Sustainable Maritime Transportation and Exploitation of Sea Resources – Rizzuto & Guedes Soares (eds)
© 2012 Taylor & Francis Group, London, ISBN 978-0-415-62081-9

Assessment of fishing gear impact and performance using Sidescan sonar technology

A. Lucchetti, M. Virgili, F. De Carlo & A. Sala
Consiglio Nazionale delle Ricerche—Istituto di Scienze Marine (CNR-ISMAR), Ancona, Italy

ABSTRACT: The increased sensibility of the International scientific community toward the exploitation of fishery resources, promoted the development of new technologies to study the behaviour and the impact of fishing gears on seabed. In the last ten years the physical disturbances caused by trawling has been widely investigated by using the sidescan sonar technology. In the Mediterranean, changes to marine habitats that are caused by fishing are most pronounced in otter trawls, Rapido and hydraulic dredge fisheries. Sidescan sonar technology permitted to identify these fishing gears impact. Hydraulic dredges and Rapido trawls are basically similar in their seafloor impact by flattening and ploughing seabed features. While the effects of otter trawling varies greatly depending on the amount of gear contact with the bottom, together with the depth, nature of the seabed, and the strength of the currents or tide. Generally otterboards imprint distinct tracks on the seabed, ploughing a groove which can vary from a few cm up to 30 cm deep. Also the present work suggests a further step in using this technology, by analyzing in real time the behaviour, the geometry and the performance of different fishing gears in addition to quali-quantitative evaluation of their impact on the seafloor.

1 INTRODUCTION

The increased sensibility of the International scientific community toward the exploitation of fishery resources, promoted the development of new technologies to study the behaviour and the physical impact of fishing gears on seabed. At the moment the most widespread technology for the evaluation of these physical effects is the "acoustic imaging" mainly through the sidescan sonar technology (Franceschini *et al.*, 2002; Smith *et al.*, 2007). During the past few decades the impact on marine ecosystems due to fishing activities got a growing degree of interest and it became important in crucial considerations on environmental management plans (Hall, 1999; Kaiser, 2002; Hiddink *et al.*, 2007). In the Mediterranean, changes to marine habitats that are caused by fishing are most pronounced in bottom trawl (Demestre *et al.*, 2000), dredges (Morello *et al.*, 2005), rapido and beam trawls fisheries (Pranovi *et al.*, 2000; ICES, 2003).

Bottom trawling impact on the benthic habitat differs among the various bottom trawl fisheries and it also depends on the bottom conditions in the area fished (Valdemarsen *et al.*, 2007). Different damage are observed on bottom community: furrows and scars left by otterboards, seabed scouring and flattening by ground rope and weights, and sediment removing and suspension. In the past, earlier studies of trawl performance were performed by scuba divers direct underwater observations. Despite the clear and immediate overview offered by these kind of methodologies, they did not allowed to investigate bottom areas under 60 m (Caddy J.F., 2000). In the last ten years the physical disturbances caused by trawling has been widely investigated by using the sidescan sonar technology (e.g. Schwinghamer *et al.*, 1998; Thrush *et al.*, 1998; Tuck *et al.*, 1998; Humborstad *et al.*, 2004). Friedlander *et al.* (1999) showed that sidescan sonar can be used to assess trawling impacts over a wide area. Physical changes due to trawling, such as trawl marks, are visible with sidescan sonar imaging systems as tracks (otterboard, dredge and net marks) across the seabed.

In previous studies sidescan sonar has been mainly used for geological surveys or in fishing effort assessment by detection and quantification of the furrows traced by bottom trawls on a georeferenced area of the seabed.

The present work suggests a further step in using this technology, by analyzing in real time the behaviour, the geometry and the performance of different fishing gears in addition to quantitative evaluation of their impact on the seafloor. Traditionally, the trawl geometry is taken under control by using small acoustically linked sensors mounted on the net and on the otterboards, which communicate with the ship via hydrophone/s mounted on the hull (Sala *et al.*, 2009). Nevertheless it is not possible to monitor some important parameters, such as the attack angle of otterboards, that is the angle comprised between the tow direction and the main side of the otter trawl, because no acoustic sensors or other technology are available for this.

