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To ignore or mitigate – Economic implications of an illegal artisanal trawl fishery in northern Peru

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ABSTRACT

An artisanal shrimp trawl fishery operating illegally in northern Peru has high levels of bycatch and three main commercial species. Here we provide the first characterisation of the socio-economic contribution of this fishery. Estimates have been generated for the capital values, operational and maintenance costs, as well as net profits at point of landing and across the value chain. This fleet sector in northern Peru is estimated at 105 vessels, generating an annual gross income of U$D 4.8 million with 315 direct jobs. Vessel owners could potentially have a net income of over ~$12,000 per year, and crew are likely to be earning 45 % above the living wage for similar land-based rural employment, including other fishing activities operating in the same areas. With an appropriate multiplier for the seafood supply chain, the gross economic value of the fishery from landings up to the retail level is estimated at U$D 35 million with 915 jobs. Recommendations for improving the sustainability of the fishery and possible mitigations are discussed to address the gulf between policy and regulatory intent and reality, where enforcement is lacking or absent.

1. Introduction

Globally, illegal, unregulated and unreported (IUU) fisheries account for 26–32 million tonnes of fish caught annually [1,42]. IUU fishing is also often associated with labour abuses [52,56,17]; and other illegal activities like human trafficking, corruption or drug trafficking [14,38,9]. IUU fishing is particularly problematic in developing countries lacking the capacity and resources for effective monitoring, control, and surveillance (MCS), but the latter is, at the same time, a consequence of poor governance and high levels of corruption [15]. Where there is deficient MCS, it may be simplistic to assume that fishers involved in IUU are criminals with little regard for the resources they are exploiting [53]. The generalization of IUU as illegal is problematic in the case of small-scale fisheries (SSF) where IUU is a consequence of weak institutional frameworks for management, control and enforcement [53,11]. Poverty coupled to poor governance and MCS, allows IUU to flourish. However, this does not necessarily mean that the fishers involved are unaware of the need to manage the fisheries they prosecute, for reasons of sustainability, financial and personal security and other advantages conferred through legitimisation.

An example of an IUU fishery seeking to legitimise itself is the artisanal trawl fishery in the Piura Region of northern Peru. Peruvian regulations prohibit trawling within the area where this fishery operates (i.e., the first five nautical miles of the Peruvian coast; [49]). However, this fishery has been operating since the 1950′s [18,36]. It targets the coffee shrimp (also known as the yellow-leg shrimp or the brown shrimp) *Penaeus californiensis* but 82 % of the catch (by weight) is bycatch, which includes two other commercial species: sand perch *Diplectrum conceptione* and sole flounder *Etropus ectenes* [33] which the fishers also sell.

This fishery threatens coastal marine biodiversity [50,51] through the physical impact of the trawl on the seabed and associated benthic communities, high levels of discarded by-catch and is challenged by socio-economic and safety concerns. There are conflicts with other local small-scale fishers, as these trawlers discard juveniles of commercial species targeted by other fisheries and operate near other small-scale fishing communities [46,16,47,48]. This issue has resulted in violence [46]. In some coastal areas, artisanal trawlers are not allowed access to ports by local fishers, resulting in transactions taking place at sea with

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fishers having limited or no negotiating power with respect to price and the physical transfer of catch raising serious safety considerations. The shrimp trawlers are targeted by pirates (disaffected local fishers and criminal gangs), who demand their catch, usually threatening them with knives and firearms. Periodically, with limited resources, government patrols confiscate fishing gear and catch and imposes fines [37]. Between 2017 and 2021, the Peruvian Ministry of Production imposed only two fines for illegal fishing onboard artisanal trawlers [44]. Despite the limited fines imposed, fishers state that they regularly suffer confiscation of nets and boats, but these are extrajudicial actions and consequently, unrecorded in official records.

Notwithstanding these challenges, this fishery has continued to grow. Following the trend of most artisanal fisheries of Peru [12] and specifically northern Peru [8], the illegal artisanal trawling fleet increased from a dozen in the 1960s [24] to more than a hundred vessels fifty years later [27,32]. Since there are no export records in official Peruvian statistics of the three commercial species [45], it can be considered that the products of artisanal trawlers are exclusively oriented to domestic markets, where weak MCS mechanisms facilitate illegal seafood products entering the market (see [31,55]), and feed into post-landing value chains. It was estimated that Piura's small-scale trawling generates 2.1 times more added value and 1.4 times more employment on land for each dollar or job generated at sea [21]. These values are similar to the socio-economic multipliers reported in other artisanal fisheries value chains of the Piura Region [21] and nationally [10].

The persistent and increasing scale of this fishery reflects that MCS actions have failed to prevent trawling, and generates perverse incentives for continued IUU fishing despite the challenges outlined above. Recognising that this fishery has persisted for decades, plays an important socio-economic role, is seeking ways to reduce bycatch [54] and be recognised and managed sustainably, there are potentially opportunities to reframe legislation, management and controls. Fishers involved in this IUU fishing have been lobbying for legal recognition for their activity for several years. However, as trawling within 5mn of the coast is forbidden by law, the situation is complex and requires high levels of coordination and commitment between government, fishers, and other fishery stakeholders. In the absence of intervention, IUU fishing will continue. To navigate a path towards a more coherent position with responsible management and regulation will require dialogue between all relevant stakeholders, and the development of trust based on a shared vision and plan. With a view to informing this dialogue and future decision making, this study provides the first economic characterisation of the artisanal trawler fishery in Piura.

2. Methodology

The overall economic importance of the fishery was characterised at an operational level; the value of the assets (start-up costs), maintenance and operational costs were estimated; the landings by volume and income were calculated for the period April 2019 to March 2020; the crew and shipowners monetary and in-kind payments were estimated; a total annual accounting balance was created. Price multipliers at wholesale and open-air retail markets were estimated to calculate then the economic value at the upper levels of the supply chain. Primary and secondary data sources were used.

2.1. Fleet characterisation

Thirty small-scale shrimp fishers from Máncora, Cabo Blanco, Talara, Constante and Sechura answered a structured interview with questions related to the number of active vessels and the main characteristics of the fishing operations, the value of the assets, fishing operational and maintenance costs, first sale prices of landed catch, estimates of in-kind/bartered goods and services, and the income shares for vessel owner and fishers (Survey – supplementary material 1). The interviewees were all participants in the illegal fishery, self-selecting and voluntary. Interviews were conducted between December 2019 and January 2020. Ethical approval for the interview work was secured through the University of St Andrews, Training and Research Ethics Committee (Ref: BL13636). Individual informed consent to participate was secured before the interview. The purpose of the interview and how the data would be used was explained to participants.

Interview data was used to estimate the median total number of vessels operating in this fishery's principal anchorages and landing points. Drone surveys of the anchorages at Cabo Blanco, Quebrada Verde and Talara together with direct vessel counts at Máncora were used as verification of the estimates of the number of small-scale trawling vessels operating in the region. Other operational characteristics were captured including days at sea per year, vessel length, hold capacity, engine power, number of crew members, etc.

