Accepted Manuscript

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PII: S0165-7836(08)00264-6
DOI: doi:10.1016/j.fishres.2008.08.021
Reference: FISH 2657

To appear in: *Fisheries Research*

Received date: 12-5-2008
Revised date: 21-7-2008
Accepted date: 20-8-2008

Please cite this article as: Shephard, S., Goudey, C.A., Read, A., Kaiser, M.J., Hydrodredge: reducing the negative impacts of scallop dredging, *Fisheries Research* (2007), doi:10.1016/j.fishres.2008.08.021

Hydrodredge: reducing the negative impacts of scallop dredging

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Abstract

Scallop dredges typically use teeth or a cutting bar to dig though the sediment and are associated with detrimental impacts on marine benthos. A low-impact 'Hydrodredge' was tested that uses 'cups' to deflect water downward in a turbulent wave sufficient to lift scallops from the seabed. Trials took place in the Isle of Man fishery for great scallop (*Pecten maximus*) with the hydrodredge and a gang of local 'Newhaven' dredges towed simultaneously either side of a commercial scallop dredge vessel. When fished over three different ground types (smooth, medium, hard) and two tow-speeds (2.5kt, 4.0kt), the proportion of dead scallops and bycatch in the Hydrodredge was significantly less than in the Newhaven dredges. This result highlighted the role of the teeth on the tooth-bar in exerting severe (fatal) damage to the catch and bycatch. Rates of non-fatal damage to scallops and bycatch did not differ between gears, suggesting that such damage occurs as a result of contact with other parts of the gears such as the chain-bag. The hydrodredge was less efficient at catching great scallops compared with the Newhaven dredges (10-40%). For great scallops, the cups did not significantly increase catch relative to the hydrodredge fished without cups, which contrasts with results for other surface-dwelling scallop species, e.g., *Placopecten magellanicus* and *Aequipecten opercularis*. Importantly, the Hydrodredge was designed in the New England fishery for giant scallop (*P. magellanicus*), a species typically lighter and less embedded than *Pecten maximus* and thus potentially more vulnerable to the flow patterns of the Hydrodredge.

Introduction

Scallops form a valuable component of commercial catch for several important fishing nations. In the UK, great scallop *Pecten maximus* now represents the third most valuable fishery after prawns (*Nephrops*) and Mackerel (*Scomber scombrus*), and was worth over £34 Million (value at the point of first sale) in 2005. A large percentage of scallops are caught using various designs of dredge. This type of fishing gear can have detrimental impacts on the marine benthos, and is associated with changes in the physical structure of the seabed (Currie and Parry, 1999), community structure (Kaiser et al., 2000; Bradshaw et al., 2002) and scavenging activity (Ramsey et al., 1998), direct damage to captured and non-captured bycatch species (Veale et al., 2001; Jenkins et al., 2001) and reduced predator escape response in discarded juvenile scallops (Jenkins and Brand, 2001). Such ecological effects are largely related to the invasive dredge teeth or cutting bar used to dig scallops from the sediment, although the degree of impact may vary subject to various environmental variables (Fifas and Berthou, 1999).

A novel 'Hydrodredge' designed at the Massachusetts Institute of Technology (MIT) and first used in the New England fishery for giant scallop *Placopecten magellanicus* has the potential to exert far less damaging effects on the seabed and its biota (Goudey, Pers. Comm.). Instead of mechanical means, the new gear uses four precisely oriented 'cups' (cut from 30 cm trawl floats) that deflect water into a downward jet and create large-scale vorticity (Fig. 1), a combination that exerts sufficient force on the seabed to lift scallops into the water column whereupon they can be captured by the trailing net/chain bag. Notably, this is a passive process based on the hydrodynamics of the gear and does not require any mechanical pumping of water. Following successful tow tank and video trials in the U.S. by MIT, this prototype gear (Fig. 2) underwent a preliminary evaluation in the Isle of Man (U.K.) great scallop fishery in April 2007. Both research and commercial vessels were used with direct involvement of fishers in the trials. The results were encouraging, and led to a more thorough evaluation of the Hydrodredge in the Isle of Man fishery during August 2007, being the subject of this report.