The attack angle is essential for the understanding of trawl behaviour, hydrodynamic drag, fuel consumption and bottom impact, nevertheless it could be defined only in flume tank tests or after computing complex formulas (Sala *et al.*, 2009).

2 MATERIALS AND METHODS

2.1 *Fishing gears investigated*

In the current study the physical impact and the performance of the commercial hydraulic dredge, rapido trawl, and two types of Italian bottom trawls have been monitored through a Sidescan sonar technology. The infaunal bivalve *Chamelea gallina* is the target of a large fleet of **hydraulic dredgers** operating in the sandy coastal bottoms (depth of 3–12 m) of the northern and central Adriatic Sea (Italy). The commercial hydraulic dredge comprises a 3 m wide rectangular cage weighing 0.6–0.8 tonnes, mounted on two sledge runners to prevent it from digging into the substratum to a depth of more than 4–6 cm (Morello *et al.*, 2005). The front of the cage is connected by a hose to a centrifugal water pump that ejects water under pressure (1.2–1.8 bar) from the nozzles at the mouth of the dredge and inside the dredge cage (Morello *et al.*, 2005). Once suitable fishing grounds are reached (depth of 3–12 m), the dredge is lowered from the bow and the vessel moves astern, warping on a big anchor for a variable distance depending on how much cable is paid out (Morello *et al.*, 2005), or by using the propeller.

The **Rapido** is a towed gear used only in the Adriatic Sea for fishing pectinids (*Pecten jacobaeus*) in sandy offshore areas and flatfish (*Solea* spp*., Platichthys flesus, Psetta maxima, Scophthalmus rhombus*) in muddy inshore areas, but little is known about the environmental impact of this gear (Hall-Spencer *et al.*, 1999; Pranovi *et al.*, 2000). Modern Rapido gear resembles a toothed beam trawl. The gear consists of a box dredge (3 m wide, 120 kg) rigged with teeth (5–7 cm long) along the lower leading edge and a net bag to collect the catch (Giovanardi et al., 1998). During fishing, the gear is towed at high speed (7 knots), with a spoiler that prevents the gear from rising off the bottom (Pranovi *et al.*, 2000). A commercial vessel typically tows four sets of gear simultaneously.

Bottom trawling (otter trawling) is the most important fishing sector in Italy in terms of fleet dimension, fishing power and incoming. The traditional Italian commercial trawl (*Volantina*, in Italian) is a commonly entirely made up of knotless polyamide netting. The trawl net is a typical asymmetric two-faces net. In the last 5–6 years several Italian bottom trawlers switched their activity from the traditional trawl to a new trawl configuration, so called *Americana*. The Americana net is a four-faces trawl, manufactured with both knotless-PA and knotted-PE netting. Some other changes have been introduced to increase the bosom height and the possibility to tow one or two nets (twin trawls), such as net made with more advanced rules and drawing designs, very short bridles, etc.

2.2 *Sidescan sonar surveys*

Sidescan sonar trials were conducted on fishing grounds of the Central Adriatic normally exploited by local fishermen. The trials took place from 23 to 25 March 2010 off Ancona coast, on board of the Italian Research Vessel RV "G. Dallaporta". The Sidescan sonar system used comprised a Sonar DeepEye 670 kHz towfish (DE670) with a horizontal and vertical beam of 0.9° and 60° respectively, surface unit 12 V (SU1-232), Kevlar coaxial cable 200 m (STC-200), rugged PC touch screen connected to a DGPS system (Garmin GPS).

Following the recommendation of Smith *et al.* (2007), weighted rope (10 m, weighing 10 kg) was attached to the cable in front of the towfish to act as a cable depressor. All sidescan trials were carried out with 50–70 m range on each side, giving a resolution of around 2 cm. The towfish was deployed over the stern of the RV Dallaporta, and counting marks on the cable were used to determine the amount of coaxial wire paid out. Track recording began when the fishing vessel was few hundred meters stern of the towfish. Normal operating height was around 5 m above the seabed, and towing speed was 2–2.5 knots.