2.2. Start-up, maintenance and operational costs

The monetary value of a vessel and net was calculated by the summing the estimated costs for the main component parts provided by the interviewees. These were assumed to be contemporary estimates of cost, rather than what these components cost when first purchased which may, in the case of vessels for example, have been many years prior to the survey. No estimates for vessel depreciation was included in this calculation as the survey data was insufficient to apportion such costs. Daily operating and annual maintenance costs were obtained by summing each of the relevant costed categories in the survey. To calculate the maintenance costs, fishers were asked to provide estimates of the costs and periodicity of the maintenance of each component of the vessel and gear.

All information related to costs was provided in the local currency soles (PEN) and then converted to United States Dollars (USD) for comparative purposes. For this purpose, the exchange rate PEN/USD of 3.34, the 2019 official average exchange rate recognised by the Peruvian Reserve Central Bank, was used [7].

2.3. Landings by volume and income

In addition to the structured interviews, off-vessel prices for each species were obtained from the Peruvian Marine Institute open-source database [25]. A total of 512 records with off-vessel prices from the analysis period (i.e., April 2019–March 2020) were retrieved: 160 coffee shrimp, 284 sand perch and 68 sole flounder. All information related to selling price was converted to United States Dollars (USD) using the criterion explained above. Landing volume for each commercial species was derived from fishing trips per vessel and season from onboard sampling between April 2019 and March 2020 (13 in autumn, 11 in winter, 11 in spring and 9 in summer; reported in [33]).

Total landings per vessel were estimated for each season as the product of the median landing per vessel and trip and the effective fishing days per season. To obtain the total landings of the entire fleet, we scale landings per vessel multiplying it by the total number of vessels operating. Seasonal gross income was calculated as the product of the volume landed and the median off-vessel price of each species. The 95 % confidence interval was calculated for each median through the percentile method, and statistical differences between seasons compared using a pairwise Wilcoxon non-parametric test (p-value <0.05).

2.4. Crew payments and consolidated accounting balance

Interview data was used to estimate the share of the weight of landed catch offered per trip to the crew as an in-kind payment. This amount was multiplied by the landed value (median price per kilogram reported by the fishers) of the species to calculate the equivalent cash contribution. This value was scaled to an estimate of all trips for the entire fleet to obtain the total cash equivalent for the in-kind contribution to the crew.

Funds to directly remunerate the vessel owner and crew were estimated by subtracting the maintenance, operating costs and in-kind value of catch given to the crew, from the gross income from landings. This income after costs is shared between the shipowner and the crew. Data from interviews referring to the crew members number and shares received by them and the shipowners were used to estimate these payments. Finally, a table summarising the accounting balance of income-costs of the fishery from April 2019 to March 2020 was created.

2.5. Multipliers of prices and employment along the value chain

Using open-source data with prices at wholesale and open-air markets from the Peruvian Ministry of Production [43], the price multiplier for the fishery's commercial species in these value chain links were determined. Prices were converted to United States Dollars (USD). Multipliers were used to estimate the gross income generated in near-to-end links of the supply chain such as wholesalers and open-air market retailers. Employment multipliers estimated by Christensen et al. [10] for the Peruvian seafood sector and Gozzer-Wuest et al. [21] for the Piura's artisanal trawl fishery were applied to generate estimates of employment for Piura's entire artisanal trawl fishery value chain.

On the 15th of January 2020, a workshop was organised with fishers, fisheries representatives and a representative from the Regional Government of Piura familiar with the artisanal shrimp fishery. The economic characterisation was presented with a view to seeking feedback and validation of the estimates generated, their implications and potential co-management solutions for the small-scale shrimp fishery.

3. Results

3.1. Characterisation of the activity

Thirty face-to-face structured interviews were conducted with fishers in five of the eight main anchorages used by vessels operating in this fishery (Fig. 1). 77 % of the interviewees were both vessel owners and skippers, the remainder were skippers only (Supplementary Table 1). The principal anchorages and landing points documented in the survey were Máncora, Quebrada Verde, Talara and Constante. Other relevant anchorages for this fishery are Bayovar, Parachique, Playa el Amor and El Bravo.

Survey numbers derived from drone surveys of Talara, Quebrada Verde and direct vessel counts at Mancora suggest that the number of vessels estimated from the survey of fishers is likely to be a reasonable estimate of the size of the fleet (i.e., 105 vessels in Piura Region; Supplementary Table 1). This being the case, the survey sample represents approximately 38 % of the entire fleet. There was considerable variation in some of the responses, but a general observation supported by feedback from the Piura workshop attendees was that in some aspects, the operation of the fleet varied considerably. Some vessels primarily focus on shrimp fishing, while others target small demersal fish species such as the sand perch and soul flounder. 77 % of survey respondents confirmed they work in this fishery the entire year. However, as the shrimp fishery is seasonal, many vessels switch to target fish species during months of low shrimp catch rates. Some survey respondents noted that during periods when shrimp availability was low, they would switch to catching jumbo flying squid *Dosidicus gigas* (27 % of respondents) or Peruvian weakfish *Cynoscion analis* (23 % of respondents).

Small-scale trawling vessels have a median vessel length estimated at 8.3 m (range from 5.8 to 12.0 m; n = 22), a median hold capacity of 7 tonnes (from 3 to 12; n = 24) and motors with median engine power of 110 HP (from 50 to 175 HP; n = 17). The age, hull design and construction of these vessels can be highly variable but most have wooden hulls and common features include a winch and two laterally positioned outriggers amidships (raised whilst steaming or at anchor). Two trawl doors are also visible on deck or suspended from the outriggers (Fig. 2). Longer vessels have wheel houses. Many of the vessels are in a poor state of repair. Based on the estimated number of ships in the fleet (105) and the median crew number of three people (n = 30), conservative direct employment of 315 crew members was estimated, including the skippers. Although not reported by survey participants, subsequent investigations suggest that additional shrimp trawling vessels may also be operating in the coves of Paita, Yacila, and potentially other coves between Constante and Talara (see Fig. 1).

3.2. Start-up, maintenance and operational costs

The median value, at the time of purchase or build, was ~\$10,200 in the case of the ones without a wheelhouse (range from ~\$2200 to \$32,500) and ~\$11,000 in those that have this asset varying from a minimum of ~\$2700 to a maximum of \$33,700 (Table 1A). The major costs were the hull (41–44 % of the total median vessel cost) and the engine (40–43 % of the total median vessel cost). The median cost to

