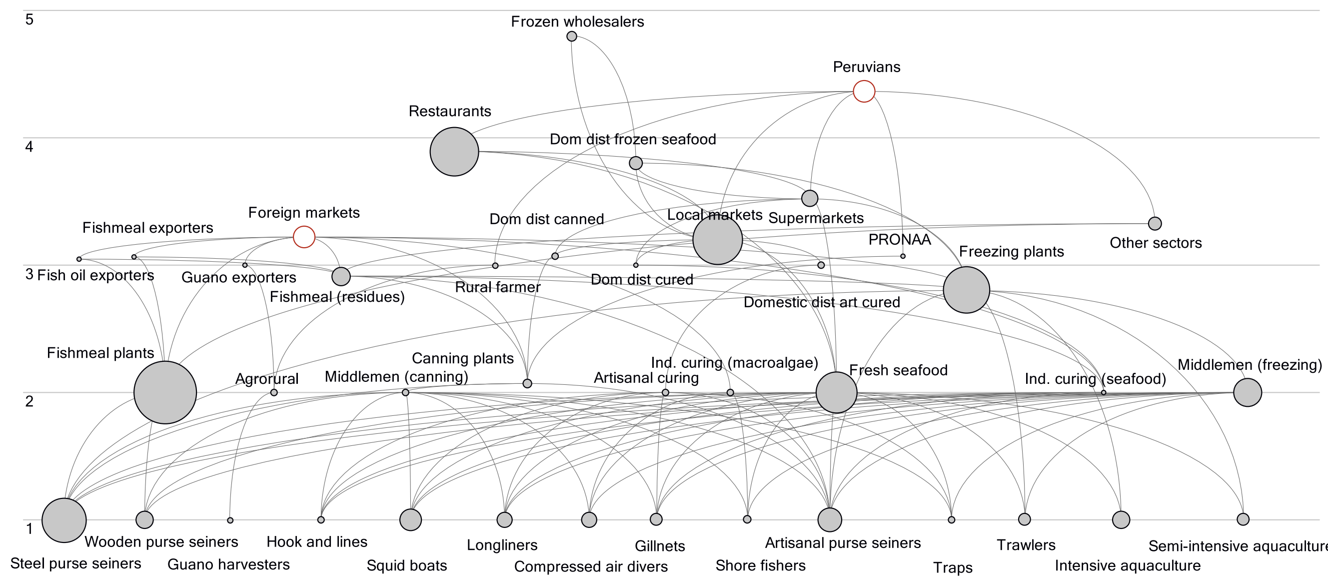

Fig. 1. Revenue by enterprise types in the Peruvian fisheries sector. The volume of each node is calculated as a 3-dimensional sphere and is relative between enterprise types. Open circles indicate end consumers for which there is no revenue. The enterprises are arranged after 'trophic levels' (*TLs*) on the vertical axis. *TLs* increase with one each time a product is passed on through the production chain.

