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# Farming-up coastal fish assemblages through a massive aquaculture escape event

Kilian Toledo-Guedes [a,*], Pablo Sanchez-Jerez [b], María E. Benjumea [a], Alberto Brito [a]

[a] BIOECOMAC, Universidad de La Laguna, Dpto. de Biología Animal. Ciencias Marinas, Facultad de Biología, Av. Astrofísico Francisco Sánchez s/n, CP 38206 San Cristóbal de La Laguna, Santa Cruz de Tenerife, Canary Islands, Spain

[b] Department of Marine Sciences and Applied Biology, University of Alicante, Ap.C. 99, CP 03080 Alicante, Spain

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ABSTRACT

We investigated the changes on the mean trophic level of fish assemblages across different spatiotemporal scales, before and after a massive escape event occurred off La Palma (Canary Islands), which resulted in the release of 1.5 million fish (mostly *Dicentrarchus labrax*) into the wild. The presence of escaped fish altered significantly the mean trophic level of fish assemblages in shallow coastal waters. This alteration was exacerbated by the massive escape. A nearby marine protected area buffered the changes in mean trophic level but exhibited the same temporal patterns as highly fished areas. Moreover, escaped fish exploited natural resources according to their total length and possibly, time since escapement. New concerns arise as a "farming up" process is detected in shallow coastal fish assemblages where marine aquaculture is established.

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## 1. Introduction

Aquaculture of high-trophic-level (HTL) fish species is growing, especially in developed countries, as a result of a rising demand on these products and the highest profit obtained from carnivorous species (Deutsch et al., 2007). This process has been named "farming-up" (Pauly et al., 2001; Stergiou et al., 2009), and one of its major concerns is the exploitation of wild fish stocks to fed high trophic level species, called "tigers of the sea" by Naylor and Burke (2005). In addition, culturing non-native or locally absent fish species is already a frequent practice (Casal, 2006; Arismendi et al., 2009; Liao et al., 2010) that is predicted to grow in the next years (Shelton and Rothbard, 2006). Thus, as a result of both mentioned trends, in some areas, HTL species that were absent or with low abundances in natural habitats are being released into the wild through escape events. Technical failures and sea storms provoke both recurrent-small or punctual-massive escapes across the coasts where open-net cage aquaculture is established (Jensen et al., 2010). This process could be comparable to continuous restocking actions with non-indigenous or locally absent species (Lorenzen et al., 2012), which benefits have been pointed by some authors (Briggs, 2008; Schlaepfer et al., 2010) but are, in general, not recommended due to the unpredictable negative effects they could have (Courtenay et al., 2009; Ricciardi and Simberloff, 2009).

Many studies have pointed out potential and detected consequences due to the release of fish (exotic or not): genetic hybridisation (McGinnity et al., 2003); predation on native species (Albins, 2013; Green et al., 2012); competition for trophic resources (Declerck et al., 2002); introduction of parasites and diseases (Arechavala-Lopez et al., 2013); changes in fisheries dynamics (Dimitriou et al., 2007), among others. Recently, it has been demonstrated that marine ecosystems are much more susceptible to large-scale invasion pressures than previously thought (Edelist et al., 2013). But even if escaped fish do not establish self-reproducing populations, they may produce persistent impacts due to the repeated supply of propagules through new escape events (Arismendi et al., 2009; Jensen et al., 2010). Given the mobility of escapees (González-Lorenzo et al., 2005; Arechavala-Lopez et al., 2011, 2012), they could affect particularly important areas such as marine protected areas (MPAs). However, it has been suggested that MPAs could show some resilience (sensu Holling, 1973; "the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures",

* Corresponding author. Present address: Department of Marine Sciences and Applied Biology, University of Alicante, Ap.C. 99, CP 03080 Alicante, Spain. Tel.: +34 965909840, +34 922318387.
*E-mail addresses:* ktoledo@ua.es, ktoledo@ull.es (K. Toledo-Guedes).

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but see Gunderson, 2000 for a review of the concept) to the effects caused by different impacts, including species introduction, as assemblages within them are expected to have a better conservation state (Stachowicz et al., 1999).

In the Canaries, where finfish production in open-net cages during 2009 was 7910 tons (APROMAR, 2012), European sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*) have been introduced in some of the islands where no natural populations of these species existed (Brito et al., 2002; Toledo-Guedes et al., 2009). That is the case of La Palma Island, where a massive escape event occurred between December 2009 and January 2010. Repeated northwest sea storms generating waves up to 6 m height resulted in both lack of maintenance operations and increased mechanical stress for aquaculture facilities (Ramírez et al., 2011; Puertos del Estado, 2012). As a result, around 1.5 million fish (90% sea bass and 10% sea bream) were released into the wild during that period (Ramírez et al., 2011). A previous study revealed that escaped fish entered a nearby (~15 km) MPA and their abundances within were similar to those found in other areas of the island (Toledo-Guedes et al., 2014). As far as we know, this is the largest sea bass escape event documented to date worldwide.