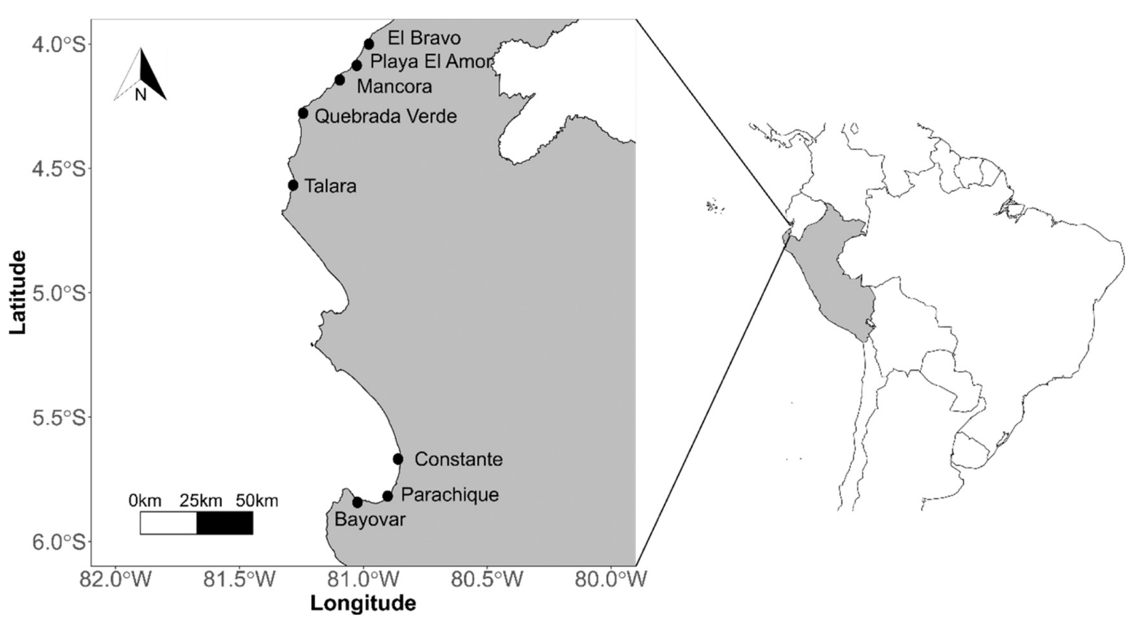

Fig. 1. Locations of the main landing points for the small-scale trawl fishery in Piura Region.

Fig. 2. Aerial image of shrimp vessels at anchor in Talara harbour. The vessels marked with "X" are not shrimp vessels.

Table 1
Estimated capital costs (in US$) of a vessel (A) and estimated capital costs of fishing gear (B).

(A) Value of a vessel assets					
Item		Median	Min	Max	Number of responses
1	Hull Cost	$ 4491	$ 299	$ 17,964	19
2	Engine Cost	$ 4431	$ 1796	$ 8982	18
3	Winch Cost	$ 1198	$ 90	$ 4491	20
4	Outriggers Cost	$ 90	$ 36	$ 1048	21
5	Wheel House Cost	$ 823	$ 449	$ 1198	6
Total cost of a new vessel without wheel house		**$ 10,210**	**$ 2222**	**$ 32,485**	
Total cost of a new vessel with wheel house		**$ 11,033**	**$ 2671**	**$ 33,683**	

(B) Value of a traditional net for artisanal trawling					
Item		Median	Min	Max	Number of responses
1	Net	$ 374	$ 159	$ 659	20
2	Buoys	$ 63	$ 24	$ 120	23
3	Doors	$ 240	$ 90	$ 898	26
4	Ropes	$ 210	$ 75	$ 647	22
5	Labour	$ 90	$ 60	$ 210	16
Total Estimated Cost of Gear		**$ 976**	**$ 407**	**$ 2533**	

build or purchase trawling gear was ~$1000 varying in a range of ~ $400 to ~$2500 (Table 1B). When asked to quantify any loans associated with their capital costs for fishing activities, the answers provided suggested that some fishers interpreted the question in different ways quoting large variations in loan values, and interest rates that bore no relation to the capital costs that they quoted for the purchase of their respective vessels and gear. As a result, these values could not be included in the estimated structure of asset costs. However, it is likely that any loans are likely to have been made be through informal arrangements.

The median annual maintenance costs were estimated ~ $2065 per vessel, with 33 % of costs for the trawling fishing gear (net, chains, ropes and cod-end) and 67 % for the vessel (engine, hull and winch). The median maintenance costs for the fishing gear were split in the net ($291 [120,898]), cod-end ($157 [105,599]), ropes ($123 [90,210]), and chains ($ 105 [60,210]) and those related to the vessel in the hull ($749 [599,898]), the engine ($550 [399,772]), and the winch ($90 [75,213]). The range of values quoted for maintenance was extensive, probably due to the use, age and state of repair of each vessel. An additional source of variability in the maintenance costs quoted is also likely to be because in some cases such costs were a direct external cost paid to third parties and in other cases maintenance may have been undertaken directly by the vessel owner or crew and therefore uncosted in terms of labour. Annual costs for documentation such as permits and taxes elicited few and inconsistent responses which were therefore not included as part of the annual maintenance costs. This result underpinned the illegal nature of the fishery and the loss to government of taxable revenue.

By far, the highest fishing operating cost (excluding crew) was fuel (Table 2). Most survey participants did not declare ice as part of their costs, except seven owners from Talara who coincidently reported fishing trips up to two days and consequently spent an additional $12 on ice. Thus, it was estimated that half of the Talara fleet (i.e., 20 vessels) had a median value for daily operational costs of $84.5 while the remaining 85 vessels were $72.5 (Table 2).

Fishers who anchored their vessels in Quebrada Verde worked for 15

Table 2
Operational fishing costs (in US$) per day and per year per vessel. Median [95 % CI].

Item	Per day per vessel	Per year per vessel	Number of responses
Fuel	$ 61.4 [56.9, 74.9]	$ 15,964 [14794,19474]	30
Food	$ 7.5 [6.0, 7.5]	$ 1950 [1560,1950]	29
Lubricant	$ 2.9 [2.1, 3.5]	$ 754 [546,910]	25
Gas	$ 0.7 [0.6, 0.9]	$ 182 [156,234]	25
Ice	$ 12 [6.0, 15.0]	$ 3120 [1560,3900]	7
Total cost with ice	**$ 84.5**	**$ 21,970**	—
Total cost without ice	**$ 72.5**	**$ 18,850**	—

days consecutively returning to anchor each night and then took six days rest, which means they operates approximately 260 days a year. Fishers from Constante, Máncora and half of vessels in Talara worked five days a week throughout the year returning to anchor each night equating to approximately 260 days per year. The remaining vessels operating out of Talara carry out two-day fishing trips accounting for ten effective days of fishing bi-weekly (~260 effectives days in a year). Thus, given the effective annual working days, one vessel that uses ice during its trips invests median operating costs of $ 21,970 annually, while one that does not use ice of $ 18,850.

3.3. Landings by volume and income

The median landings for the three main commercial species per vessel and trip are shown in Table 3 and Fig. 3A–D.

This can be scaled to an estimated annual landing of ~4400 tonnes by the entire fleet of 105 vessels (total annual landings are presented as Supplementary Table 2). Fig. 3D shows the dominance of shrimps during Spring and Summer in landings (75 % and 65 % of landings, respectively). Sand perch and sole flounder become a more important proportion of landings during Autumn (73 %) and Winter (67 %).

The median off-vessel price per kilogram of landed coffee shrimp fluctuated seasonally between $ 1.20 and $ 2.69; sand perch between $ 0.45 and $ 0.60, and sole flounder between $ 0.45 and $ 0.60. The estimated gross income of the fleet was $ 4.7 million in the year assessed. Although coffee shrimp did not represent the most significant landed volume each season (see Fig. 3), it always generated the greatest portion of gross income (Fig. 4). Coffee shrimp represented 77 % of the monetary value, while sand perch and sole flounder with 17 % and 6 %, respectively. In autumn and winter, the relative importance of sand perch and sole flounder derived income increased significantly and decreased in spring and summer (Fig. 4D).