Methods

Sampling

A commercial scallop dredger configured with over-the-side beams was used for all experiments (FV De Bounty CT 73, 54.25GT, l.o.a. 19.05 m, 272.4 Kw). The hydrodredge was fished on one beam, while three x 75 cm wide Newhaven dredges (Fig. 3) were fished simultaneously on the other. The design and function of the two types of gear differed markedly, reflecting varying local (U.S. and European) practices and the hydro modifications. The hydrodredge was 2.1 m wide and used four hydrocups (23 cm diameter) placed at regular intervals across the mouth. A single chain bag was used, being 2.1 m wide and 1 m deep and comprised of 10 cm steel rings. The belly chain sagged from its connection points, contacting the seafloor approximately 45 cm behind the outer and 90 cm behind the inner hydrocups. The top of the bag was constructed as a heavy nylon mesh panel to reduce weight. Newhaven dredges were of standard construction, being 75 cm in width and having nine teeth evenly spaced across the mouth.

Each dredge had a bag comprising a belly of 10 cm steel rings and a top of heavy nylon mesh.

Due to the difficulty of rigging dredges at sea, gears could not be switched between sides of the vessel during the trials, but were interchanged between trials. We devised an experiment to compare the performance of the two gears when fished over different grounds (smooth, medium and hard) and at different speeds (slow 2.5 kn and fast 4.0 kn). This range of ground types is typical of the Isle of Man fishery, with preferred target ground depending on recent catches, sea state and individual skipper. Study grounds were 'Chickens' (five miles SW of the Island), being smooth sand/mud; 'Bradda Inshore' (just off Port Erin Bay on the SW), being medium stones and coarse sand; and 'Port St Mary Bay' (South coast of Island), being hard rocky shelf and large stones. At each fishing site, five replicate tows (approximately 15 min duration) were made for each treatment. The slower speed is typical for fishing the Newhaven gear, while the faster speed was intended to optimise the performance of the hydrodredge by increasing water flow around the cups. For all catches, scallops were measured (width, mm) and assigned a damage score (1-4) according to Veale et al. (2001). A suite of 10 common bycatch species also were enumerated and assigned a damage score (Veale et al., 2001).

An additional set of tows at each speed but on a single ground type (medium) were made, for which the hydrodredge cups were removed for alternate groups of 2-3 tows (comparison of 'cups' versus 'no cups') . This allowed assessment of the contribution of the cups to gear function and efficiency.

Analysis

Relative numbers of each of scallops and bycatch species were compared separately using full factorial Type III ANOVA, with Ground, Gear and Speed as fixed effects, and corrected number (allowing for differing mouth widths of gear) of scallops or bycatch respectively were the dependent variables. Tukey post-hoc multiple comparison tests for ground type were conducted. Comparison of scallops and bycatch damage scores by gear used the same analysis, but were based on Ln (n+1) transformed percentages by damage score. Comparisons of Hydrodredge catch of scallops between tows with and without cups (evaluating a 'cup effect') were conducted using t-tests on each of a) all data combined, b) with and c) without cups, using scallop catch in the Hydrodredge as a percentage of catch in the Newhaven dredges by tow as the response variable. The dependent variables were checked to ensure that they met the appropriate assumptions prior to using the parametric statistics outlined above. Significance was assumed at $P \leq 0.05$ for all tests.

