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Short Communication

Experimental study of ghost fishing by gillnets in Laguna Verde Valparaíso, Chile

Dante Queirolo[1] & Erick Gaete[1]
[1]Escuela de Ciencias del Mar, Facultad de Ciencias del Mar y Geografía
Pontificia Universidad Católica de Valparaíso, P.O. Box 1020, Valparaíso, Chile

ABSTRACT. In 2010, two experiments were carried out in order to study ghost fishing generated by lost or abandoned gillnets. The first experiment was aimed to identify and quantify the number of captured specimens in intentionally abandoned gillnet between 45 and 86 m depth, which were periodically checked up to 156 days after being abandoned. In this experiment, 912 specimens of 12 taxa were caught, mostly invertebrates such as *Cancer porteri* (81.6%) and *Platymera gaudichaudii* (9%). After the abandonment, the fish caught were only registered until day 63, while benthic species were captured during all the experiment. The second experiment consisted of checking and registering periodically the loss of height of an abandoned gillnet at 34 m depth in order to determine the reduction of the fishing capacity of the net. After 19 days of abandonment, the functional area of the net was reduced to 40% of the original area, reaching nearly zero after 155 days of abandonment. In order to estimate the potential effect of lost or abandoned gillnets in Chilean hake fisheries (*Merluccius gayi gayi*), an additional information-collecting process must be carried out, mainly in terms of frequency of gillnets losses.

Keywords: ghost fishing, gillnet, artisanal fishery, Chile.

Estudio experimental de pesca fantasma por redes de enmalle en Laguna Verde Valparaíso, Chile

RESUMEN. Se realizaron dos experimentos en 2010 para estudiar la pesca fantasma que generan las redes de enmalle luego de ser perdidas o abandonadas. El primer experimento tuvo por objetivo la identificación y cuantificación de ejemplares retenidos en redes abandonadas intencionalmente entre 45 y 86 m de profundidad, las que fueron revisadas periódicamente hasta 156 días luego de su abandono. En este experimento se capturó un total de 912 ejemplares pertenecientes a 12 taxa, en su mayoría invertebrados como *Cancer porteri* (81,6%) y *Platymera gaudichaudii* (9%). Sólo se registró la captura de peces hasta el día 63 luego del abandono, mientras que especies bentónicas fueron capturadas durante todo el experimento. Por su parte, el segundo experimento consistió en revisar y registrar periódicamente la pérdida de altura de una red de enmalle abandonada a 34 m de profundidad para conocer la reducción de la capacidad de pesca de la red. A los 19 días luego del abandono, el área funcional de la red se redujo al 40% del área original, y llegó prácticamente a cero al cabo de 155 días de abandono. El levantamiento de información adicional debe ser realizado para estimar el efecto potencial de las redes perdidas o abandonadas en la pesquería de merluza común (*Merluccius gayi gayi*), especialmente en términos de la frecuencia de pérdida de las redes de enmalle.

Palabras clave: pesca fantasma, enmalle, pesca artesanal, Valparaíso, Chile.

Corresponding author: Dante Queirolo (dante.queirolo@ucv.cl)

Gillnets are considered as an environmentally friendly fishing gear due to its proper size selectivity (He & Pol, 2010). However, they can have a negative impact on other vulnerable species and produce ghost fishing due to lost or abandoned gillnets (Rihan, 2010). In this sense, ghost fishing is a global concern since lost or abandoned fishing gear can keep generating unquantified mortality during weeks, months or even years depending on the construction of nets, operational depth and environmental conditions (Tschernij & Larsson, 2003; Matsuoka *et al*., 2005; Brown & Macfadyen, 2007; Suuronen *et al*., 2012). Due to the negative impact on species and environment, the FAO's code of conduct for responsible fisheries points out that states should cooperate to develop and apply technologies, materials and operational methods that reduce fishing gear losses and the ghost fishing effects of lost or abandoned fishing gear.

In this way, Matsuoka *et al*. (2005) suggest that the change of the mortality in time due to ghost fishing after nets have been lost or abandoned should be examined. Accordingly, different authors have experimentally quantified ghost fishing in gillnets (*e.g.*, Erzini *et al*., 1997; Santos *et al*., 2003, 2009; Tschernij & Larsson, 2003; Akiyama, 2010), through which they have estimated retention equations according to the time nets have been in the sea.