3.4. Crew payments and consolidated accounting balance

The crew is being defined as the skipper plus two deck hands, noting that the skipper may also be the vessel owner. The number of shares and the manner in which they are allocated varies by vessel, but based on the survey responses and through verification with fishers it was agreed that most vessels split the net income between seven shares; four to the vessel owner and one to each of the three crew members. Where the vessel owner is also the skipper of the vessel they therefore receive five shares. Moreover, a proportion of the catch is often given to the crew or used to barter for other goods such as drinkable water. We estimated that ~13 kg of the three commercially valued species were allocated as an in-kind payment to the crew per trip. The in-kind allocations have been estimated to be $11.1 per trip which means $302,000 for the entire fleet in a year. In addition, the crew could keep part of the non-commercial bycatch; however, the volume and economic value of this portion was not considered in this study because it involves nearly 250 species [33] of which most lack market value or are landed in too small a volume to sustain regular commercial activity.

Each crew member receives near $3000 plus $950 extra in in-kind contributions annually and the vessel owners $12,000. It was not possible to determine the cost of depreciation within the operational costs and these would need to be deducted from net profits, but given the age and condition of the vessels operating within this fleet sector, together with the lack of regulation with respect to health and safety for example, it would be reasonable to assume that depreciation may not be a significant factor. In total, operational fishing costs were estimated as: 43 % of the total gross income; vessel owners payment was 26 %; crew payments were 20 % (6.6 % for each of them); the value of the fish given to the fishers as an in-kind contribution was 6 % and; maintenance costs represented 5 % (Table 4).

Table 3
Median landed weight (kg) per vessel per trip by season.

Austral Season	Total Weight (kg) Per Day	Coffee shrimp (kg)	Sand Perch (kg)	Soul Flounder (kg)
Autumn (Q2–2019)	165	44	106	15
Winter (Q3–2019)	156	51	75	30
Spring (Q4–2019)	144	108	20	16
Summer (Q1–2020)	185	121	44	20

3.5. Multipliers of prices and employment along the value chain

The median shrimp prices at wholesale and open-air retail were $7.0 and $ 11.4 per kilogram, respectively (see seasonal changes in Supplementary table 3). The wholesale/landing and retail/landing price rates were 4.5 and 7.4, respectively, which means that the landed shrimp gross income estimated at $ 3.7 million would have generated an additional $23.4 million at the retail level. Sand perch price data at wholesale was $3.0 with a wholesale/landing price multiplier of 6.4 (equating to $4.3 million additional gross income at wholesale level). Open-air retail data were unavailable during the analysed period and it was impossible to calculate its price multiplier. This species is commonly sold filleted, making identification difficult in markets for statistics purposes. Sole flounder had a wholesale/landing multiplier of 7.4 ($4.2 per kilogram) and a retail/landing of 9.6 ($5.5 per kilogram). The catches valued at nearly ~$0.3 million generated ~$2.5 million in additional income throughout the value chain to retail. In summary, the three commercial species generated $30.2 million more income through sales at domestic markets, equating to a total gross income from the landing point to consumption of $35.0 million.

Whilst acknowledging that employment multipliers vary across fishing sectors, Christensen et al. [10] suggest that 2.9 is a reasonable multiplier for employment in the Peruvian fishing sector and Gozzer-Wuest et al. [21] that 2.4 is appropriate for the workforce that remains within the borders of the Piura Region. Thus, if direct on-vessel employment is about 315, this would equate to 915 people employed along the entire value chain of this unregulated and illegal bottom trawl fishery, of which 83 % remain in Piura.

4. Discussion

This paper provides the first characterisation of the artisanal shrimp fleet operating in northern Peru, together with estimates of this fishery's socio- economic impact. Conservative mid-point estimates of catch volumes, gross and net income values, and direct employment suggest significant social and economic benefit is being generated by a relatively small fleet of ~100 vessels likely involving direct full time employment of more than 300 fishers. Although Peru does not stand out as being one of the top shrimp producers worldwide [6], and the overall income of Piura's small-scale trawling fishery is relatively low in comparison with countries like Indonesia, Mexico, or the US [19], the socio-economic contribution of the fishery is better understood and relevant in the local context where this fishery occurs in northern Peru.

Piura's 2019 average monthly income was $343, and the national average monthly income in rural areas (where artisanal trawling occurs) was $228 [28]. If the income estimated is a reasonable reflection of incomes in this fishery, fishers earned (including in-kind payments) more than the average income in rural areas (+45 %) but slightly less than the average regional income (–4 %). Vessel owners earned 193 % and 340 % more than Piura and rural average incomes, respectively. Thus, for both crew and vessel owners, this fishery is clearly profitable. In addition, artisanal trawlers received considerably higher payments than other local fisheries in the same geographic area [13,22]. For example, 67 % of fishers in Cabo Blanco and 65 % of El Ñuro (two