During trawling operations, due to higher speeds (4–7 knots), the fishing vessel overcame the RV Dallaporta along the axis of towfish towing. Such parallel pass survey design properly permitted to detect trawl and otterboard marks that ran approximately parallel to the survey track. This made it suitable for quantitative assessment of the dimensions of trawl marks and gear performance, although a simple visual inspection of the sonar images did provide a reasonable qualitative assessment.

2.3 *Sidescan sonograms processing*

Detailed analysis of the sonograms was carried out ashore using the DeepView SE 2.2 software.

In playback in the laboratory, each sidescan track was investigated for measuring the width and height of the different trawl and otterboard marks. Measurement of gear parameters such as otterboard spread and horizontal net opening were also detected. A successful attempt was made to quantify the otterboard attack angles through the video analysis software Image Pro Plus v.4.5.1.

3 RESULTS

The analysis of the sidescan sonograms permitted for the first time to study both the performance of fishing gears and bottom impact. Marks left by fishing gears were very evident as furrows along the sediment surface. The images from Figures 1–5 are screenshots from the sidescan tracks.

3.1 *Hydraulic dredge*

The monitoring of hydraulic dredges took place in an area close to the Ancona coast characterized by shallow waters (3–10 m). Sidescan sonar records showed evidence of considerable physical disturbance in the surveyed area, with tracks criss-crossing the area (Figure 1). During the survey, the poor stability of the towfish and the turbulence noise (both from strong tidal flow and the vessel's propeller) was a problem and often obscured the sidescan acquisition completely in areas of low acoustic reflection. Also the resuspended sediments, disturbed the sound transmission and often determined low quality sonograms. Only few sonograms recorded when the resuspension ended permitted an identification of the furrows left by the dredge on the bottom. As showed in Table 1 and Figure 1, the furrows have an average height of 10 cm and a width of 3 m, equivalent to the dredge width.

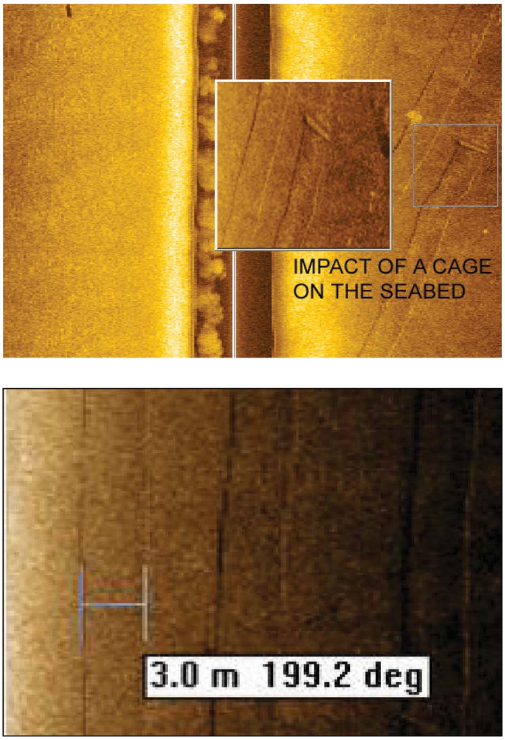


Figure 1. Sidescan sonar sonograms of hydraulic dredging marks (up) and width (down) of furrows left by the dredge on the seabed.

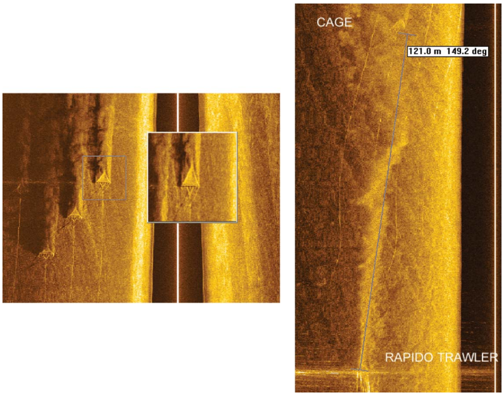


Figure 2. Sidescan sonar sonograms of Rapido trawling marks. Four Rapido trawls towed simultaneously by a commercial vessel (left) and furrows left by Rapido on the seabed (right).

