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Short Communication

Jellyfish bycatch diminishes profit in an anchovy fishery off Peru

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ABSTRACT

Peru supports one of the world's largest single-species fisheries based on the Peruvian anchovy (*Engraulis ringens* L. Jenyns, 1842), and bycatch of the scyphomedusa *Chrysaora plocamia* (Lesson, 1832) affects this fishery. Medusae display strong seasonal fluctuations, with peak abundances during summer. Off southern Peru and during the austral summer 2008–2009, *C. plocamia* were >30% of the catch in 5% of the hauls, which was enough to cause economic losses of more than 200,000 US$ in only 35 d of fishing. Fishery factories refused to receive the catch if jellyfish bycatch was >40% of the catch in weight. Economic losses could substantially increase during warm periods like El Niño, during which *C. plocamia* medusa abundances greatly increase. This study was the first attempt to quantify economic losses due to jellyfish through the use of bycatch rates and interviews with employees of fishery factories.

1. Introduction

Outbreaks of indigenous or invasive medusae or ctenophores have commonly been documented in the last 15 years, contributing to a perceived increase of jellyfish blooms (e.g., Mills, 2001; Lynam et al., 2006; Purcell, 2005; Xian et al., 2005; Condon et al., 2012). Various explanations were offered as possible drivers for increased blooms, including overfishing, eutrophication, accidental translocations, proliferation of artificial structures in coastal environments, and global warming (e.g., Parsons and Lalli, 2002; Purcell, 2011; Holst and Jarms, 2007; Brodeur et al., 2008; Richardson et al., 2009). Independently of their causes, it is clear that jellyfish blooms can have negative impacts on economic activities. Jellyfish interfere with the economy of coastal cities by clogging nets of fishermen and cooling-water intake screens of power and desalination plants, as well as hampering tourist industries by deterring beachcombers that fear the stings of some species (Möller, 1984; Mianzan, 1989; Mianzan and Cornelius, 1999; Uye, 2008).

The connections between jellyfish and commercial fish populations have become widely studied (reviewed in Purcell et al., 2007; Purcell, 2011), especially after the invasion of the ctenophore *Mnemiopsis leidyi* (Agassiz, 1865) in the Black Sea during the late 1980s (e.g., Shiganova et al., 2003). Recently, many commercial fisheries have been diminished and seemingly replaced by jellyfish. For example, in the Benguela current system, the jellyfish biomass of *Chrysaora hysoscella* (Linnaeus, 1766) and *Aequorea forskalea* (Forsskål, 1775) increased while pelagic fish biomass decreased during the last four decades (Lynam et al., 2006). A similar situation was described for the East China and Yellow seas, where the fisheries decline was associated with jellyfish increase (Dong et al., 2010). In both cases, the relationship was thought to result from the depletion of fish resources.

Jellyfish negatively affect fisheries in various ways, including (1) clogging and bursting nets (Lotan et al., 1993; Graham et al., 2003; Purcell et al., 2007), (2) increasing labor to remove medusae from nets (Kawahara et al., 2006b), (3) producing painful stings to fishermen who handle medusae (Purcell et al., 2007; Kawahara et al., 2006a; Uye, 2008), (4) increasing the risk of capsizing trawl boats due to a heavier payload (Kawahara et al., 2006b), (5) diminishing fish catches (Cheng et al., 2005; Dong et al., 2010), and (6) increasing fish mortality due to nematocyst venom (e.g., Båmstedt et al., 1998). In Japan, several blooms of the giant scyphomedusa *Nemopilema nomurai* (Kishinouye, 1922) caused severe economic damage to the local fisheries. A loss of ca. 20 million US$ in one area was attributed to decreased fish catch and damage to nets (Kawahara et al., 2006b). In North America, the invasive jellyfish *Phyllorhiza punctata* (von Lendenfeld, 1884) cost 10 million US$ in losses to the shrimp fishery of the Gulf of Mexico by fouling fishing gear and reducing the shrimp harvest (Graham et al., 2003). South America also has experienced the negative relationship between jellyfish and fisheries. In southeastern Brazil, year-round blooms of the scyphomedusa *Lychnorhiza lucerna* (Haeckel, 1880) have affected the shrimp fishery by shortening and displacing hauls, as well as clogging nets (Nagata