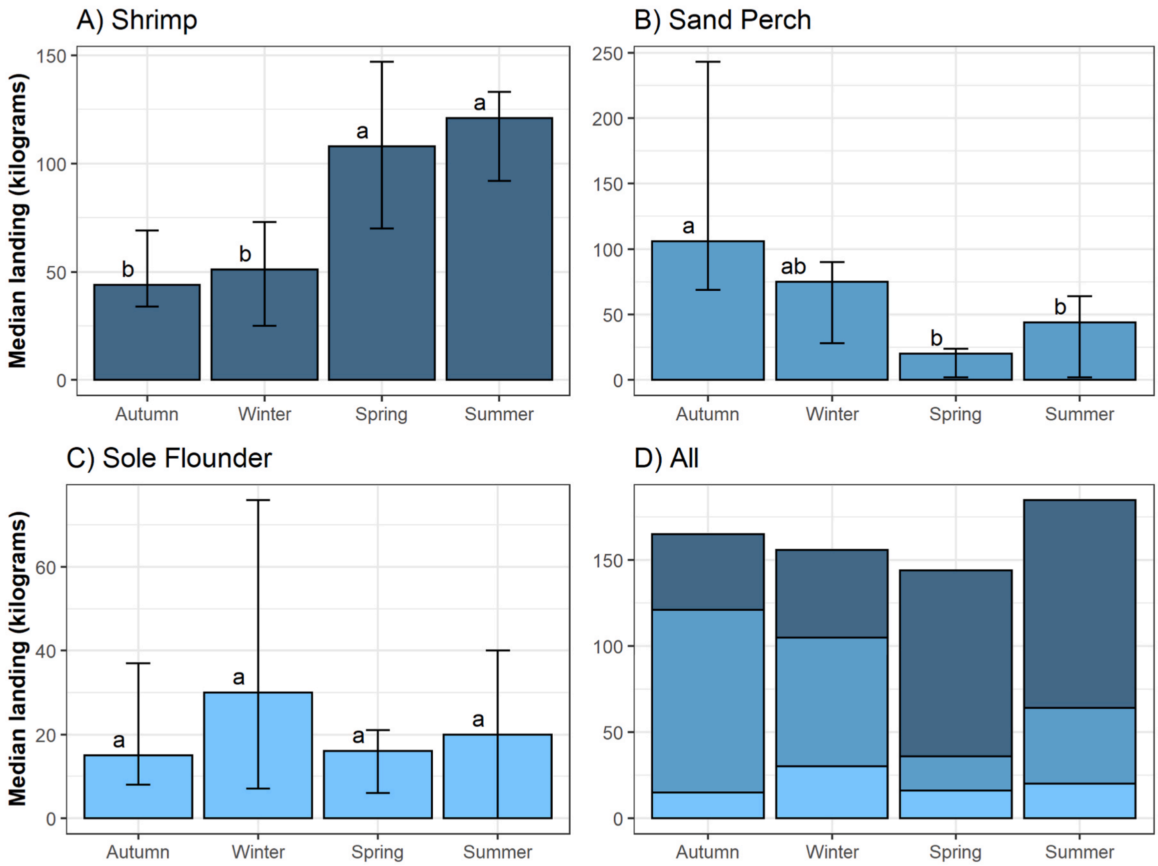

Fig. 3. Volume of landing (kg) per one vessel by austral season: shrimps (A), sand perch (B), sole flounder (C) and the three species stacked (D). Lowercase letters above bars in each graphic by species are there to show statistical differences between seasons.

communities in which trawlers operate in their surrounding waters) had monthly earnings of up to $ 156 in 2017 [13], 53 % below the earnings of a shrimp vessel crew member. The explanation for this difference is that despite being caught illegally, shrimp command a higher value than the legally fished commercial fish species (e.g., common hake landed by fishers from El Ñuro).

Considering the estimated capital costs of a vessel ($ 10,210–11,033), together with annual maintenance costs of $2065, operational costs of $ 18,850–21,970, and a net profit of $12,043 per year, it is clear to see the incentives for owners in continuing to prosecute this fishery. In the absence of data related to possible loans and based on some crude assumption of vessel depreciation, this fishery yields a return on investment for owners that far exceeds the opportunity costs of standard investments, acknowledging that there are significant risks operationally and potentially legally in participating in this fishery. The sustained costs-benefits for both crew and vessel owner, despite punitive extrajudicial confiscations of vessels, gear and catch, suggest that there are strong incentives for long term participation in this fishery. An ineffective MCS system is also a contributory factor ([44]; more information on the weaknesses of the MCS system in Peru can be found in [20]).

The results show that the fishery maintains a relatively stable seasonal income of over $1.2 million (except for the winter), and the shrimp contributes most of the income. However, the results also show that its relative importance increases in Spring (90 % of income and 75 % of volume) and Summer (83 % and 65 %); and decreases in Autumn (66 % and 27 %) and Winter (68 % and 33 %). From an economic and sustainability perspective, it is important that this fishery is regarded as mixed, seasonally targeting sand perch and sole flounder as well as coffee shrimp to maintain income levels throughout the year.

Thus far, sand perch and sole flounder have been regarded as part of the overall bycatch to the shrimp fishery. This has implications for the way that the proportion of bycatch within this fishery is documented and viewed. If considered as part of the overall commercial catch – they are, by definition, not bycatch and quoted levels of bycatch are consequently and legitimately reduced. Future potential management of this fishery would also need to take into account its mixed nature and manage it with respect to the stocks being targeted.

It is important to note that the products of this fishery are not recorded in the exports of Peruvian seafood products [45] but are found in domestic trading records in wholesale and open-air retailers [43]. In the twelve months of analysis, the illegal trawl fishery in Piura generated approximately $35 million across the entire value chain. Only 13.6 % of this income circulated within the artisanal fishers and vessel owners. Most of the added value was generated in the mid and final domestic market sectors of the value chain. The social and economic impact of this fishery propagates well beyond those directly involved in IUU fishing because there are no *de facto* restrictions to legally selling the products of this activity in Peruvian national markets. The demand for these resources probably ignores their origin. Both morally and practically, Peruvian consumers also need to reflect on continued consumption of seafood products derived from IUU fishing. Generating awareness of the problem could building market pressure to positively influence decision-makers to seek innovative solutions that could promote sustainable fishing practices whilst maintaining choice and affordability for the consumer.

From a management perspective, it is highly probable that fishers operating within this fishery have a desire and strong financial incentives to secure legitimisation, through formal regulation and management. Whilst this would inevitably increase costs, the stabilisation of the sector could attract long term investment, access to markets, increased returns on their catch and improve working conditions for

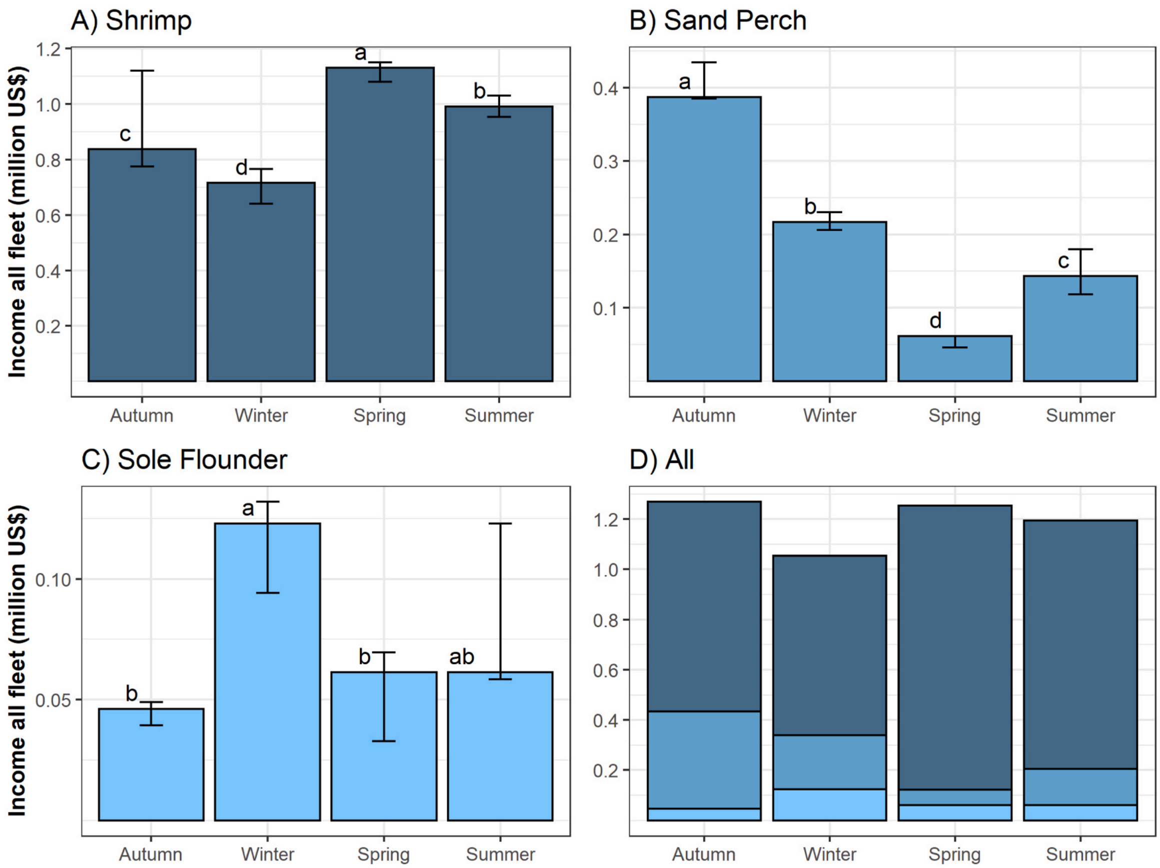

Fig. 4. Fleet income (million US$) by austral season: shrimps (A), sand perch (B), sole flounder (C) and the three species stacked (D). Lowercase letters above bars in each graphic by species are there to show statistical differences between seasons.