We capitalize on this event to examine the potentiality of escaped fish to alter the mean trophic level (mTrL) of fish assemblages in shallow coastal waters and discuss the potential consequences of these changes. In particular we studied i) if fish assemblages mTrL was affected by the massive escape of HTL fish, ii) if the magnitude in mTrL alteration was related to the presence of an MPA and iii) the trophic role of escaped sea bass in coastal waters. For that we analyse the spatiotemporal variation of mTrL before and after the massive escape event, using the estimation of fish abundances and size by visual census in shallow coastal waters, and additionally we studied the diet of fugitive sea bass, in relation to size, through stomach content analysis.

## 2. Material and methods

### 2.1. Study site and sampling effort

Our study was carried out in La Palma (Fig. 1), one of the westernmost islands of the Canarian archipelago, situated in the north-eastern part of the Central Atlantic (28°40′N, 17°52′W). Aquaculture facilities are in a single location off the western coast. A marine protected area (MPA) is situated 15 km to the south from fish farms.

A total of 6 localities (Fig. 1), and three sites ($n = 6$) in each locality, were sampled by means of visual census (see next section), at different distances from release point (0.8–30 km). Three of the localities were situated in La Palma MPA, the other three, outside the MPA, were considered as highly fished areas (HFA) following Sangil et al., 2013a. Each locality was sampled four times: March 2009, October 2009, March 2010 and October 2010. A total of 432 visual censuses were carried out through the study.

### 2.2. Visual censuses

Based on previous methodology (Toledo-Guedes et al., 2009), snorkelling visual censuses of escapees were performed in transects of $100 \times 5$ m, between 1 and 5 m depth. In the initial 25 m, all the fish species abundances and sizes were recorded, while across the rest of the survey only escaped fish were counted. A second pass

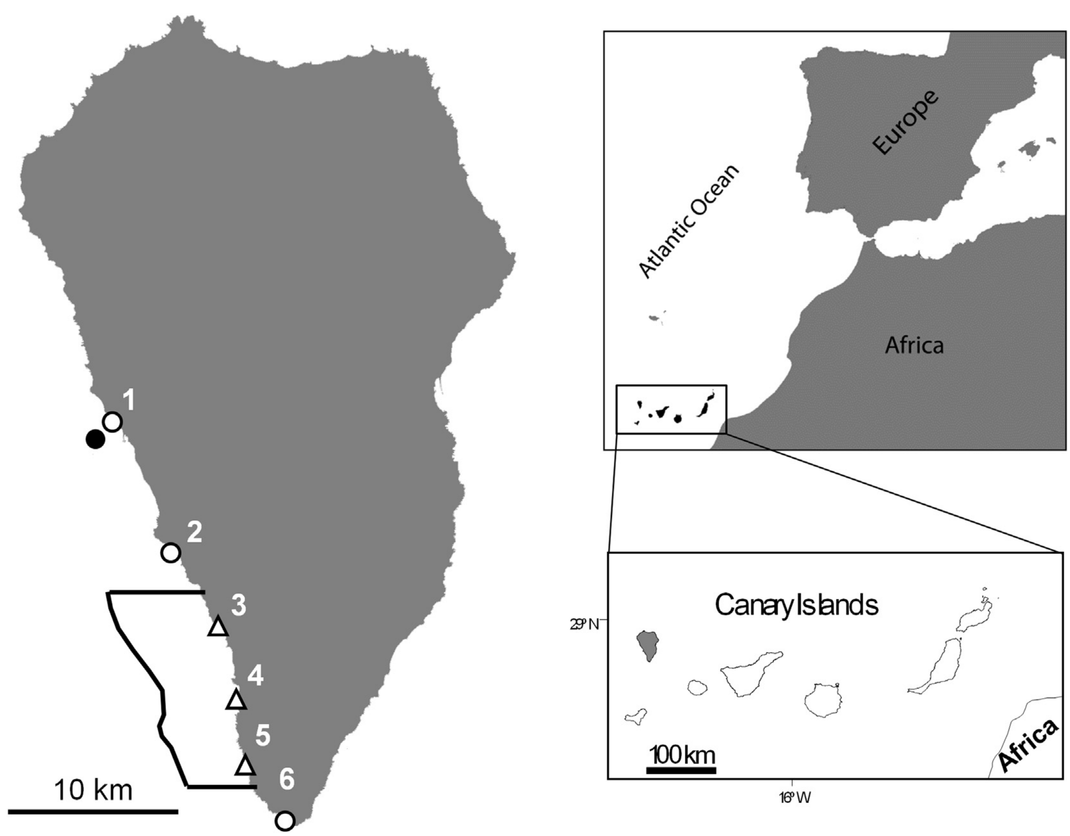


**Fig. 1.** Study area. Black circle: aquaculture facilities/release point. White circles: localities sampled outside La Palma MPA. White triangles: localities sampled at MPA. Black line: limits of La Palma MPA.

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