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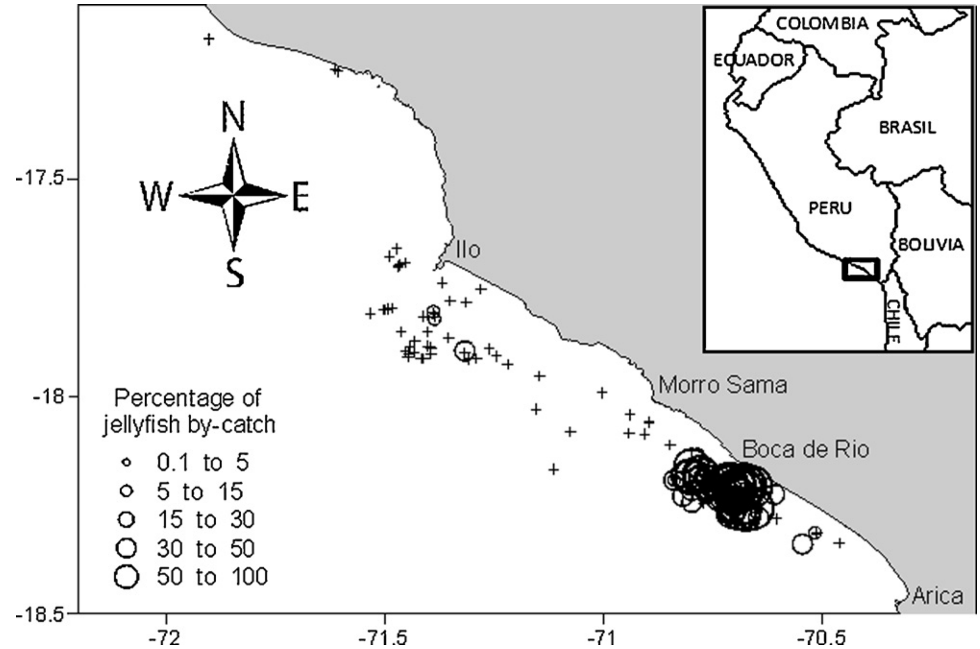

Fig. 1. Jellyfish (*Chrysaora plocamia*) relative abundances from anchovy purse seines of the fishery industry off southern Peru. Small crosses show hauls with no jellyfish catch.

et al., 2009). In northern Argentina during summer, *L. lucerna* also causes fishing problems by reducing total fish captures and catch quality, damaging nets, and preventing fishermen from operating (Schiariti et al., 2008).

In recent studies fishermen and their cooperatives have been interviewed to assess if there is a "jellyfish problem" by determining whether or not jellyfish have increased and the possible negative impacts on fishing activities (Uye and Ueta, 2004; Nagata et al., 2009). Those reports, however, did not quantify the potential profit losses to fisheries. Although the negative effects of jellyfish on fisheries are undeniable, quantifying economic loss is difficult. Usually the jellyfish contribution to bycatch is ignored or not reported in the official statistics. The Peruvian purse seine industrial fisheries offered an opportunity to quantify income losses due to jellyfish presence. Thus, the aim of this study was to assess for the first time the potential economic losses by estimating jellyfish bycatch in the Peruvian fishing industry. To achieve this aim, a pilot research study was conducted by making estimations of jellyfish bycatch and interviewing employees from selected factories processing anchovy in southern Peru.