Table 4
Accounting balance of the artisanal trawling fishery from Piura Region.

Item	Per vessel		Entire fleet
	Daily	Yearly	Yearly
Gross Income	$ 174.8	$ 45,460	$ 4773,300
Fishing cost			
Operational fishing cost (85 vessels that do not use ice)	$ 72.5	$ 18,850	$ 1602,250
Operational fishing cost (20 vessels that use ice)	$ 84.5	$ 21,970	$ 439,400
Maintenance	$ 7.9	$ 2065	$ 216,825
Value of in-kind contribution to the entire crew	$ 11.1	$ 2875	$ 301,902
Revenue before crew payment	$ 81.1	$ 21,075	$ 2212,923
Skipper	$ 11.6	$ 3011	$ 316,132
Deck Hand one	$ 11.6	$ 3011	$ 316,132
Deck Hand two	$ 11.6	$ 3011	$ 316,132
Revenue after crew payment (vessel owner payment)	$ 46.3	$ 12,043	$ 1264,527

those involved. Fishers have shown interest in gaining knowledge about their impact on the ecosystem and partnered with researchers to find ways to reduce their impact [35,34]. This could pave the way to more proactive co-management of the fishery, where fishers and managers have mutual interests in making the fishery sustainable and environmentally acceptable. Encouraging self-policing by fishers coupled with more effective compliance action by government could also be piloted.

The economic evidence suggests that it is likely that vessel owners could cover additional costs related to operating the fishery in a manner that might be considered more acceptable if the government could be persuaded to undertake the necessary steps to resolve the legal and environmental challenges of this activity without generating high social costs. In this regard, some potential solutions may emerge from studies of the spatio-temporal patterns of this fishery [34]. The seasonal use of passive fishing gears such as the *Suripera* [2,26,3,23], to catch shrimps when they constitute the major proportion of catch and income, could reduce impacts in spring and summer. A solution that may work year round, reducing unwanted bycatch by 50 % is the use of a modified trawl net (see [54]). Notwithstanding potential technical mitigations to minimise unwanted bycatch and reduce seabed impacts caused by trawling, the fishery remains classified as IUU within 5 nm of the coast.

The results of this study provide the first snapshot of this fishery's potential scale and value. Given the instability in which this activity occurs, coupled with major environmental changes resulting from El Niño (see [5,39]), the economic estimates are likely to be subject to significant variability. For example, increased catches of coffee shrimp have been associated with the 2017 coastal El Niño event [30]. However, the analysis provides clear evidence of the drivers that underpin this sustained economic but illegal fishing activity. Ongoing and more detailed data collection from this fishery is recommended to monitor the fishery and inform management – even if this is self-imposed by those that have a vested interest in making sure the fishery is conducted as sustainably as is possible under the prevailing circumstances. In this regard, voluntary recording of spatio-temporal fishing trip data by some fishers was successfully tested [35], demonstrating that the incentive for regularisation could also push fishers to provide data to support management decisions. However, at this point, data collection is not necessarily a way of legitimising the fishery but merely a pragmatic response to reality.

This research represents a snapshot of a fishery which, whilst illegal, has a potentially significant bio-economic footprint. In order to capture this and reflect fluctuations in shrimp availability between seasons and years we would recommend future studies designed to capture this variability. In addition, it is important to gain an understanding of the nature and costs of financing this fishing activity including any loans, interest rates and whether lenders are formal or informal. Whilst formal taxation is unlikely, it is important to take into account the cost of informal "taxation" or expenses related to evading the legal system which may include extorsion and corruption.

No simple solution exists to the complex problem of IUU fishing, particularly whilst consumer demand is high and there is limited or no functional regulation and compliance. There is an urgent need adopt pragmatic and adaptive co-management approaches that involve all fishers independent of their legal status [4,40,41] and that incentivizes their participation [29]. Simply ignoring reality on the basis of legal statute fails to recognise or deal with important threats and opportunities.

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CRediT authorship contribution statement

Authors: James and Gozzer-Wuest are joint first authors having led on the development of the concept, methodology, survey, analysis of the results and writing the original draft and subsequent reviewing and editing. **Authors: Mendo, T and Mendo, J** were involved in the development of the concept and methodology, led the research in Peru, critiqued the results and contributed to the original draft. **Author: Gomez led** the conduct of the survey work in Peru and assisted in the analysis of the results and provided contextual information. **Author: Grillo-Núñez** contributed to the development to the concept and commented on early drafts as well as helping to corroborate the results with fishers in Peru.

Conflict of interest

The authors have declared that no competing interests exist.

Data Availability

The data that has been used is confidential.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2023.105865.

References

[1] D.J. Agnew, J. Pearce, G. Pramod, T. Peatman, R. Watson, J.R. Beddington, T. J. Pitcher, Estimating the worldwide extent of illegal fishing, PLoS ONE 4 (2009), e4570, https://doi.org/10.1371/journal.pone.0004570.

[2] F. Amezcua, J. Madrid-Vera, H. Aguirre-Villaseñor, fecto de la pesca artesanal de camarón sobre la ictiofauna en el sistema lagunar de Santa María la Reforma, suroeste del Golfo de California, Ciencias Marinas 32 (1B) (2006) 97–109.

[3] F. Amezcua, J. Madrid-Vera, H. Aguirre, Incidental capture of juvenile fish from an artisanal fishery in a coastal lagoon in the Gulf of California, N. Am. J. Fish. Manag. 29 (1) (2009) 245–255.

[4] D. Armitage, R. Plummer, F. Berkes, R. Arthur, R. Charles, I. Davidson-Hunt, A. Diduck, N. Doubleday, D. Johnson, M. Marschke, P. McConner, E. Pinkerton, E. Wollenberg, Adaptive co-management for social-ecological complexity, Front. Ecol. Environ. 7 (95–102) (2009) 2009, https://doi.org/10.1890/070089.

[5] R.T. Barber, F.P. Chávez, Ocean variability in relation to living resources during the 1982–83 El Niño, Nature 319 (6051) (1986) 279–285.

[6] R.T. Bauer, Shrimp fisheries, Fish. Aquac. 9 (2020) 91.

[7] BCRP (2021). Cuadros estadísticos de la nota semanal. 〈https://www.bcrp.gob.pe/estadisticas/cuadros-de-la-nota-semanal.html〉 (Accessed 1 November 2021).