Results

The Newhaven dredges consistently caught more scallops than the Hydrodredge (Table 1; Fig. 4). There was some interaction between gear and ground (Table 1). A significantly greater percentage of scallops (ANOVA $F_{1, 48} = 18.352$, $P < 0.0001$) in the Newhaven dredges were dead (damage score 4) (Fig. 5) while there was no significant difference in percentage of scallops that had other damage scores. Bycatch was dominated by starfishes (particularly *Asterias rubens, Astropecten irregularis and*

Porania pulvillus), with crabs (*Cancer pagurus* and *Liocarcinus spp*.) and urchins (*Echinus esculentus)* also common. A significantly greater percentage of individuals of bycatch species (ANOVA $F_{1, 47} = 14.028$, $P < 0.0001$) in the Newhaven dredges also were dead (Fig. 6) while there was no significant difference in percentage of bycatch that had other damage scores. These results imply that the tooth-bar on the Newhaven dredge is primarily responsible for the fatal/severe injuries sustained by scallops and bycatch species, while other components of the gear or the catching process account for the less severe physical damage that occurs.

In the trials to examine the 'cup' versus 'no-cup' effect at different speeds, the analysis indicated that there was no significant difference in numbers of scallops caught in the Hydrodredge when fished with ($t_2 = -1.190$, $P = 0.1781$) or without ($t_4 = -0.616$, $P = 0.2861$) the cups, although the cups appeared to perform better when towed 'fast'.

Discussion and Conclusions

Scallop dredging exerts a negative impact on the benthic environment and on discarded and non-captured scallops and bycatch organisms. By avoiding the use of teeth/cutting bar, the hydrodredge has potential to reduce such damage. Encouragingly, during these trials, the hydrodredge significantly reduced the proportion of dead scallops and bycatch. This emphasizes the likely role of the dredge teeth in exerting fatal damage and highlights the potential of non-toothed dredge designs in reducing the ecological impacts of dredging. It also presents potentially useful results from a longer term perspective on the sustainability of this sector. Interestingly, there was no difference between gears in the incidence of non-fatal damage to captured organisms. This suggests that most of such damage occurs in the chain bag common to both the Hydrodredge and Newhaven dredges. Notably, because the hydrodredge has less leveling effect on the bottom than a toothed dredge, the chain bag probably bounces between high spots and spares the dips. However, modifications to the chain bag still could yield important conservation benefits for both target and non-target species. Various approaches are available here, from supporting the bag on runners to lightening it through the use of buoyancy or hydrodynamic lifting devices. Lifting the bag off the abrasive bottom would have the additional advantage of reducing the need for durable steel rings and allow lighter materials to be used.

In the trials around the Isle of Man, the Hydrodredge was significantly less efficient than an equivalent team of Newhaven dredges, and caught between 10-40% as many *P. maximus*. This is a much lower relative catch rate than suggested by preliminary trials of the Hydrodredge in the U. S., when targeting *P. magellanicus*. Notably, the North American species is thinner shelled than *P. maximus*, and typically more active and lives directly on (rather than recessed into) the seabed. These characteristics may render *P. magellanicus* more susceptible to the water flows generated by the hydro cups, and hence more likely to be lifted into the water column and caught. The same issue probably explains the lack of 'cup effect' observed in the Isle of Man trials. The hydro cups seem to be relatively ineffective at lifting the heavy and well recessed *P. maximus*, so many of the scallops that were retained could have been caught simply because of the action of the belly chain. Despite these findings, if targeted at appropriate scallops species (*P. magellanicus* or *Aequipecten opercularis*), the Hydrodredge offers an exciting potential to reduce the environmental impacts in fisheries for these species, particularly the cumulative effect of sub-lethal damage on the benthos. The Hydrodredge is therefore worthy of further field trials specifically targeted at these species.

Acknowledgements

This study was funded by the Department of Agriculture, Fisheries and Forestry, Isle of Man Government and by a grant from Seafish. The authors thank skipper Ian Skell and the crew of the FV De Bounty for their support in this work and the members of the Manx Fish Producers Organization for comments and support during the research.

References

Bradshaw, C., L. O. Veale, and A. R. Brand. 2002. The role of scallop-dredge disturbance in long-term changes in Irish Sea benthic communities: a re-analysis of an historical dataset. J. Sea Res. 47:161-184.