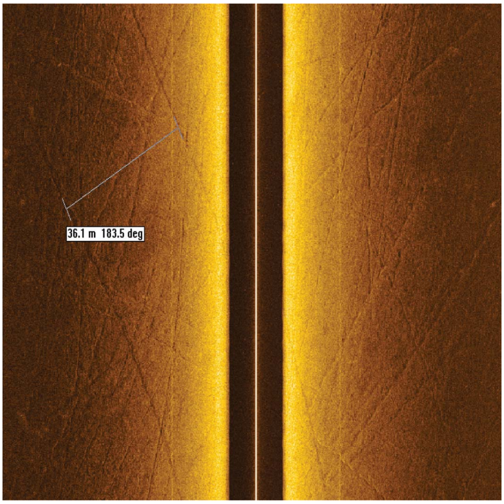


Figure 3. Sidescan sonar sonograms of otter trawling marks and measure of the distance between two doors.

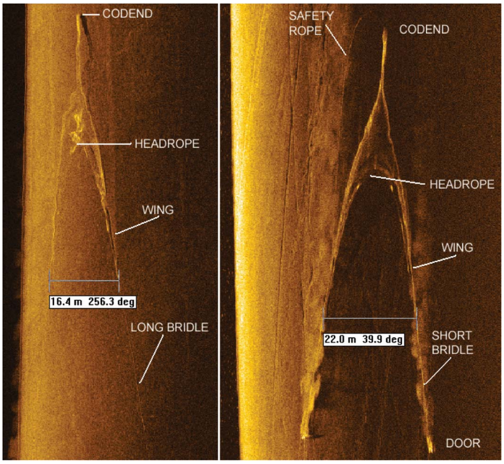
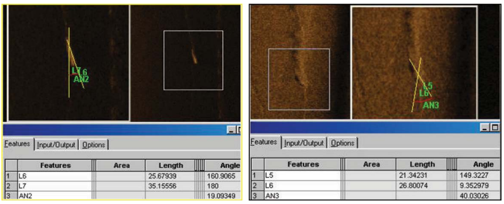


Figure 4. Sidescan-sonar images of a traditional bottom trawl net Volantina (left) and an Americana net (right). The horizontal openings (distance between the wings) are also reported.



	Features	Area	Length	Angle
1	L6		25.67939	160.9065
2	L7		35.15556	180
3	AN2			19.09349

	Features	Area	Length	Angle
1	L5		21.34231	149.3227
2	L6		26.80074	9.352979
3	AN3			40.03026

Figure 5. Comparison of otterboard attack angles between the Volantina (left) and the Americana (right) trawl gear, obtained by the video analysis software Image Pro Plus v.4.5.1.

3.2 *Rapido trawl*

Compared to the hydraulic dredge the survey of Rapido trawl was performed in deeper waters (22–24 m). In these conditions the sonograms were relatively clearer and more assessable. Evidence of the resuspension of sediments, i.e. turbidity clouds, can be easily identified from these observations (Figure 2). When towing speeds dropped below 6 kn, the towing warp and bridle periodically came into contact with the seabed, stirring up sediment ahead of the gear. The furrows left by Rapido trawls are 4 m in width, equivalent to the dimension of the frames, and 10 cm in height (Table 1). The teeth of the Rapido projected their full 7 cm length into the sediments and redistributed the surface layer (Figure 2). Sidescan sonar observations taken one hour after trawling revealed extensive sediment redistribution with suspended particles reducing visibility.

Table 1. Measured parameters during the Sidescan sonar surveys of Volantina (VOL) and Americana (AME) otter trawls, Rapido (RAP) trawls and Hydraulic dredge (HYD). HGO: horizontal gear opening; HOS: horizontal otterboard spread; α: attack angle of otterboards; FH: height of the furrow; FW: width of the furrow.

Parameter		**VOL**	**AME**	**RAP**	**HYD**
HGO	[m]	12-15	15-18	4	3
HOS	[m]	45-50	25-30	-	-
α	[°]	19-20	40-45	-	-
FH	[cm]	20	30	10	10
FW	[cm]	30	40	400	300

3.3 *Bottom trawls*

Sidescan survey of bottom trawls was performed at about 70 m of depth. The most noticeable physical effects of trawling are the furrows produced by the otterboards (up to 20–30 cm high and 30–40 cm wide), whereas other parts of the trawl created only faint marks (Table 1, Figure 3). Less pronounced marks were made by the groundrope, whereas the bridles left no visible marks. Also area between the outer edges of the otterboards was visibly disturbed, i.e. by the two otterboards and the groundgear.

