

The little fish that can feed the world

Patricia Majluf¹ | Santiago De la Puente²  | Villy Christensen²

¹Oceana, Lima 18, Peru

²Institute for the Oceans and Fisheries, The University of British Columbia, Vancouver, BC, Canada

Correspondence

Santiago de la Puente, Institute for the Oceans and Fisheries, The University of British Columbia, Vancouver, BC, Canada.
Email: s.delapuate@oceans.ubc.ca

Abstract

Peru is home to the world's biggest fishery with catches of over 95 million tonnes of anchoveta (*Engraulis ringens*), since 2000, yet one in six small children in Peru suffer from chronic malnutrition. This is not because anchoveta is unsuitable for human consumption—on the contrary, they are nutritious, tasty and available year-round, close to the coast. Almost all anchoveta are, however, reduced to provide fishmeal and oil for export. Only a few per cent of the landings are used for direct human consumption, and while this use has increased significantly over the last decade, the growth has stopped because of perverse incentives that encourage landing for reduction purposes, combined with production methods that are expensive and unsuitable for large-scale operations. We discuss the roadblocks and prospects for significantly increasing the contribution of anchoveta to global food security and provide an outlook for how big this contribution potentially could be. It is time to change how anchoveta is used.

KEYWORDS

anchoveta, children malnutrition, fish products, fisheries, global food security, perverse incentives

Peru is host to the world's biggest fishery with landings of anchoveta (*Engraulis ringens*, Engraulidae) amounting to 7% of all global marine landings over the last 64 years (FAO FishStat 2014). Its waters are among the most productive in the world (Chávez, Bertrand,

Guevara-Carrasco, Soler, & Csirke, 2008). Peru has been South America's Leading Culinary Destination for the last five consecutive years (World and Travel Awards 2016), mainly due to its seafood. Yet, 47% of the small children in Peru are anaemic, 15% of young children



Ghoti papers

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Etymology of Ghoti

George Bernard Shaw (1856–1950), polymath, playwright, Nobel prize winner, and the most prolific letter writer in history, was an advocate of English spelling reform. He was reportedly fond of pointing out its absurdities by proving that 'fish' could be spelt 'ghoti'. That is: 'gh' as in 'rough', 'o' as in 'women' and 'ti' as in palatial.

The 11th Larkin Lecture: The Larkin Lectures are named in honour & memory of Dr Peter Larkin, of the University of British Columbia at Vancouver, an urbane, popular and productive academic, whose insight into things fishy was tempered by a remarkable sense of both empathy & humour. Peter Larkin was the founder of the UBC Institute of Fisheries in the 1960s, a forerunner of the Fisheries Centre and Institute for the Oceans and Fisheries. When Peter Larkin retired, and later when he passed away in 1996, his family, friends and colleagues contributed money to a Trust fund in his memory that sponsors the Larkin Lectures, which are held approximately biennially at the Fisheries Centre and which are published after passing a full peer review.

are chronically malnourished, and in many districts of the Amazon and Andes regions, the rate of child malnourishment is higher than 70% (INEI 2015), even though anchoveta is cheap, tasty, nutritious and available year-round, close to the coast. But instead of feeding people, 98% of all anchoveta landings are reduced to produce fishmeal and fish oil that is exported to be used as feed for farmed animals (PRODUCE 2015).

It is not because Peruvians have no tradition of eating anchoveta. Anchoveta has always been an important source of protein for Peru, and it has provided food security back to the origin of Andean civilizations. Anthropogenic deposits found at archaeological sites along the Peruvian coast have revealed the importance of marine ecosystems and their resources for sustenance and trade for more than 13,000 years (Sandweiss, 2003). Their relevance, however, was heightened during the Late Archaic (3000–1800 B.C.), as fish and mollusks became the basis for major development in coastal Peru (Moseley, 2005), where the transition from nomads to civilization required a surplus of calories and nutrients that could support activities not directly related to food production. This surplus was provided through improvement of fishing techniques, not by the development of agriculture as in most other parts of the world. Nets yielded great catches of small pelagic fish—to such an extent that large quantities of anchoveta and sardine (*Sardinops sagax*, Clupeidae) are found in virtually all archaeological sites of this period where detailed dietary studies have been conducted, and they have been identified as the primary sources of protein for ancient Peruvians (Moseley, 2005; Shady, 2006).