[8] G. Castillo Mendoza, J. Fernández, A. Medina Cruz, R. Guevara Carrasco, Tercera encuesta estructural de la pesquería artesanal en el litoral peruano, Result. Gen. (2018).

[9] I. Chapsos, S. Hamilton, Illegal fishing and fisheries crime as a transnational organized crime in Indonesia, Trends Organ. Crime 22 (3) (2019) 255–273.

[10] V. Christensen, S. La Puenta, C. Sueiro, J. Steenbeek, P. Majluf, Valuing seafood: the Peruvian fisheries sector, Mar. Policy 44 (2014) 302–311.

[11] A.M. Cisneros-Montemayor, T. Cashion, D.D. Miller, T.C. Tai, N. Talloni-Alvarez, H.W. Weiskel, U.R. Sumaila, Achieving sustainable and equitable fisheries requires nuanced policies not silver bullets, 2018, Nat. Ecol. Evol. 2 (1334) (2018), https://doi.org/10.1038/s41559-018-0633-0.

[12] S. De la Puente, R. López de la Lama, S. Benavente, J.C. Sueiro, D. Pauly, Growing into poverty: reconstructing Peruvian small-scale fishing effort between 1950 and 2018, Front. Mar. Sci. 7 (2020) 681.

[13] S. De la Puente, R.L. de la Lama, C. Llerena-Cayo, B.R. Martínez, G. Rey-Cama, V. Christensen, M. Rivera-Ch, A. Valdés-Velasquez, Adoption of sustainable low-impact fishing practices is not enough to secure sustainable livelihoods and social wellbeing in small-scale fishing communities, Mar. Policy 146 (2022), 105321.

[14] J.L. Decker Sparks, L.K. Hasche, Complex linkages between forced labor slavery and environmental decline in marine fisheries, J. Hum. Rights 18 (2) (2019) 230–245.

[15] A. Doumbouya, O.T. Camara, J. Mamie, J.F. Intchama, A. Jarra, S. Ceesay, A. Guèye, D. Ndiaye, E. Beibou, A. Padilla, D. Belhabib, Assessing the effectiveness of monitoring control and surveillance of illegal fishing: the case of West Africa (MAR), Front. Mar. Sci. (4) (2017), https://doi.org/10.3389/fmars.2017.00050.

[16] El Regional Piura, 2021. Talara: pescadores artesanales de Cabo Blanco denuncian depredación del Banco de Máncora (20/12/2021).(En Línea). Disponible en < 〈https://www.elregionalpiura.com.pe/index.php/region-piura/151-talara/54356-talara-pescadores-artesanales-de-cabo-blanco-denuncian-depredacion-del-banco-de-mancora〉 >

[17] Environment Justice Foundation (EJF). 2020. Illegal fishing and human rights abuses in the Taiwanese fishing fleet. (24/11/2022). Available at https://ejfoundation.org/resources/downloads/Taiwan-briefing-IUU-HR-2020-July.pdf.

[18] M. Espino, C. y Wosnitza-Mendo, R. Castillo, La pesca de arrastre de la flota costera de Paita entre 1970 – 1982. Instituto del Mar del Perú, Boletin 8 (5) (1984) 163–187 (Available at), 〈https://repositorio.imarpe.gob.pe/bitstream/20.500.12958/940/1/BOL%208%285%29.1.pdf〉.

[19] R. Gillett, Global Study of Shrimp Fisheries, vol. 475, Food and Agriculture Organization of the United Nations,, Rome, 2008.

[20] R. Gozzer-Wuest, E. Alonso-Población, G.A. Tingley, Identifying priority areas for improvement in Peruvian fisheries, Mar. Policy 129 (2021), 104545.

[21] R. Gozzer-Wuest, J.C. Sueiro, J. Grillo-Núñez, S. De La Puente, M. Correa, T. Mendo, J. Mendo, Desafiando la tradición de país harinero: Una mirada económica de la actividad pesquera de Piura, Perú, Mar. Fish. Sci. (MAFIS) 35 (2) (2022) 255–274.

[22] J. Grillo-Núñez, T. Mendo, R. Gozzer-Wuest, J. Mendo, Impacts of COVID-19 on the value chain of the hake small scale fishery in northern Peru, Mar. Policy 134 (2021), 104808.

[23] Herrera, Y., Sanjurjo, E., Glass, C. 2017. Artes alternativas a las redes de enmalle en el Alto Golfo de California. (25/11/2022). Avaiable at https://www.gob.mx/cms/uploads/attachment/file/378348/ECOFT_Espanol_Nov_16_2017.pdf.

[24] IMARPE. (1969). Informe preliminar sobre la pesca de arrastre. Dirección Técnica. Inst. Mar Perú. Serie de Informes Especiales Nro. IM 41. 18p.

[25] IMARPE. (2021). INFOMAR: Proyecto Pesca Artesanal - Sistema de información de precios playa, mareas y oleajes. 〈http://infomar.imarpe.gob.pe:8080/Portal/PrecioPlaya〉 (Accessed 1 November 2021).

[26] INAPESCA/WWF. 2009. Evaluación de las atarrayas "Suriperas" como opción para la captura comercial de camarón en el Alto Golfo de California. Informe Técnico Final de las Campañas 2007-2008 y 2008- 2009. 34 p. Available at: http://www.wwf.org.mx.

[27] INEI. (2012). Primer Censo Nacional de la Pesca Artesanal 2012 (I-CENPAR 2012). Lima: Instituto Nacional de Estadística e Informática.

[28] INEI. (2021). Perú Compendio Estadístico 2021. Tomo 1. Capítulo 7 Empleo y Previsión Social. 509–611.

[29] A.M. Keane, J.P.G. Jones, G. Edwards-Jones, E.J. Milner-Gulland, The sleeping policeman: understanding issues of enforcement and compliance in conservation, 2008, Anim. Conserv. 11 (75–82) (2008), https://doi.org/10.1111/j.1469-1795.2008.00170.x.

[30] L.C. Kluger, S. Kochalski, A. Aguirre-Velarde, I. Vivar, M. Wolff, Coping with abrupt environmental change: The impact of the coastal El Niño 2017 on artisanal fisheries and mariculture in North Peru, ICES J. Mar. Sci. 76 (4) (2019) 1122–1130.

[31] A. Marín, J. Serna, C. Robles, B. Ramírez, L.E. Reyes-Flores, E. Zelada-Mázmela, R. Alfaro, A glimpse into the genetic diversity of the Peruvian seafood sector: unveiling species substitution, mislabeling and trade of threatened species, PloS One 13 (11) (2018), e0206596.

[32] J. Mendo, M. James, P. Gil-Kodaka, R. Gozzer, J. Martina, I. Gómez, J. Grillo, et al., Desarrollo de un modelo dinámico de co-manejo para la protección de la biodiversidad en una pesquería de arrastre de langostino en el Perú (2020) 69.

[33] J. Mendo, T. Mendo, P. Gil-Kodaka, J. Martina, I. Gómez, R. Delgado, J. Fernández, A. Travezaño, R. Arroyo, K. Loza, M.A. James, Bycatch and discards in the artisanal shrimp trawl fishery in Northern Peru, Plos One 17 (6) (2022), e0268128.