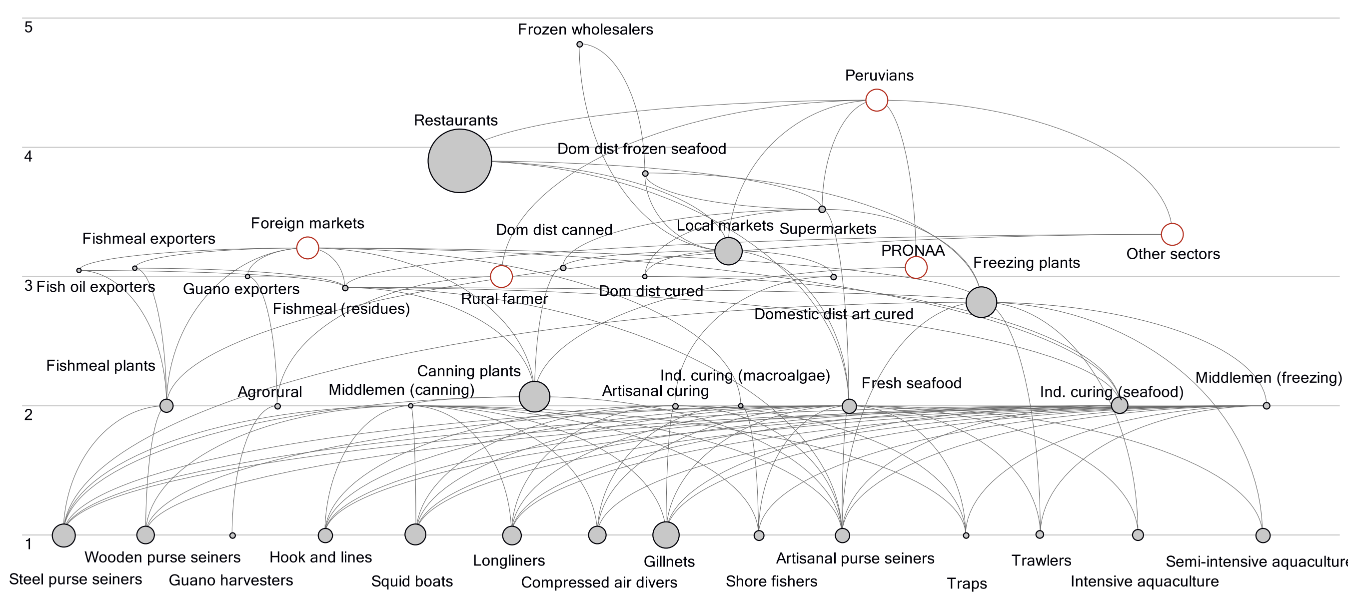

Fig. 2. Employment by enterprise types in the Peruvian fisheries sector. The volume of each node is calculated as a 3-dimensional sphere and is relative between enterprise types. Open circles indicate end consumers for which there is no employment. The enterprises are arranged after 'trophic levels' (*TLs*) on the vertical axis.

placed at TL 1, and enterprises that receive all their products directly from producers (e.g., fishmeal plants) will be placed at TL 2, and so on. Higher TLs thus indicates that the seafood products have passed through more steps, each of which will contribute to the economy and employment.

At the top of the 'food web' on these figures were frozen wholesalers, a niche market with rather low production and employment, but with long 'processing chains'. A typical processing chain for frozen seafood is, as an example, producer – frozen fish middlemen – freezing plant – domestic distributor of frozen seafood – frozen wholesalers – local markets – consumers. Such long chains increase revenue and employment.

3.2. Contribution to GDP

Following seafood through the process chain from producers to consumers, the revenue, cost, and employment was estimated by enterprise categories, and based on this the contribution to GDP was calculated. The primary sector and processing were found to provide the biggest contribution to the overall economy with 36% and 34% of the total, respectively (Table 2). Retailers followed at a close third with 26% though, indicating especially the importance of the restaurant business.

The total contribution of the marine fisheries sector to the Peruvian economy was estimated to be US$ 3.2B for 2009 (Table 2), and this should be a conservative estimate given that this study, as explained in the methodology section, did not include all parts of the sector in the analysis. For instance, the study does not include freshwater fisheries and aquaculture, or illegal, unreported, and unregulated (IUU) fisheries (apart for the artisanal purse seiners' catch of anchoveta that is illegally landed for the reduction industries), and only restaurants that are specialized exclusively on seafood are considered.

Table 2
Production (t), economic and social indicators by enterprise categories in the Peruvian fisheries sector in 2009. Economic parameters are in 10^3US$, and employment is number of jobs.

	Producer	Processing	Distribution	Wholesaler	Retailer	Total
Production	7,174,288	2,399,894	585,419	317,082	417,574	–
Production value	1,728,269	2,767,065	539,079	603,388	2,033,337	7,671,137
Other production	–	169,130	842	–	930	170,902
Subsidies	388	–	–	–	–	388
Total revenue	1,728,657	2,936,195	539,921	603,388	2,034,266	7,842,427
Salaries/shares	459,143	244,608	3613	21,885	331,768	1,061,018
Input (fish)	–	1,304,319	448,641	468,670	1,087,536	3,309,166
Input other	564,148	478,953	8950	17,227	32,994	1,102,273
Taxes	–	–	–	–	–	–
Management, a.o.	28,883	20,000	–	–	1717	50,600
Total cost	1,052,174	2,047,880	461,204	507,781	1,454,016	5,523,056
Average salaries	5.8	4.9	3.8	3.5	3.5	4.6
GDP contribution	1,164,121	1,152,923	82,330	117,491	913,736	3,430,601
Jobs, female	10	19,633	129	1082	54,729	75,583
Jobs, male	79,449	30,757	824	5177	40,566	156,773
Jobs, total	79,459	50,390	953	6260	95,295	232,357