Diets changed through Peruvian history to become more diversified, but small pelagics remained an important source of protein for coastal communities. The tradition of eating anchoveta was, however, largely lost with the industrialization of the fishery (Wintersteen, 2011). The modern anchoveta fishery started developing in the 1950s—on the back of the collapse of the Californian sardine fishery—and the foundation was not just surplus boats from California, but also techniques for fishmeal and fish-oil production.

As the anchoveta fishery developed and became established as the single biggest fishery in the world, so did the perception that anchoveta was food for animals, stinky, oily fish, inedible or just a poor man's food (CSA-UPCH unpublished data). Interest and opportunities to eat anchoveta were very limited after forty years of an industrial reduction fishery. However, a decade ago, four events came together to question the best use of this little fish.

One was that the Government of Peru provided a supportive environment by promoting anchoveta for direct human consumption, notably through subsidies to supply school children with anchoveta products as part of the National Program of Food Assistance (PRONAA). This was supported by new technology and products developed by the Institute of Fishery Technology of Peru (ITP).

The second event was the discovery of what may have been America's first city, Caral, on the central coast of Peru. Professor Ruth Shady (2006) demonstrated how important anchoveta had been from the earliest history. The third that a fishing company, Corporación Nutrimar SAC, started producing high-quality canned anchoveta that resembled the European sardine and started marketing these locally

under the *Ayllu Novoandina* brand. And finally, “Aventura Culinaria” (Culinary Adventure) a TV food show hosted by Gaston Acurio, Peru's leading chef, got Peruvians to try a variety of local ingredients for the first time. After each episode of this show, the featured ingredients or restaurants quickly become foodie trends (Vargas Llosa, 2010).

The first author visited Gaston Acurio in 2006 to ask him to join and support the first Anchoveta Week, an initiative developed by the Centro para la Sostenibilidad Ambiental of the Universidad Peruana Cayetano Heredia (CSA-UPCH) to create demand for anchoveta for human consumption in Peru. His answer was simple: “show me that they are worth eating.” A can of Ayllu's anchoveta did that on the spot. The little fish could satisfy one of the world's leading gastronomists, and soon many other top chefs in Lima. Working together, they showed people in Peru that anchoveta was delicious food that one can aspire to eat, and indeed food that can be served in the best restaurants and at the highest tables in the land; it is food for all people.

It took time for the little fish to get that far; indeed, it took four “Anchoveta Weeks” (2006–2012), with up to a hundred of the best restaurants in Lima participating. During these events, dishes and sauces with anchoveta as a core ingredient were prepared, dishes that appealed to peoples' stomachs as well as eyes. More than 95,000 people visited and tried these dishes during these four campaigns. To reach beyond the restaurants, anchoveta recipes were published in colour sections of the major newspapers. For all this, Corporación Nutrimar SAC supplied the canned anchoveta and established contacts to fishers that could supply the fresh product. Behind the scenes, the CSA-UPCH did the legwork, raised the funding for promotion, research and development, bought and brought the fresh anchoveta to restaurants, took care of the promotion and indeed kept the arrangements on track and rolling.

The *Anchoveta Weeks*, together with major marketing efforts from the Peruvian canning industries, changed peoples' perception in Lima. A survey ($N = 561$) conducted by the CSA-UPCH in Lima before the first *Anchoveta Week* (Aug. 2006) showed that over 70% of the sampled population knew about anchovetas, closely relating them with words such as “fish” (40%), “fishmeal” (36%) and “smelly” (22%). Only 12% of the people surveyed identified anchovetas as “food.” Four *Anchoveta Weeks* later, people surveyed ($N = 600$) responded very differently: 98% of the sampled population knew that anchoveta was a “fish,” which happened to be “nutritious” (62%) and “delicious” (30%) “food” (80%; CSA-UPCH unpublished data). In that same time span, the resulting demand increased the landings of fresh anchoveta for direct human consumption from less than 43 kt in 2006 to 105 kt in 2013 (PRODUCE 2015).

While 105 kt is a substantial amount of fish, it represented <2% of the total allowable landings of anchoveta in 2013, just a miniscule fraction, and since then, the landings for direct human consumption have decreased. Why? There are some strong forces combined with perverse incentives at play.

First, the Peruvian General Fisheries Law of 1992 and the catch share regulations of 2009 state that the industrial fleets can land anchoveta for reduction purposes only, while the landing for direct

human consumption is the prerogative of the artisanal fleets—which in turn cannot land anchoveta for reduction.