Sediment clouds are produced when trawls were towed over a bottom of muddy sediments. The clouds spread rapidly, reaching a height of 3.0–3.5 m and a width of 4.5–6.0 m in dependence on the type of otterboard used.

In agreement with Krost *et al.* (1990), Jones (1992) and Tuck *et al.* (1998) we noticed that the height of the groove depends on the weight of the otterboard, the angle of attack (higher the attack angles higher the groove's height), and the nature of the substrate, being deepest in soft mud. The two type of trawls investigated in the current study presented different rigging characteristics (Figure 4), in particular the so called Americana trawl was characterized by short bridles and high otterboard attack angle.

As reported in Table 1, the Americana trawl had a higher otterboard impact on the seabed. Parallel tracks could be seen in all the surveyed area. The distance between these tracks varied from 30 to 50 m, which corresponds to the mean measured distance between the otterboards (Table 1).

It can be assumed that all these tracks have been left by otterboards. Horizontal net openings of the Volantina, ranging from 12 m to 15 m, is generally lower than the Americana trawls, which normally are in the range 15–18 m (Table 1, Figure 4).

High resolution and good quality images also permitted to measure the angle of attack of the otterboards by using the video analysis software Image Pro Plus v.4.5.1 (Table 1, Figure 5). In agreement with Sala *et al.* (2009), sidescan sonar sonograms show that the attack angles of the otterboards used in the Americana (40–45°) trawl were higher than that of the Volantina trawl (19–20°) (Table 1). Furthermore, otterboards of the Volantina advanced producing continuous marks due to the sliding movement, while the Americana otterboard advanced jumping on the seabed. The latter produced a series of small but higher furrows into the otterboard path with more evident muddy clouds as showed in Figure 4.

4 CONCLUSIONS

Sidescan sonar technology has become more accurate and more affordable in recent years and now it is a rapid assessment tool for evaluating trawling impacts. From the work performed in the current study, it would appear that hydraulic dredges and Rapido trawls are basically similar in their seafloor impact by flattening and ploughing seabed features. Notably, because the hydraulic dredge operate in restricted coastal areas (i.e. from 3 to 10 m of depth), the density of the dredge tracks is very high.

Gear type and the nature of the seabed are two factors that seem to have a great influence on the level of disturbance caused by fishing activity (Collie *et al.*, 2000). The effects of otter trawling vary greatly depending on the amount of gear contact with the bottom, together with the depth, nature of the seabed, and the strength of the currents or tide. Generally otterboards imprint distinct tracks on the seabed, ploughing grooves which can vary from a few cm up to 30 cm deep.

Chains in the Americana trawl can also leave recognizable tracks and may skim off the surface sediment layers between the two grooves left by the otterboards. Sidescan sonar provided also quali-quantitative information on gear performance during fishing operations and therefore might be useful proof against the information provided by trawl monitoring acoustic systems.

REFERENCES

Caddy J.F., 2000. A short retrospective on personal research carried out in eastern Canada in the period 1966-'75 relevant to impacts of fishing gear on the benthic environment, and some perspectives for further research. *Impact of trawl fishing on benthic communities – Proceedings*, ICRAM: 109–128.

Collie J.S., Escanero G.A., Valentine P.C., 2000. Photographic evaluation of the impacts of bottom fishing on benthic epifauna. *ICES Journal of Marine Science*, 57: 987–1001.

Demestre M., Sánchez P., Kaiser M.J., 2000. The behavioural response of benthic scavengers to otter-trawling disturbance in the Mediterranean. *In*: Kaiser M.J., de Groot S.J. (*eds*.). Effects of Fishing on Non-target Species and Habitats. Blackwell Science, London: 121–129.

Franceschini G., Raicevich S., Giovanardi O., Pranovi F., 2002. The use of side scan sonar as a tool in Coastal Zone Management. Littoral. Porto, 22–26 September 2002: 11–14.

