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Short communication

Direct observation of Chilean hake (*Merluccius gayi gayi*) behaviour in response to trawling in a South Central Chilean fishery

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A B S T R A C T

The behaviour of Chilean hake (*Merluccius gayi gayi*) in a bottom trawl was observed with an underwater camera positioned in the trawl mouth and in the front of the codend extension. Significant differences were observed in the fish behaviour in the two sections, demonstrating that this species is more active in the mouth of the net. The fish activity was lower in the trawl extension, where the fish were merely carried by the flow into the net.

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1. Introduction

Optical and acoustical systems, set at the depth and light levels at which the commercial fleets operate, have allowed direct observations of fish behaviour (Graham et al., 2004) regarding their response to towed trawls (Glass and Wardle, 1995; Piasente et al., 2004) and to the herding and escape responses to selective systems (Grimaldo et al., 2007; Kim et al., 2008). However, the information gathered is still too scarce to adequately inform behavioural differences among species.

Chilean hake (*Merluccius gayi gayi*, Guichenot, 1848), the main demersal fishery resource in the South Central Chilean coast, is distributed along the Chilean coast from 23° 39′S to 47° 00′S between 50 and 500 m deep and is associated with the subsuperficial equatorial waters. In recent years, a marked increased of the proportion of juveniles in the fishing areas has been reported (Lillo et al., 2006), particularly from 2005 to 2007, when more than 50% of catches were under the mean size at maturity (ca. 37 cm) (Gálvez et al., 2008). To avoid growth overexploitation and discards in this fishery, square mesh devices have been implemented to allow the release of juveniles (Queirolo et al., 2008). The current study aims to contribute to understanding how hakes behave in relationship to trawls so that a suitable selection system for this species can be developed.

2. Materials and methods

The system used was a programmable underwater camera with a 600 m immersion capacity, encompassing three interconnected modules: the camera film, power and light source. A Sony Handycam miniDV model DCR-TRV17 was employed to film and record with the power supplied by a rechargeable 12-V battery. The illumination consisted of two 30 W stainless steel halogen lamps with Xenophot light bulbs. To optimise the film during the hauls, a controller plate was used with a cyclical scheduled sequence of 5 min of recording and 10 min of waiting, completing three sequences per tow. The towing duration was variable, ranging from 50 to 75 min, and the first recording sequence started 10 min after the trawl was on the bottom in each tow.

The observations *in situ* of Chilean hake were made during daylight aboard a commercial fishing vessel in August 2005, at a depth range between 300 and 330 m in the fishing grounds (36° 30′S–37° 00′S). A two-panel demersal trawl was used with 53 m of head line, 86 m in total length and a 100 mm internal mesh size in both the extension and the codend. Five films of 15 min each were made. In the first film, the camera system was located at 2 m in the front of the extension section on the upper panel (Fig. 1). In the remaining films, the camera system was located at the mouth section on the lower panel set on the rockhopper. In all of the films, the camera was focused forward to the trawl gear. The mean towing speed was 4.0 kn (range: 3.7–4.3 kn).

The categories defined by Piasente et al. (2004) were adopted to describe the Chilean hake behaviour. These authors used 10 categories to classify the behaviour of these species, including the swimming behaviour and the direction and estimated speed of the fish relative to the towing speed. Each behavioural category was

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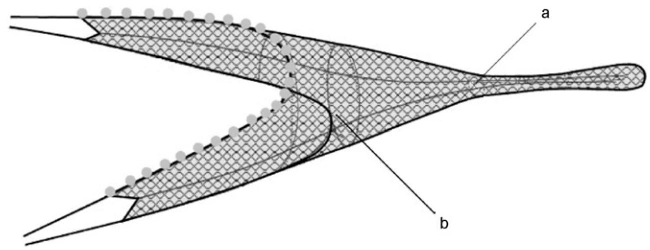

Fig. 1. Camera locations in the demersal trawl gear: (a) mouth and (b) extension. Modified from Pol (2003).

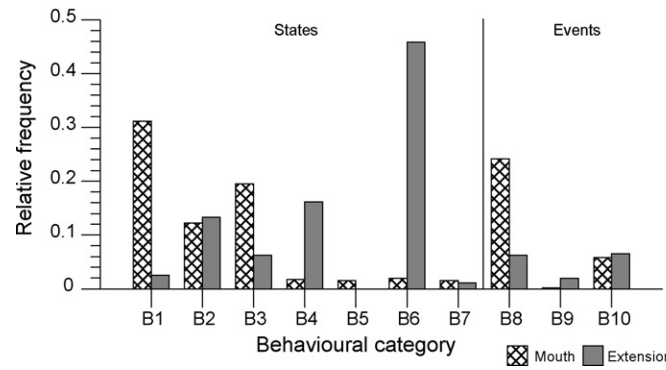

Fig. 2. Relative frequencies of Chilean hake records in the mouth and in the extension of the net by the behavioural category.

recorded as either an "event" or a "state", in which an "event" is defined as a discrete instantaneous action such as a burst swim or turn and a continuous action of longer duration such as cruise swimming is defined as a "state" (Lehner, 1996). The relative frequency of each of the 10 categories of fish behaviour was recorded for the total observations according to the location of the camera system in the trawl net (Table 1).