In the Chilean hake (*Merluccius gayi gayi*) artisanal fishery is mainly carried out using gillnets at depths between 25 and 200 m (Queirolo *et al*., 2013). In 2012, more than 900 vessels participated in this fishery between the regions of Coquimbo and Los Lagos (29º02'-41º28.6'S), where 90% were boats and 10% were small-decked vessels. The total number of registered vessels in fishery is 2445 (SUBPESCA, 2011). However, there are no surveys to know the existence of lost or abandoned nets, nor about the potential effect of ghost fishing of nets among other species. In this fishery, 24 taxa have been identified as by-catch of Chilean hake in gillnet, mainly crustaceans such as crabs and squat lobster (Queirolo *et al*., 2014).

Based upon the foregoing, the objective of this investigation consisted of quantifying the capture produced by a lost gillnet and calculating the rate of decline in its fishing capacity over time in the coast of central Chile. In this way, two experiments were carried out in the area of Laguna Verde (33º06'S, 71º41'W) in the region of Valparaíso.

The first experiment consisted of quantifying the capture in abandoned nets in the sea. Five 63 m experimental gillnets were constructed and deployed perpendicular to the coast, between 45 and 86 m of depth and separated 250 m each. The nets were randomly lifted up at different periods of time after being abandoned, over a total period of 156 days. Two nets were reused during the experiment after quantifying their capture and being completely cleaned, starting again from zero the abandonment time of deployment. All specimens caught in each net were classified and quantified in number.

The second experiment consisted of checking and registering periodically the height of an abandoned gillnet. This information was used as a proxy value to calculate the reduction in the fishing capacity of the net. In this case, an individual net was deployed at 34 m depth to allow for inspection through diving and underwater filming. This net was abandoned in the sea during 115 days, and it was inspected approximately every 20 days. During each diving, the general condition of the net was checked and its height was calculated in various sections, approximating in this way the functional area in relation to the original area.

All gillnets used in both experiments were constructed according to the features of the nets used by artisanal fishermen of Valparaíso in daily fishing, with the exception of the total length, which was restricted to 63 m to avoid excessive mortality. The length of the commercial nets is normally between 400 and 1200 m. In the construction, 52 mm mesh size net of green polyamide monofilaments and 0.3 mm diameter were used. The height of the nets was 50 meshes. Flotation was provided by floats pieces and ballast by 35 weights of 130 g each. The hanging ratio, that is, the relation between the length of the headline and the length of the stretched mesh, was 0.5.

The capture of the abandoned gillnets was registered seven times (t = 13, 42, 52, 63, 106, 116 and 156 days of abandonment in the sea), obtaining a total of 912 specimens of 12 taxa. The highest proportion (n = 879; 84.7%) corresponded to invertebrates (crustaceans n = 851; mollusks n = 24; order Pantopoda n = 4) while fish represented a lower portion (n = 33; 15.3%) (osteichthyes n = 30; chondrichthyans n = 3) (Table 1). By taxa, the most abundant were *Cancer porteri* (n = 744; 81.6%), *Platymera gaudichaudii* (n = 82; 9.0%), *Merluccius gayi gayi* (n = 25; 2.7%) and *Aeneator* sp. (n = 24; 2.6%).

The capture was notoriously reduced in time, decreasing from 279 caught specimens at 13 days of abandonment to 25 specimens at 156 days of abandonment. Only during the first part of the experiment fish capture was registered (until 63 days of abandonment), while during the second part, only the capture of crustaceans and mollusks was reported. Exponential curves were adjusted to the data of the total capture and to the capture of the most abundant species (*C. porteri*) (Fig. 1) showing the reduction of the effect of abandoned nets according to the time.

During second experiment, five diving immersions were carried out after the abandonment of the gillnet (t = 1, 19, 42, 64 and 115 days in the sea). After 19 days of abandonment, the functional area of retention reduced to 40% of the original area, decreasing to 25% after 42 days of abandonment. After 64 days, the functional area did not exceed 10% of the original area, practically reaching zero after 115 days of abandonment. In this way, according to the time, a reduction of the height of the net was verified, from where it was possible to fit an exponential curve that represents the loss of the relative capture efficiency of the net (Fig. 2).