Second, the supply of anchoveta for reduction has decreased (FAO 2014), while its demand for fishmeal and notably fish oil has increased, mainly due to aquaculture (Tacon & Metian, 2008). This has led to increased prices of anchoveta for reduction. The off-vessel price of fresh anchoveta landed for human consumption has often been lower than when landed for reduction, and even though its price for human consumption currently exceeds the reduction landing price, the differential is not big enough to cover the higher costs associated with landing anchoveta fresh (Avadí, Fréon, & Tam, 2014; Fréon *et al.*, 2013).

The relatively low landing price of anchoveta for direct human consumption is not the only factor that makes it more favourable to land for reduction purposes. Formally, as stated previously, the artisanal fleet can only land anchoveta for direct human consumption, but this regulation is not enforced. Moreover, the artisanal fleet is not included in the catch share system that only regulates the industrial fishery (Aranda, 2009), and they are in effect unregulated. Artisanal boats can fish for anchoveta irrespective of stock status and El Niño conditions, and almost year-round with only very short closures when juvenile anchoveta dominates landings (Table 1).

Understandably, the weak rule of law and the high—and less variable—availability of anchoveta being landed by the artisanal fleet make its supply attractive for residual reduction plants, which operate with considerable surplus capacity, and this results in a price incentive for diverting landings from consumption towards reduction (Fréon *et al.*, 2013). This has resulted in a reduction in the amount of anchoveta used for direct human consumption, from a peak of 125 kt in 2011 to 58 kt in 2014 (PRODUCE 2015).

Furthermore, most anchoveta used in the production lines of the canning, curing and freezing industries also ends up in reduction plants. Let us consider the input–output relationship of the canning industry as an example. A single ton of fresh anchoveta landed for canning will only produce 150 kg of final products (fish in cans), while producing up to 600 kg of raw materials for the residual fishmeal industry—mainly anchoveta heads, guts, trimmings as well as specimens that are too small for canning (Avadí, Fréon, & Quispe, 2014).

There are some caveats, however: (i) residual fishmeal tends to have marginally lower protein content in comparison with the prime and super-prime meals made from whole fishes, but in the worst case scenario, the difference amounts to only 6% (Pesquera Exalmar SAA 2015); (ii) residual fishmeal is produced at lower yields, requiring up to 24% more inputs per ton of fishmeal (Avadí *et al.*, 2015); and (iii) Peruvian residual fishmeal plants are not coupled with fish-oil production lines reducing their potential profit margins.

Assuming all of the anchoveta landings (4.8 million tonnes in 2013, PRODUCE 2015) were used for canning, what could we expect in terms of revenue and employment? And how about protein production for human consumption?

From an employment perspective, it would be very good news. Unemployment is a major problem in Peru, and fish processing can provide new job opportunities. We have estimated that per tonne of fish, there is 10.8 times more employment in anchoveta canning compared to production of fishmeal and fish oil (Christensen, de la Puente, Sueiro, Steenbeek, & Majluf, 2014). Anchoveta landings in 2013 could thus have led to more than 40,000 additional jobs in the processing sector alone, more than doubling the estimated number of jobs that the anchoveta produced in that year in Peru (Table 2).

TABLE 1 Management tools currently included in the regulations for the artisanal and industrial anchoveta fishing fleets. Based on Heck (2015)

Management tools	Industrial fleet	Artisanal fleet
Minimum landing size	12 cm	12 cm
Maximum tolerance of juveniles in the landings	10% of the landings	10% of the landings
Minimum mesh size	13 mm	13 mm
Seasonal closures	February–March and August–September	—
“In-season” closures	If juvenile landings represent more than 10% of the total landings recorded at a single port for three consecutive days or if on-board observers detect areas with high concentration of juveniles.	Only if juvenile landings represent more than 10% of the total landings recorded at a single port for three consecutive days
Closed fishing grounds	The first five nautical miles from the coastline and within marine protected areas.	Within marine protected areas
Total allowable catch (TAC)	TACs are set for each fishing season (October–March and April–September)	—
Access to the fishery	Closed (in paper and in practice)	Closed (only in paper)
Catch share system	Individual semitransferable vessel quota programme	—
On-board observers	Present in 4%–5% of the fleet	—
Vessel monitoring system	Present in 100% of the fleet	Present only in some vessels
Landing monitoring system	100% of the landing sites are monitored daily throughout the year (24-hour-long surveillance)	Less than 30% of the landing sites are monitored daily throughout the year between 5 a.m. and 7 p.m.