The estimate of total GDP for the fisheries sector updates the 2005-estimate of the fisheries contribution to GDP of US$0.6B [5], and indeed increases the estimate with a factor of five. It also exceeds the 2008-gross value of the fisheries exports of US$2.4B, (which does not consider costs), [5]. The increased estimate of contribution to GDP was higher than the previous estimate, partly because it was for 2009 rather than 2005, and partly because of the much more comprehensive description of the fisheries sector that was derived here.

3.3. *Employment*

Fisheries have always been important in Peru for providing livelihood and food, and this is still the case. The total employment in the fisheries sector was here estimated to 232,000 jobs (full time), which exceeds the previous estimate from FAO of 145,000 (full and part time) with more than 50%. Yet, the estimate should be considered conservative, as the study did not account for all parts of the fisheries sector.

The estimate of the total sector employment was lower than that of Teh and Sumaila [28], who estimated the employment to 440,000 $\pm$ 200,000 jobs. As the estimate for primary sector employment (79,500 jobs) derived here was close to the estimate (72,000 jobs) of Teh and Sumaila [28] the difference was in the higher multiplier used in their study (6.1 vs. 2.9 in the present study).

Among enterprise types, the anchoveta-based industry is not the leading employer – fishmeal plants only provided 5% of the jobs in the industry (Table 1). Instead, fish restaurants dominated with 35% of the employment, followed by freezing and canning plants with 8% and 7%, respectively. By categories, the retailer section was dominating with 45% of the jobs, followed by the primary sector (producers) responsible for 32% of the total employment, and processing with 20% (Table 2).

There were only males employed in the primary sector; the 10 women that were estimated to be working in the sector work with guano processing, (which we have lumped with guano extraction) (Table 2). In the processing sector there was a 50–50 split between males and females, and in the retailer section there was a small dominance of females with 57% of the total. Overall, however, the total fisheries sector was male-dominated with 64% of the total employment.

3.4. *Primary sector and multipliers*

The study followed the fish products from the primary sector through to the consumers and could therefore be used to evaluate for each fishing fleet how much it contributed to the economy and the employment. This is illustrated in Table 3, from which it is clear that more than half of the GDP contribution came from the steel (34%), artisanal (15%), and wooden (5%) purse seiners. There are numerous species that contribute to this, with anchoveta being the most important.

Table 3
Production (t), revenue (10^3 US$), cost ($10^3$ US$), and employment for primary sector enterprise types (fleets) as derived values through the entire fisheries sector. Multipliers give ratios between total sector and primary sector values (jobs from Error! Reference source not found.).

Enterprise	GDP contribution			Employment	
	Fleet	Sector	Multiplier	Sector	Multiplier
Steel purse seiners	322,854	1,156,834	3.6	37,862	3.5
Artisanal purse seiners	177,390	513,952	2.9	58,598	5.7
Squid boats	165,805	409,564	2.5	39,121	4.6
Compressed air divers	95,989	244,065	2.5	13,288	1.9
Longliners	72,724	230,277	3.2	19,239	2.9
Intensive aquaculture	80,648	192,982	2.4	3497	1.5
Wooden purse seiners	74,061	183,383	2.5	9328	1.5
Gillnets	54,929	180,683	3.3	25,288	1.7
Trawlers	52,170	146,146	2.8	6428	4.2
Semi-int. aquaculture	24,637	71,592	2.9	5075	1.2
Hook and lines	15,418	42,857	2.8	7018	1.7
Traps	14,233	41,737	2.9	2158	5.9
Shore fishers	12,034	15,039	1.2	5034	2.6
Guano harvesters	1227	1491	1.2	426	1.0
All	1,164,121	3,430,602	2.9	232,357	2.9

The economic multipliers from the primary sector to the entire fisheries sector varied around an average of 2.9, with, interestingly, steel purse seiners having the highest multiplier of 3.6. The high value for steel purse seiners can be explained by (1) the high value increase and profit margin for fishmeal plants (Fig. 3) relative to the much lower revenue for the fishing fleets; and (2) that this fleet also landed mackerel, which have a long and profitable value chain. But, the first factor here illustrates that it is fishmeal and fish oil that is valuable, rather than anchoveta by itself.