[34] T. Mendo, J.M. Ransijn, I. Gomez, R. Gozzer-Wuest, I. Paradinas, M. James, J. Mendo, Minimising discards while taking revenue into account: Spatio-temporal assessment of catches in an artisanal shrimp trawl fishery in Peru, Fish. Res. 261 (2023), 106623.

[35] T. Mendo, J. Mendo, J. Ransijn, I. Gomez, P. Gil-Kodaka, J. Fernández, R. Delgado, M. Travezaño, R. Arroyo, K. Loza, P. McCann, S. Crowe, E. Jones, M. James, Using fisher-led reporting technology to compare discard reporting in an illegal small-scale fishery (2022).
[36] Ministerio de Hacienda y Comercio, 1959. Anuario estadístico del Perú (1995–1957). (25/11/2022). Avaiable at: ⟨https://books.google.com.pe/books?id=1skQAQAAMAAJ&printsec=frontcover#v=onepage&q&f=false⟩.
[37] Ministerio Publico. (2021). Intervienen embarcación con productos hidrobiológicos ilegal en la bahía de Talara. (6/08/2021). Available at ⟨https://www.gob.pe/institucion/mpfn/noticias/510081-intervienen-embarcacion-con-productos-hidrobiologicos-ilegal-en-la-bahia-de-talara⟩.
[38] W.D. Moreto, R.W. Charlton, S.E. DeWitt, C.M. Burton, The convergence of CAPTURED fish and people: examining the symbiotic nature of labor trafficking and illegal, unreported and unregulated fishing, Deviant Behav. 41 (6) (2020) 733–749.
[39] National Oceanic and Atmospheric Administration (NOAA). 2022. El Niño & La Niña (El Niño-Southern Oscillation). (Accessed 26/11/2022). Available at https://www.climate.gov/enso.
[40] E. Ostrom, Polycentric systems for coping with collective action and global environmenta change, 2010, Glob. Environ. Chang 20 (2010) 550–557, https://doi.org/10.1016/j.gloenvcha.201o0.07.004.
[41] Oyanedel, R. 2019. Pesca Ilegal e Incumplimiento. En Ruiz, E.; Oyanedel, R. y Moteferri, B (Eds). Mar, costas y pesquerías: Una mirada comparativa desde Chile, México y Perú (71–77). Sociedad Peruana de Derecho Ambiental. Disponible en: <⟨https://spda.org.pe/wpfb-file/mar-costas-y-pesquerias-pdf⟩>
[42] D. Pauly, D. Zeller, Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining, Nat. Commun. 10244 (2016) (2016), https://doi.org/10.1038/ncomms10244.
[43] PRODUCE. 2021. Datero Pesquero. Available at:(⟨https://consultasenlinea.produce.gob.pe/ConsultasEnLinea/consultas.web/datero⟩.
[44] PRODUCE. 2022. Carta No 00000817–2022-PRODUCE/FUN.RES.ACC.INF. Acceso a la Información Pública: "Solicito base de datos de los últimos 10 años de las infracciones y sanciones realizadas a personas naturales o jurídicas, relacionado a llevar a bordo o extraer recursos hidrobiológicos utilizando redes de arrastre de fondo dentro de las 5 millas náuticas en el litoral peruano.
[45] PromPerú. (2021). Desenvolvimiento del comercio exterior pesquero y acuícola en el Perú. Informe Anual 2020. Available at ⟨https://boletines.exportemos.pe/recursos/boletin/desenvolvimiento-comercio-exterior-pesquero-acuicola-2020.pdf⟩.
[46] La República, 2020. Talara: pescadores intervienen embarcación que realizaba pesca de arrastre. (7/06/2020) (En Línea). Available at ⟨https://larepublica.pe/sociedad/2020/06/07/talara-pescadores-intervienen-embarcacion-que-realizaba-pesca-de-arrastre-lrnd/⟩.
[47] RPP, 2021a.Un monstruo en el mar: La pesca de arrastre en Piura, su amenaza a las especies marinas y el daño ambiental (5/11/2021). (En Linea). Disponible en < ⟨https://rpp.pe/peru/piura/piura-pesca-ilegal-un-monstruo-en-el-mar-la-pesca-de-arrastre-su-amenaza-a-las-especies-marinas-y-el-dano-ambiental-informe-noticia-1367350?utm_medium=Social&utm_source=Facebook&fbclid=IwAR0XYidlW5Avs3-bDpaHdYvO7RsJmw7D5JyC1bH0RxTMuQPU_se0_f3RD8s#Echobox=1636127264⟩ >
[48] RPP, 2021b. Pesca de arrastre, una amenaza contra el ecosistema marino del norte del Perú (9/09/2021). (En Línea). Disponible en: < ⟨https://rpp.pe/peru/actualidad/pesca-de-arrastre-una-amenaza-contra-el-ecosistema-marino-del-norte-del-peru-noticia-1290393⟩ >
[49] C.M. Salazar, R. Bandín, F. Castagnino, B. Monteferri, Informe: Propuestas para reducir conflictos e impactos a los ecosistemas dentro de la "Zona reservada para la pesca artesanal", a partir del análisis de los artes y métodos de pesca empleados en el Perú por la flota artesanal y de menor escala, Lima: Soc. Peru. De. Derecho Ambient. (2020).
[50] Salazar Cespedes, C.M. (2018). Impacto ecosistémico de las artes de pesca artesanal peruana: propuestas de investigación tecnológicas y manejo pesquero.
[51] Salazar Céspedes, C.M., Chacón Nieto, G., Alarcón Vélez, J., Luque Sánchez, C., Cornejo Urbina, R., & Chalking, F. (2015). Flota de arrastre de fondo de menor escala en la Región Tumbes.
[52] E.R. Selig, S. Nakayama, C.C. Wabnitz, H. Österblom, J. Spijkers, N.A. Miller, J. L. Decker Sparks, Revealing global risks of labor abuse and illegal, unreported, and unregulated fishing, Nat. Commun. 13 (1) (2022) 1–11.
[53] A.M. Song, J. Scholtens, K. Barclay, S.R. Bush, M. Fabinyi, D.S. Adhuri, M. Haughton, Collateral damage? Small-scale fisheries in the global fight against IUU fishing, Fish Fish 21 (2020) 831–843, https://doi.org/10.1111/faf.12462. ⟨https://onlinelibrary.wiley.com⟩.
[54] M.A. Travezaño Ambrosio, Abundancia y composición específica de la captura usando dos diseños de redes de arrastre en la pesquería del langostino - Piura. Tesis para optar el grado de ingeniera pesquera, Univ. Nac. Agrar. La Molina (2022) 133.
[55] X. Velez-Zuazo, J. Alfaro-Shigueto, U. Rosas-Puchuri, C. Guidino, A. Pasara-Polack, J.C. Riveros, J.C. Mangel, High incidence of mislabeling and a hint of fraud in the ceviche and sushi business, Food Control 129 (2021), 108224.
[56] S. Yea, C. Stringer, Caught in a vicious cycle: connecting forced labour and environmental exploitation through a case study of Asia–Pacific, Mar. Policy 134 (2021), 104825.