TABLE 2 Production estimates and economic and social parameters based on (a) use of anchoveta in 2013, and (b) a hypothetical scenario where anchoveta is used exclusively for canning. MT is metric tonne. Parameterization is based on Christensen *et al.* (2014)

	Anchoveta inputs (MT)	Cost of production (US\$/MT)	Anchoveta in products (MT)	Anchoveta in by-products (MT)	Price of products (US\$/MT)	Price of by-products (US\$/MT)	Jobs/MT	Total employment (no.)	Net profit (10 ⁶ US\$)
a. Current use of anchoveta									
Canning industry	86,785	811	12,584	51,958	2,284	80	0.0840	8,552	23
Curing industry	12,874	1352	2,745	9,164	2,740	80	0.2574	3,313	5
Freezing industry	5,056	1508	3,802	1,254	1,700	80	0.0415	210	1
Fresh fish markets	222	210	200	—	280	—	0.0194	4	0
Fishmeal plants	4,691,719	703	1,116,764	175,196	1,580	3,640	0.0078	9,841	1,618
Residual fishmeal plants	62,399	463	12,480	—	1,400	3,640	0.0044	135	12
							Total	22,055	1,657
b. Anchoveta used for canning only									
Canning industry	4,796,067	811	695,439	2,871,395	2,284	80	0.0840	58,432	1,254
Residual fishmeal plants	2,871,395	703	522,072	107,222	1,400	3,640	0.0078	4,051	754
							Total	62,483	2,008

From an economic perspective, it can also be a win-win situation. Our estimates thus point to US\$351 million higher net revenue (or 21% increase) after a full conversion to canning.

From an environmental perspective, the conversion of the fishery would be neutral, provided that there are no changes in the methodologies and reference points used to establish the TAC. It is key to highlight that Anchoveta fishery management in Peru has improved considerably, achieving sustainable landings from 1995 to the present (Arias-Schreiber, 2012). According to Guevara-Carrasco, Ñiquen, and Bouchon (2010), the total allowable catch (or TAC) is set for the industrial fleet by establishing reference points for annual exploitation rates (U) and for the protection of the spawning stock biomass (SSB) through escapement. Values for U oscillate between 0.45 and 0.50, while an escapement of 4–5 million tonnes of SSB will increase the probability of high recruitment. Moreover, decision rules that affect the choice of U and thus the definition of a TAC in a given season depend on environmental conditions (i.e. La Niña, El Niño and average conditions) and recruitment levels (i.e. low, moderate and high; Table 3).

However, at the political level, greater profits at lower catch levels could grant some leeway for actively pursuing the reduction of uncertainty through management interventions (Walters & Hilborn, 1978; Williams, 2011). These interventions would also contribute to the

implementation of ecosystem-based fishery management and climate change adaptation measures in Peru.

Given that anchoveta is a key forage species in the Humboldt Current, understanding how changes in fishing mortality impact it and the rest of the ecosystem is imperative. Studies suggest that operating at lower fishing mortality rates could lead to the recovery of seabirds and marine mammals, as well as large piscivore fish species (Pikitch *et al.*, 2014). As the artisanal and industrial fleets of Peru also target the latter, a reduction in the anchoveta quota could lead to higher profits (indirectly) and improved ecosystem health.

Moreover, the anchoveta biomass and carrying capacity are highly susceptible to changes in environmental conditions (Bertrand *et al.*, 2011; Chávez, Ryan, Lluch-Cota, & Ñiquen, 2003). Climate change models suggest severe reductions in the maximum catch potential of Peru by 2050 (Lam, Cheung, Reygondeau, & Sumaila, 2016), which will in turn result in threats to human health and food security (Golden *et al.*, 2016). Thus, operating without changing the ways we use and manage this resource will inevitably lead to reduced catches, profits and employment, and given the trophic role of this species, the negative impacts could echo across the food web (Barange *et al.*, 2014). Thus, moving from fishmeal to “fish meals” could be an interesting climate change adaptation measure for the Peruvian fishery sector.

TABLE 3 Decision rules for estimating the total allowable catch. Modified from Guevara-Carrasco *et al.* (2010)

Environmental conditions	Low recruitment	Average recruitment	High recruitment
El Niño	Maintain SSB (No fishing)	Maintain SSB (No fishing)	Exploitation rate is kept below the “low exploitation rate” threshold
Coastal warming	Low exploitation rate	Low exploitation rate	Low exploitation rate
La Niña	Low exploitation rate	Moderate exploitation rate	High exploitation rate
Average	Low exploitation rate	Moderate exploitation rate	High exploitation rate

While a full conversion to canning is a hypothetical scenario, it is not the only option; there are other ways to use anchoveta for direct human consumption, for example through freezing or curing. There is, however, no reason to believe that this would change the findings from this scenario. Also, it must be noted that even a full conversion does not mean a stop to fishmeal and fish-oil production. There will still be a significant production based on anchoveta residues.