A Kolmogorov–Smirnov non-parametric analysis was performed to test for significant differences in the frequency distributions between the observed behaviour in the mouth of the net and in the extension at $\alpha = 0.05$. The comparative frequencies of the occurrence in the mouth and extension sections were also established, revealing the dominant behaviour in each section. A representative sample for each film was obtained by randomly checking the different films for each haul because the number of fish observed was too high. The film viewing ended when the increase in the sample size did not generate a significant change in the relative frequencies of the observed behaviour.

3. Results

A total of 513 records were filmed in the mouth of the net, and three main "states" were identified in relation to the trawl speed: "faster" (B1 = 31%), "same" (B3 = 19%) and "slower" (B2 = 12%) (Table 1; Fig. 2). The most important "event" was burst swimming with a vigorous and intense but brief high-speed response (B8 = 24%). In 6% of the total records, burst movements were observed when the fishes made one or more turns which resulted in a change of swimming direction (B10) (Fig. 2).

In the net extension, 353 records were used to classify the behaviour. The highest relative frequency was the "resting state" (B6 = 46%) followed by the cruise swimming states, i.e., "unknown" (B4 = 16%), "slower" (B2 = 13%) and "same" (B3 = 16%) (Table 1; Fig. 2). The "events" in the net extension were mainly represented by burst speed changes (12%), with a fraction of fish maintaining their swimming direction and some changing direction (B8) and turning (B10) (Fig. 2).

Significant differences were found in the frequency distribution of the fish behaviour between both sections (P value <0.001). In the mouth, a greater relative proportion of the cruise swimming states that were "faster" (B1) or at the "same" towing speed (B3) was observed. In the net extension, the resting behaviour (B6) and cruise swimming at unknown speeds (B4) were important (Fig. 3). Comparatively, in the front section of the net, more vigorous reactions of the fish were observed, while the passive state was the dominant fish behaviour in the extension.

4. Discussion

The observations made in the current study showed that the swimming speed capacity of Chilean hake was considerably higher in the trawl mouth and remarkably low in the extension. These facts are consistent with previous observations that most fish that enter the trawl mouth exhibit an optomotor response and swim with

Table 1
Categories of fish behaviour used in examining the response of Chilean hake to trawl nets.

Behaviour	Type	Swimming speed[a]	Swimming direction[b]	General description	Code
Cruise swimming	State	Faster	Forwards	Fish swimming with a steady tail beat frequency faster than the trawl in the towing direction	B1
Cruise swimming	State	Slower	Forwards	Fish swimming with a steady tail beat frequency slower than the trawl in the towing direction	B2
Cruise swimming	State	Same	Forwards	Fish swimming with a steady tail beat frequency at the same speed as the trawl in the towing direction	B3
Cruise swimming	State	Unknown	Unknown	Fish swimming with a steady tail beat frequency at an unknown speed and towing direction	B4
Cruise swimming	State	Slower or same	Turn	Fish performing a slow movement resulting in a change in orientation or direction after the response is performed	B5
Rest	State	None	None	Fish motionless, resting on panel of netting or observed drifting back toward the codend	B6
Impigned	State	None	None	Fish impinged on panel of netting or against other fish in the codend	B7
Burst swimming	Event	Faster	Forwards or backwards	Fish swimming with a high tail beat frequency, a vigorous and intense but brief high-speed response	B8
Burst swimming	Event	Faster	Random but strikes trawl netting	Fish performing a burst swim resulting in contact with the trawl net	B9
Burst swimming	Event	Faster	Turn	Fish performing a burst swim resulting in a change in orientation or direction after the response is performed	B10

Adapted from Piasente et al. (2004).
[a] Relative to the towing speed.
[b] Relative to the towing direction.

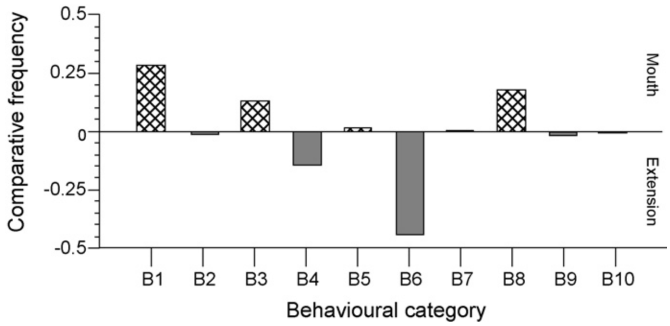

Fig. 3. Comparative frequencies of the records of Chilean hake behaviour in the mouth and extension.

the gear, with an increased ability to maintain the cruise speed behaviour in the front section (Watson, 1989). The results have led to the understanding of the main behaviour of Chilean hake in trawl nets. This species is more active in the mouth of the net than in the extension, which suggests that selective systems might be more efficient in the front section of the trawl. Others factors such as the fish size, light effect, capture efficiency, turbidity and reproductive stages (Webb, 1975; Weinberg and Munro, 1999; Olla et al., 2000) that have not been studied yet could also influence the Chilean hake behaviour in towed trawls and should be further researched.

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