The high biological productivity of the Peruvian upwelling system, supports one of the world's largest single-species fisheries (Chavez et al., 1999, 2008; Pennington et al., 2006), making a major contribution to the world fish production (Bakun et al., 2010). A fleet of >1200 purse-seiners operate along the coastline (Fréon et al., 2008) and annually caught >5 million t of the Peruvian anchovy (*Engraulis ringens*) during the last decade (Ñiquen and Fréon, 2006). This ecosystem is characterized by high inter-annual and inter-decadal fluctuations, and *Chrysaora plocamia* medusae are conspicuous members of the coastal fauna during summer (Quiñones, 2010; Quiñones et al., 2010) when their distribution overlaps with that of anchovies (Ganoza et al., 2000; Bertrand et al., 2004). Fish are removed from the purse seine nets by use of a suction hose and then stored directly in the ship's hold without sorting. When present, jellyfish are suctioned and stored with the anchovies. Fishermen cannot discard the jellyfish at sea and so they occupy storage space that otherwise would be used for anchovies.

2. Methods

In this study, several people in charge of quality control in five anchovy processing factories were interviewed for 5 weeks from 17 to 21 December 2008 and from 2 to 31 January 2009 at the southernmost Peruvian port of Ilo (17°37′ S, 71°20′ W) where catch was landed (Fig. 1). To test a null hypothesis that jellyfish do not cause economic damage to the Peruvian anchovy fishery, we followed the methods of Uye and Ueta (2004) and Nagata et al. (2009) and asked the following questions:

1. – Do you apply a deduction (jellyfish weight is subtracted from the total catch landed) if jellyfish are present? If yes, how much deduction is applied per ton landed?
2. – What is the maximum percentage of jellyfish bycatch accepted in order to avoid a deduction?
3. – If jellyfish enter the fishmeal production process, does it imply a delay in the production? Can you quantify this in terms of time spent?
4. – Is it possible that the total catch can be discarded due to jellyfish bycatch?

Of the five factories, three applied a deduction if jellyfish bycatch weight was >10%, one deducted if weight was >15%, and one deducted if weight was >30%. To decide if jellyfish bycatch was causing economic damage, we considered 13% of jellyfish bycatch weight as a critical value which represents the weighted mean of bycatch value applied by the processing factories. When jellyfish bycatch exceeded 40% of the total landing, then total capture was discarded because too much jellyfish produces low quality fish meal.

The fleet, at the time of the interview, consisted of 200 vessels, which represents almost 17% of the whole Peruvian fleet. Seventy percent of the vessels were iron made, with an average storing capacity of 220 t. Other vessels were wood made; with an average storing capacity of 120 t. 28% (N = 417) of the total landings were analyzed in Ilo port during the study period. When ships arrived at the harbor, catches were deployed using a hopper. A random subsample of 14 kg of the landing was taken from each factory, where jellyfish and fish catches were weighed separately. As a result, the contribution of jellyfish bycatch was obtained, and this proportion was extrapolated to the total capture recorded in the official landing statistics. Jellyfish were identified according to Stiasny (1937) and Mianzan and Cornelius (1999).

3. Results

During the study period, a total of 20,958 t were landed. Of this total, 19,953 t corresponded to anchovy (94.3%), 1113 t to *C. plocamia* (5.3%) and 91.8 t to other fish species (0.4%) (Table 1). About 75% of the largest jellyfish catches were obtained in shallow waters, to a maximum distance of 9 km from the coast (Fig. 1). Jellyfish landings, although variable, tended to increase as the summer progressed (Table 1). The seasonal proliferation of *C. plocamia* in southern Peru occurs during spring and summer when sea surface temperature increases; moreover, medusae are larger during late summer (Quiñones, 2010).