What will it take to convert the fishery? It will be a considerable change, but the elements for it are both known and possible. As a first step, the quota system must be changed so as to allow the industrial fleet to land anchoveta for direct human consumption. The quota system must also be changed so that there is a total quota that includes the artisanal fleets; without this, there is no mechanism in place to prevent overshooting of the quota, notably during adverse conditions. These reforms must be coupled with increased public investment in fisheries monitoring and enforcement programmes to reduce the large marginal profits that incentivize illegal fishing practices (Nøstbakken, 2008).

The fishing fleets must be converted to use refrigerated seawater systems to preserve catches in good condition. Such systems have been used for decades around the world and are already used by a part of the industrial fleet in Peru. The artisanal fleets currently use ice when fishing anchoveta for human consumption, but such systems are much less efficient than refrigerated seawater systems—which also can be implemented for small scale fisheries (Careche, García, & Borderías, 2002).

But there also need to be markets for the anchoveta, and this calls for development of new products as well as marketing initiatives. Recent developments have created greater access to anchoveta throughout Peru (Jacquet *et al.*, 2010); however, the formats and portions in which they are currently obtainable act as barriers that limit availability and acceptance in rural areas, where they are most needed.

Anchoveta is mostly offered in small cans or frozen, making them too expensive or requiring refrigeration in areas where electricity largely is unavailable. There is thus a clear need for anchoveta products in formats and portions that are tasty and economical that facilitate reach and are familiar and easy to use, in order to increase access, acceptance and consumption in rural areas of Peru and elsewhere.

Development of such products is underway, and there has been significant progress where notably ITP and cooperators have developed new methodologies aimed at massive upscaling of the anchoveta production. The focus for this is “convenience food” formats that could have higher product acceptance than traditional products, and which can be produced efficiently and at low cost.

Once, or if, such upscaling is possible, the next step can be a ban on the use of whole anchoveta for reduction—allowing only the use of trimmings and discards from the production line for this purpose. Based on recent catch levels, this could result in up towards 5 million tonnes of anchoveta catches being available for direct human consumption on an annual basis. Another—less drastic—measure to foster the transition towards direct human consumption could be the application of taxes on the use of whole anchoveta for reduction. However, their effectiveness might be limited in a country like Peru, where the informal sector of the economy is dominant (Machado, 2014).

Anchoveta also has ecological importance. It is by far the primary forage species in the Humboldt Current system and thus has a direct economic value through fishing, but also an indirect economic value as food source for a large part of the food fish species (Pikitch *et al.*, 2014). Current estimates of the direct contribution of these species suggest they provide 69% of the revenue from the Peruvian Exclusive Economic Zone and 87% of the fisheries sector employment in Peru (Christensen *et al.*, 2014). Increasing the value of the anchoveta fishery by giving it a more profitable end-use could result in larger profits at lower catch levels, which in turn could act as an incentive for rebuilding stocks of larger dependent piscivorous fish, seabirds and marine mammals, ultimately buffering the expected negative impacts of climate change on the Peruvian EEZ (Barange *et al.*, 2014).

Anchoveta thus serves important ecological, economic and social roles, and this more than anything strengthens the need for a precautionary approach to management of anchoveta. Yet, the strongest and most important argument for a full conversion to fishing anchoveta for human consumption is of an ethical character.

Anchoveta is rich in polyunsaturated fatty acids (such as omega-3 and omega-6), essential amino acids, vitamins A and C, iron, zinc and calcium, and its nutritional value is heightened given that malnourished children in Peru suffer deficiencies especially in proteins, vitamin A, iron and zinc (Fundación contra el Hambre 2012).

Anchoveta can therefore be used as a key component in strategies to reduce the health burden, especially for malnourished people. Five million tonnes of fresh anchoveta a year can be used to produce 750 thousand tonnes of canned anchoveta or 1.25 million tonnes of anchoveta “convenience food,” which in turn can provide up to 40 kg of nutrient-rich and tasty food for every Peruvian.

Given that there globally were around 795 million chronically undernourished people in 2015 and that 68 million children under five were severely malnourished (FAO *et al.* 2015), the anchoveta production could potentially amount to 1.6 kg for every undernourished person, or 18 kg of essential food for every severely malnourished child on the planet, every year. We are indeed talking about the little fish that can feed the world.

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