Employment-wise, the dominant primary sector was the small-scale artisanal purse seiners, which supplied 25% of the total employment through the entire fisheries sector (Table 3). Squid boats (18%) and steel purse seiners (14%) came next, and together these fisheries made up more than half of the contribution to employment.

The employment multipliers for the primary sector also varied around an average of 2.9, indicating that there on average are 3 times as many people employed in the entire fisheries sector as

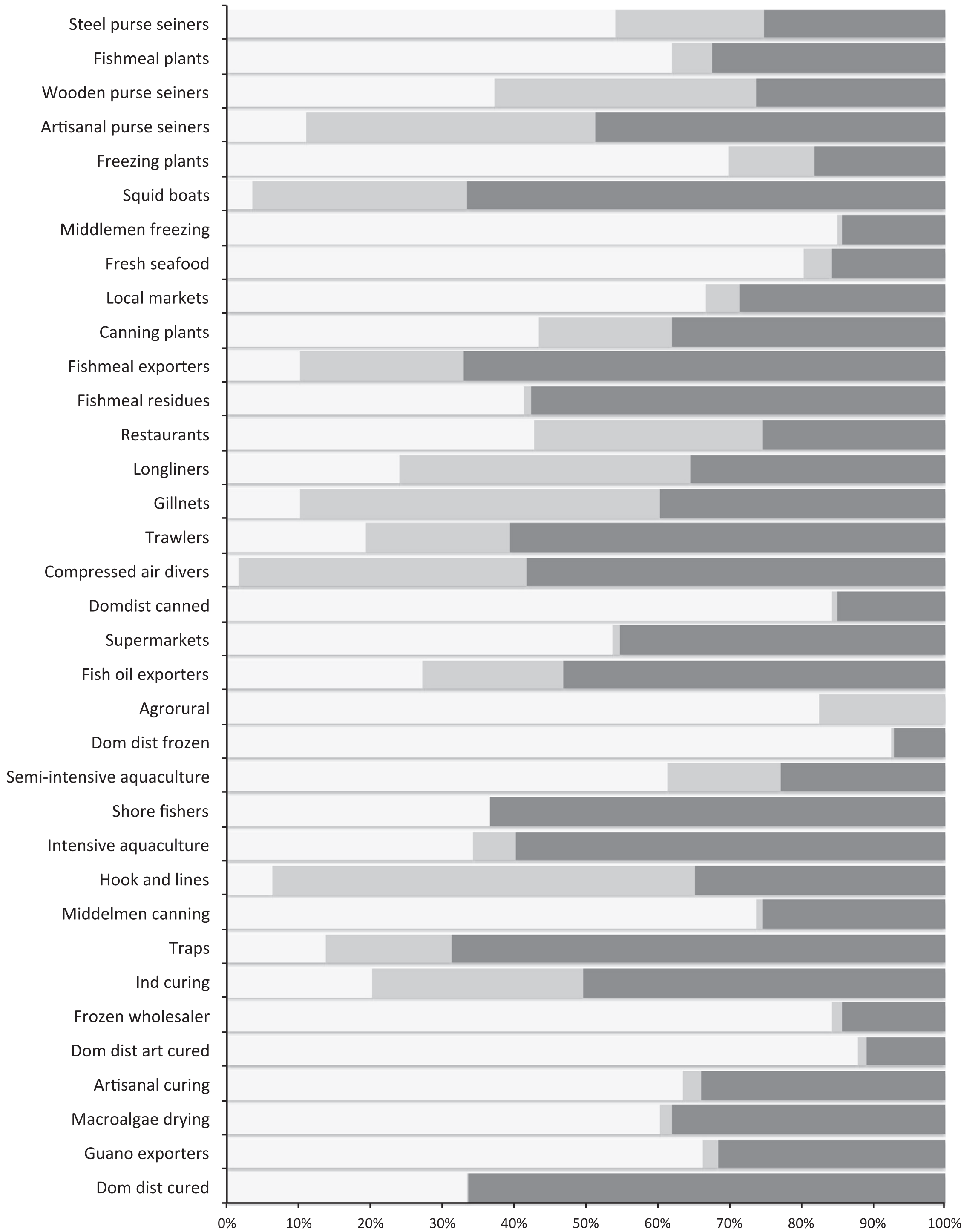

Fig. 3. Distribution of cost of inputs (light gray), salaries (intermediate gray), and profit (dark gray) by enterprise types, all expressed as percentage of total revenue. Enterprises are arranged after production.

there are in the primary part of it – two working on land for everyone onboard. The highest employment multipliers are for mackerel (Table 4), and can be explained by this group having especially long value chains.