Although the fits show the existence of an exponential reduction on captures and on the relative capture efficiency, the time during the nets continued their action showed some difference. The nets deployed in deeper areas (Experiment 1) showed the capture of specimens during a longer time and the projection shows

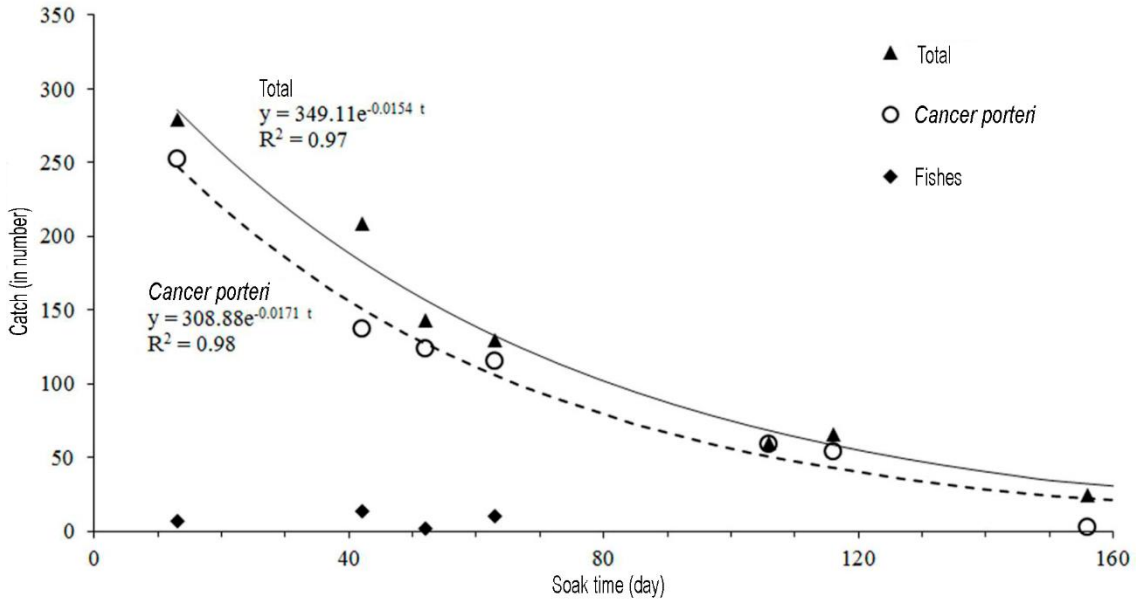

Figure 1. Capture of the lost gillnets during a period of 156 days and fitted models in terms of the number of specimens.