Currie, D. R., and D. R. Parry. 1999. Impacts and efficiency of scallop dredging on different soft substrates. Can. J. Fish. Aquat. Sci. 56(4):539-550.

Fifas, S., and P. Berthou. 1999. An efficiency model of a scallop (*Pecten maximus*, L.) experimental dredge: Sensitivity study. ICES J. Mar. Sci. 56: 489-499.

Jenkins, S. R., B. D. Beukers-Stewart, and A. R. Brand. 2001. Impact of scallop dredging on benthic megafauna: a comparison of damage levels in captured and non-captured organisms. Mar. Ecol. Prog. Ser. 215:297-301.

Jenkins, S. R., and A. R. Brand. 2001. The effect of dredge capture on the escape response of the great scallop, *Pecten maximus* (L.): implications for survival of undersized discards. J. Exp. Mar. Biol. Ecol. 266:33-50.

Kaiser, M. J., K. Ramsay, C. A. Richardson, F. E. Spence, and A. R. Brand. 2000. Chronic fishing disturbance has changed shelf sea benthic community structure. J. Anim. Ecol. 69(3):494-503.

Ramsey, K., M. J. Kaiser, and R. N. Hughes. 1998. Responses of benthic scavengers to fishing disturbance by towed gears in different habitats. J. Exp. Mar. Biol. Ecol. 224:73-89.

Veale, LO, AS Hill, SJ Hawkins and AR Brand. 2001. Distribution and damage to the by-catch assemblages of the northern Irish Sea scallop dredge fisheries. J. Mar. Biol. Assoc. U.K. 81: 85-96.

Tables

Table 1. Results from full factorial Type III ANOVA, with Ground, Gear and Speed as fixed effects, and corrected number (allowing for differing mouth widths of Hydrodredge and Newhaven gear) of scallops being the dependent variable.

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Figure 1. Diagram showing water flow around hydro cups (Upper image is side view, lower image is front view). Water flow is passive and due only to hydrodynamics of gear.

Figure 2. Diagram of hydrodredge incorporating novel cup design.

Figure 3. A team of Newhaven dredges similar to those used during the hydrodredge trials. This gear is typical of U.K. scallop dredge fisheries.

Figure 4. Scallop catch (±SE) in each of Hydro- and Newhaven dredges for three ground types (smooth, medium and hard) at each of slow (2.5 kn) and fast (4.0 kn) towing speeds.

Figure 5. Percentage of scallops (±SE) showing damage score 4 (dead) in each of Hydro- and Newhaven dredges for three ground types (smooth, medium and hard) at each of slow (2.5 kn) and fast (4.0 kn) speeds.

Figure 6. Percentage of bycatch showing damage score 4 (dead) in each of Hydro- and Newhaven dredges for three ground types (smooth, medium and hard) at each of slow (2.5 kn) and fast (4.0 kn) towing speeds. No slow tows were conducted on medium ground.

Tables

Table 1. Results from full factorial Type III ANOVA, with Ground, Gear and Speed as fixed effects, and corrected number (allowing for differing mouth widths of Hydrodredge and Newhaven gear) of scallops being the dependent variable.

Source	Type SS	dfs	MS	F	*P*
Corrected model	69805.189	11	6345.926	18.438	0.000
Intercept	73146.227	1	73146.227	212.526	0.000
Gear	24117.744	1	24117.744	70.074	0.000
Ground	35983.181	2	17991.590	52.274	0.000
Speed	329.848	1	329.848	0.958	0.333
Gear*Ground	8426.112	2	4213.056	12.241	0.000
Gear*Speed	221.645	1	221.645	0.644	0.426
Ground*Speed	702.684	2	351.342	1.021	0.368
Gear*Ground*Speed	23.975	2	11.988	0.035	0.966
Error	16520.423	48	344.175		
Total	159471.839	60			
Corrected Total	86325.612	59			