3.5. *Seafood commodities*

Anchoveta is important but far from the only species of importance for the fisheries sector. Based on the process chain from the 26 functional groups in ecosystem model with landings (out of the 46 groups overall in the model) through to the end consumers, and on quantification of the importance of aggregated groups, anchoveta was indeed the most important species being responsible for 31% of the contribution from the fisheries sector to the GDP (Table 4). But still, more than 2/3 of the contribution came from other species, many of which depend on anchoveta as their forage basis [29]. The aggregated group of invertebrates indeed equaled the anchoveta with 31%, with shrimps and jumbo squid (*Dosidicus gigas*) as the two big contributors.

Table 4
Contribution to GDP for types of seafood (10^3 US$) from the primary sector and from the entire fisheries sector, and derived value multiplier. Also, employment as derived from seafood types and evaluated through the fisheries sector. 'Other' includes small pelagics, sardine, silverside, macroalgae, and guano. Large fish have asymptotic length (L_∞) > 90 cm, medium (med) have L_∞ between 30–89 cm, and small L_∞ < 30 cm.

	GDP contribution			Employment		
	Fleet	Sector	Multi-plier	Fleet	Sector	Multi-plier
Invertebrates	414,643	1,057,684	2.6	22,635	63,712	2.8
Anchoveta	389,340	1,075,649	2.8	24,260	53,461	2.2
Pelagics large/med	112,261	360,312	3.2	12,609	32,003	2.5
Mackerel	102,089	510,374	5.0	4218	37,806	9.0
Dem large/med	89,326	251,882	2.8	7510	24,080	3.2
Other	22,836	76,572	3.4	2317	6926	3.0
Dem small	19,937	47,789	2.4	3544	9335	2.6
Sharks and rays	13,690	50,341	3.7	2366	4606	1.9
Total	1,164,121	3,430,602	2.9	79,459	231,929	2.9

The average GDP multiplier by commodity was 2.9 – of course, the same as when evaluated for primary sector types. Here the highest multiplier was 5.0 for mackerel, followed by sharks and rays with 3.7.

When employment was evaluated based on seafood commodities (Table 4), invertebrates provided most jobs (27%), followed by anchoveta (23%), and mackerel (16%). The employment multipliers topped for mackerel, again indicating the importance of this group.

4. Discussion

This study is the most comprehensive value chain study of the fisheries sector that has been published, and by building on a widely used and freely available modeling approach, it is possible not just to examine the details of the present study, but it is also facilitated that similar studies can be conducted for other countries. Given how the present study changes the general perception of what is important in the fisheries sector in Peru, it is very likely that similar lessons can be drawn in many other countries with regards to the importance of the small scale versus the industrial part of the fishing industry.

The study provided bottom-up derived estimates for the contribution of the marine fisheries sector to the economy of and employment in Peru. Peru is known for the biggest single species fishery in the world, and this fishery, for anchoveta, have up to now been what is known about, and generally considered when discussing Peruvian fisheries.

The present analysis demonstrated that even though the anchoveta indeed was the key species for the fishery, it was far from the only one species of importance. Other species contributed more than two thirds of the contribution from the fisheries sector to the GDP of Peru, and more than three quarters of the employment in the sector overall.

The total revenue from the primary marine seafood sector, i.e. from capture fisheries and mariculture, in Peru was estimated to 1.7B US$ in 2009. The total first-hand, gross revenue from global capture fisheries has a direct value of US$ 80–85 B [30], and the Peruvian fisheries therefore contribute around 2% to the global value of the primary fisheries sector. Given that Peru accounts for almost 10% of the global fish landings, this raises the question if using anchoveta for direct human consumption rather than for fishmeal and fish oil production can increase the economic and social benefit from the Peruvian fisheries.