Results from the interviews indicated that medusa bycatch diminished the profits the fishermen would have earned. In fact, all factories deducted the jellyfish weight when bycatch exceeded a certain percentage (Table 1). The deduction per ton of jellyfish landed equaled the value of one ton of anchovy, which was 160 US$ at the time of the study. All employees interviewed agreed that fishmeal processing might suffer a delay of approximately 20% if jellyfish bycatch was considered high, with the consequence of more energy consumed. Furthermore, when jellyfish bycatch exceeded 40% of the total landings, factories refused to receive the total catch, discarding also all the fish within it (Table 1).

4. Discussion

Coastal pelagic catches in Peru are mainly composed of anchovies and a few other pelagic fishes, e.g., the jack mackerel (*Trachurus murphy*, Nichols 1920) and the mote sculpin (*Normanichthys crockery*, Clark 1937), which cannot be discarded onboard. Fishermen usually sell the total catch to fishing factories. During the study period, jellyfish bycatch reached levels that affected the incomes of the fishermen. Although only 10% and 5% of all analyzed catches had >10% and >30% of jellyfish bycatch, respectively (Table 1), it was enough to produce economic loss to the fishermen. In total, 876.5 t that corresponded to jellyfish bycatch (>4% of total landing) were deducted at the factories. When total jellyfish bycatch overpassed 40%, then the total capture was discarded, anchovies included. This happened 13 times with a total anchovy discard of 387.4 t. When we applied 160 US$ deduction per ton landed (jellyfish and anchovies discarded = 1268 t), the estimated losses exceeded 200,000 US$ over the course of 35 days (Table 1) with an average individual ships loss of 5466 U$.

Our sampling occurred during a neutral phase of the Oceanic Niño Index (see NOAA, 2011), when normal seasonal abundance of jellyfish was expected, but even though enough to cause a negative economic effect for fishermen. Jellyfish bycatch greatly increases during El Niño warm periods and mostly during El Viejo warm phase/regime (Quiñones et al., 2010), when a single haul can catch more than 100 t of jellyfish (Quiñones, personal observations). It is expectable that significant economic loss to fishermen due to jellyfish bycatch will also increases during these events.

It must be noted however that our case study encompassed a short time period and was restricted to just one port covering about 17% of the total Peruvian fishing fleet. To what extent the estimated negative effects can be projected to the rest of the Peruvian fisheries, needs to be evaluated.

Table 1
Statistics of purse seines sampled during 5 weeks (W) between 17 December 2008 and 31 January 2009. Jellyfish and anchovy landings were grouped in 5 weeks (W): December third week (DEC 3 W) to January fourth week (JAN 4 W). The last week of December was not analyzed because few landings were registered. Factories deductions were applied when jellyfish bycatch was >13% as a critical value. Also, a 40% critical implied the discard of the whole catch (fish and jellyfish). Deducted values were given according to the price at the time of the study (160 US$ per ton of anchovy).

Sampled weeks	Factories sampled	Purse seine numbers	Anchovy landed (t)	Jellyfish landed (t)	# vessels >13% jellyfish (critical value)	Jellyfish landed >13% (t)	Discounted value 1(US$)	# vessels >40% jellyfish (anchovy discarded)	Anchovy landed (t) in >40% jellyfish	Discounted value 2 (US$)	Total Discounted value (US$)
DEC 3W	Factory #2 and 4	69	4580.5	89.3	0	0.0	0.0	0	0.0	0.0	0.0
JAN 1W	Factory #1,2,3 and 4	79	3800.8	91.4	6	57.7	9232.0	2	17.0	2720.0	11952.0
JAN 2W	Factory #1,2,3 and 4	75	3558.7	323.7	16	251.9	40302.8	5	124.6	19932.5	60235.3
JAN3W	Factory #1,2,3 and 4	112	4234.8	148.7	8	119.7	19146.3	0	0.0	0.0	19146.3
JAN4W	Factory #2,4 and 5	82	3577.9	459.5	7	447.2	71557.5	6	245.9	39338.4	110895.9
Total		417.0	19,752.7	1112.6	37	876.5	14,0238.6	13	387.4	61,991.0	2,02,229.5

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