Friedlander A.M., Boehlert G.W., Field M.E., Mason J.E., Gardener J.V., Dartnell P., 1999. Sidescan-sonar mapping of benthic trawl marks on the shelf and slope off Eureka, California. *Fishery Bulletin US*, 97: 786–801.

Giovanardi O., Pranovi F., Franceschini G., 1998. "Rapido" trawl-fishing in the Northern Adriatic: preliminary observations on effects on macrobenthic communities. *Acta Adriatica*, 39: 37–52.

Hall-Spencer J.M., Froglia C., Atkinson R.J.A., Moore P.G. (1999). The impact of Rapido trawling for scallops, *Pecten jacobaeus* (L.), on the benthos of the Gulf of Venice. *ICES Journal of Marine Science*, 56: 111–124.

Hall S.J., 1999. The Effects of Fishing on Marine Ecosystems and Communities. Blackwell Science, Oxford, 274 pp.

Hiddink J.K., Jennings S., Kaiser M.J. 2007. Assessing and predicting the relative ecological impacts of disturbance on habitats with different sensitivities. *Journal of Applied Ecology*, 44: 405–413.

Humborstad O-B, Nottestad L., Løkkeborg S., Rapp H.T., 2004. RoxAnn bottom classification system, sidescan sonar and video-sledge: spatial resolution and their use in assessing trawling impacts. *ICES Journal of Marine Science*, 61: 53–63.

ICES, 2003. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 2003/ACE:05.

Image Pro Plus, 2005. Image Pro Plus v.4.5.1. Media Cybernetics, Inc. USA.

Jones J.B., 1992. Environmental impact of trawling on the seabed: a review. *New Zealand Journal of Marine and Freshwater Research*, 26: 59–67.

Kaiser M.J., Collie J.S., Hall S.J., Jennings S., Poiner I.R., 2002. Modification of marine habitats by trawling activities: prognosis and solutions. *Fish and Fisheries*, 3: 114–136.

Krost P., Bernhard M., Werner F., Hukriede W., 1990. Otter trawl tracks in Kiel Bay (Western Baltic) mapped by side-scan sonar. *Meeresforschung*, 32: 344–353.

Morello E.B., Froglia C, Atkinson R.J.A., Moore P.G., 2005. Impacts of hydraulic dredging on a macrobenthic community of the Adriatic Sea, Italy. *Canadian Journal of Fisheries and Aquatic Sciences*, 62: 2076–2087.

Pranovi F., Raicevich S., Franceschini G., Farrace M.G., Gionavardi O., 2000. Rapido trawling in the northern Adriatic Sea: effects on benthic communities in an experimental area. *ICES Journal of Marine Science*, 57: 517–524.

Sala A., D'Arc Prat Farran J., Antonijuan J., Lucchetti A., 2009. Performance and impact on the seabed of an existing- and an experimental-otterboard: Comparison between model testing and full-scale sea trials. *Fisheries Research*, 100: 156–166.

Schwinghamer P., Gordon D.C., Rowell T.W., Prena J., McKeown D.L., Sonnichsen G., et al., 1998. Effects of experimental otter trawling on surficial sediment properties of a sandybottom ecosystem on the Grand Banks of Newfoundland. *Conservation Biology*, 12: 1215–1222.

Smith C.J., Banks A.C., Papadopoulou K-N., 2007. Improving the quantitative estimation of trawling impacts from side scan sonar and underwater video imagery. *ICES Journal of Marine Science*, 64: 1692–1701.

Thrush S.F., Hewitt J.E., Cummings V.J., Dayton P.K., Cryer M., Turner S.J., et al., 1998. Disturbance of the marine benthic habitat by commercial fishing: Impacts at the scale of the fishery. *Ecological Applications*, 8: 866–879.

Tuck I.D., Hall S.J., Robertson M.R., Armstrong E., Basford D.J., 1998. Effects of physical trawling disturbance in a previously unfished Scottish sea loch. *Marine Ecology Progress Series*, 162: 227–242.

Valdemarsen J.W., Jørgensen T., Engås A., 2007. Options to mitigate bottom habitat impact of dragged gears. *FAO Fisheries Technical Paper*, 506: 29 pp.