There have been steps in that direction, notably since 2006 when a campaign was launched to promote anchoveta for human consumption [31], and this has resulted in the amount of anchoveta for direct human consumption increasing from 5000 t annually to over 160,000 t within a few years. While this is impressive, it should be seen in the light of the total landings being in the range of 5–10 million t annually – it is still but a drop in the ocean.

The study shows that the biggest multipliers for GDP and employment were for mackerel fisheries, and it is interesting that these landings primarily are from purse seiners, which also are responsible for the anchoveta landings. This makes it clear that there is a potential for obtaining more value from the anchoveta fisheries by landing for direct human consumption rather than for reduction purposes.

The anchoveta industry is indeed interested in developing anchoveta as a product for direct human consumption, but this is presently hampered by government regulations, which restrict landings of anchoveta for human consumption to artisanal purse seiners only. The industrial purse seiners, who catch the bulk of the anchoveta, are thus excluded from landing anchoveta for direct human consumption. In addition, the increased global demand for fishmeal and fish oil has created a perverse incentive in that fishing boats currently are paid more for landing anchoveta for reduction than they are for landing a fresh product for direct human consumption.

The average economic multiplier for the primary sector to the overall fisheries sector was estimated to 2.9, indicating that for every dollar (or soles) the primary sector contributed to the GDP, the other parts of the sector added almost two dollars. In comparison, Dyck and Sumaila [32] estimated the total landed value for Latin America to US$ 7.2B (for 2003) and the economic impact of these landings to US$ 14.8B, i.e. an average economic multiplier of 2.0 for Latin America. At the global level they estimated the average multiplier to 2.8, which is almost the same as what we obtained for Peru overall.

The study by Dyck and Sumaila [32] used input–output analysis to estimate the economic multipliers from fisheries, and additional estimates from other input–output analysis studies are available from the Global Trade Analysis Project database (GTAP) as reported by Sumaila and Hannesson [33]. For Latin America the regional average for the economic multiplier is 3.3, which indeed also indicates that Peru is getting less spin-off values for its fisheries than the neighboring countries.

The methodologies discussed here for estimating economic multipliers for the fisheries sector are completely independent, and with this in mind it is interesting that the outcome is very similar.

In this study it was not possible to include import taxes and value added tax. Also, it was not possible to include the export subsidies of US$ 567 million that are paid to the industry to compensate for their payment of value added tax and import taxes as the distribution of this was unclear. This means that the omission to some extent (perhaps almost fully) will cancel out with regard to contribution to the GDP. It should further be noted, that the study indicated that there was very little direct economic benefit for Peru as a society, i.e. taxes and licenses were negligible in comparison to the profit that was made in the sector.

It is expected that the present estimates for contribution of the fisheries sector to the GDP and to employment are conservative in the sense that the actual values are likely to be higher. As discussed, freshwater fisheries and aquaculture, IUU fisheries, were not included, and the estimates for the value chain notably included only restaurants that were fully specialized on seafood, not the many other restaurants with more varied menus – most of which will also serve seafood. The study also did not include spin-off effects from rural farmers and other sectors, while doing so would have increased employment and economic benefit from the

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marine fisheries sector. Further refinements of the study are expected to add the missing links, however, in order to give an even more complete picture. Still, this study has provided a new and comprehensive overview of the Peruvian fisheries sector that is of importance for managing the fisheries in Peru.

Peru recently introduced a catch share and quota system for the industrial anchoveta fishery. The quota system should be modified to directly consider landings from all anchoveta fisheries, not just from the industrial part, and perverse price incentives and restrictions on landing anchoveta for direct human consumption should be removed. With this, the chances of severe collapses of the fisheries will be diminished.

The risk for fisheries collapse may well, however, be greater for fisheries for other species than anchoveta, i.e. for the table fish. These fisheries are unregulated apart from not-enforced boat licensing requirements for the small-scale boats (10–32 GRT). If the wide spread building of such small-scale boats that currently is taking place at many landing sites is not curtailed, Peru may well experience wide-spread collapses in table fish populations within the next decade. Given the importance of these species from economic and social perspectives as demonstrated through this study, this will have serious consequences for Peru.

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