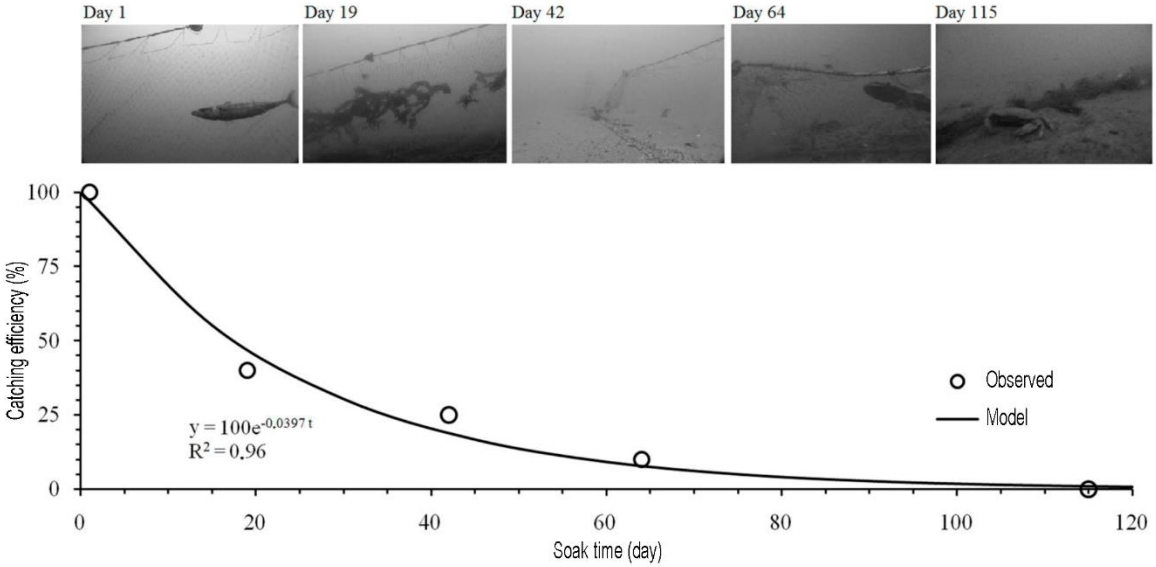

Figure 2. Relative catching efficiency of lost gillnets estimated from the functional area observed by underwater filming records.

that after 300 days, the capture would be less than 1% in comparison to a recently deployed net. On the other hand, the deployed net in a shallow area (Experiment 2) lost capture efficiency faster. This difference can be explained by the higher presence of particulate material and detritus in shallow waters and the high influence of the bottom currents (Erzini *et al*., 1997; Santos *et al*., 2009), which contributes to increase the weight of the net and its hydrodynamic resistance compared to deeper areas.

In comparison, the results of this investigation show that the reduction of the capture rate in time ($e^{-0.0154*t}$) is similar to the one reported by Ayaz *et al*. (2006) and Akiyama (2010) in monofilament gillnets, corresponding to $e^{-0.0127*t}$ and $e^{-0.0158*t}$, respectively, ratifying that lost or abandoned gillnets in the sea produce a decreasing mortality of different species during almost a year. Nevertheless, the nets loss height and increase their visibility due to fouling, then the capture of pelagic and demersal species decreases gradually, cap-

Table 1. Number of specimens caught by taxa in the experimental gillnets.

Taxa	Time after abandonment (days)							Total
	13	42	52	63	106	116	156	
Chondrichthyes								
Schroederichthys chilensis	1		2					3
Osteichthyes								
Thyrsites atun		1						1
Ophichthus remiger	2							2
Prolatilus jugularis	1							1
Merluccius gayi gayi	2	13		10				25
Congiopodus peruvianus	1							1
Mollusks								
Aeneator sp.	1			2			21	24
Crustaceans								
Cancer porteri	252	137	124	115	59	54	3	744
Homalaspis plana			8					8
Platymera gaudichaudii	18	41	7	2	1	12	1	82
Pleuroncodes monodon		17						17
Pycnogonida								
Order Pantopoda	1		2	1				4
Total	279	209	143	130	60	66	25	912

turing at the end, only benthic species (Ayaz *et al*., 2006; Santos *et al*., 2009).

In order to reduce the ghost fishing, some alternatives have been proposed, such as the use of biodegradable materials in some sections of the fishing gear to partially disable gillnets (Matsushita *et al*., 2008). In particular, the most viable is for floats to be united to the headline using cotton threads, being essential to know the degradation rate of the fiber. Depending on the scale of the problem, other more complex measures such as restricting the size of the nets and reducing the deployment time should also be considered, in order to mitigate the ghost fishing (Santos *et al*., 2009). However, it is recognized that the best solution is to avoid the loss or abandonment of gillnets, or to take the proper measures promptly to obtain a fast recuperation (Suuronen *et al*., 2012).

The Chilean hake corresponds to an overexploited resource with a high risk of stock depletion (CCT-RDZCS, 2013), so it is recommended to carry out a detailed information-collecting process about the frequency and quantity of annually lost or abandoned nets in fishing areas in order to estimate the ghost fishing generated over the target species and associated species. In this way, the operation regime can be one of the most relevant variables that affect the risk of loss fishing gears. Queirolo *et al.* (2011) indicate that undecked boats usually stay in the fishing area from the setting to hauling, and the soak time of the nets is less than two hours, therefore there is a low probability of loss. However, in the southern area of the fishery operate small-decked vessels using longer gillnets, which are left in the sea bottom for about 24 h unsupervised, increasing the risk of losing them. Due to the above, an information-collecting process aimed to solve this problem and also to conduct experiments in other representative areas and depths of the fishery are recommended.

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