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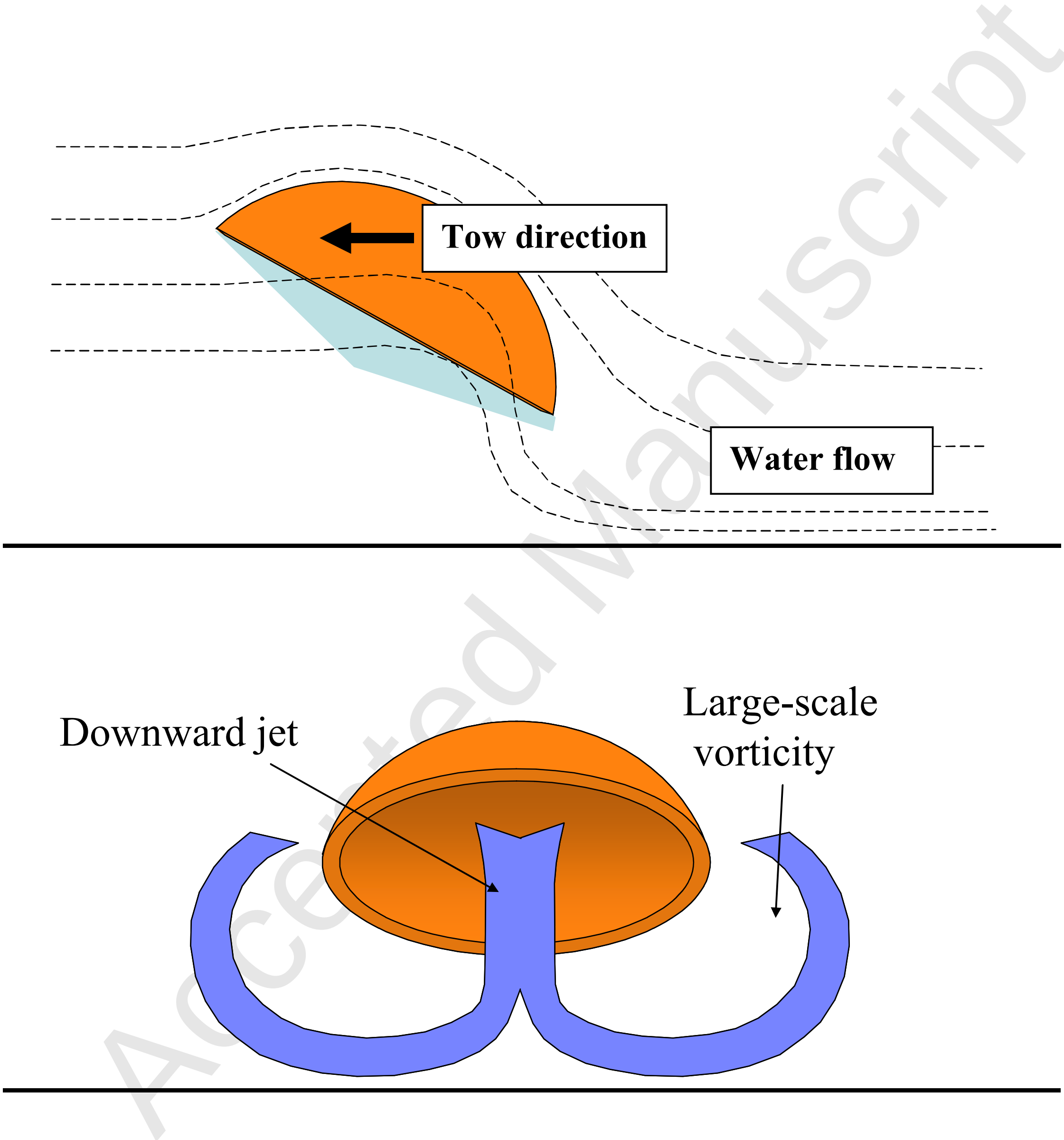

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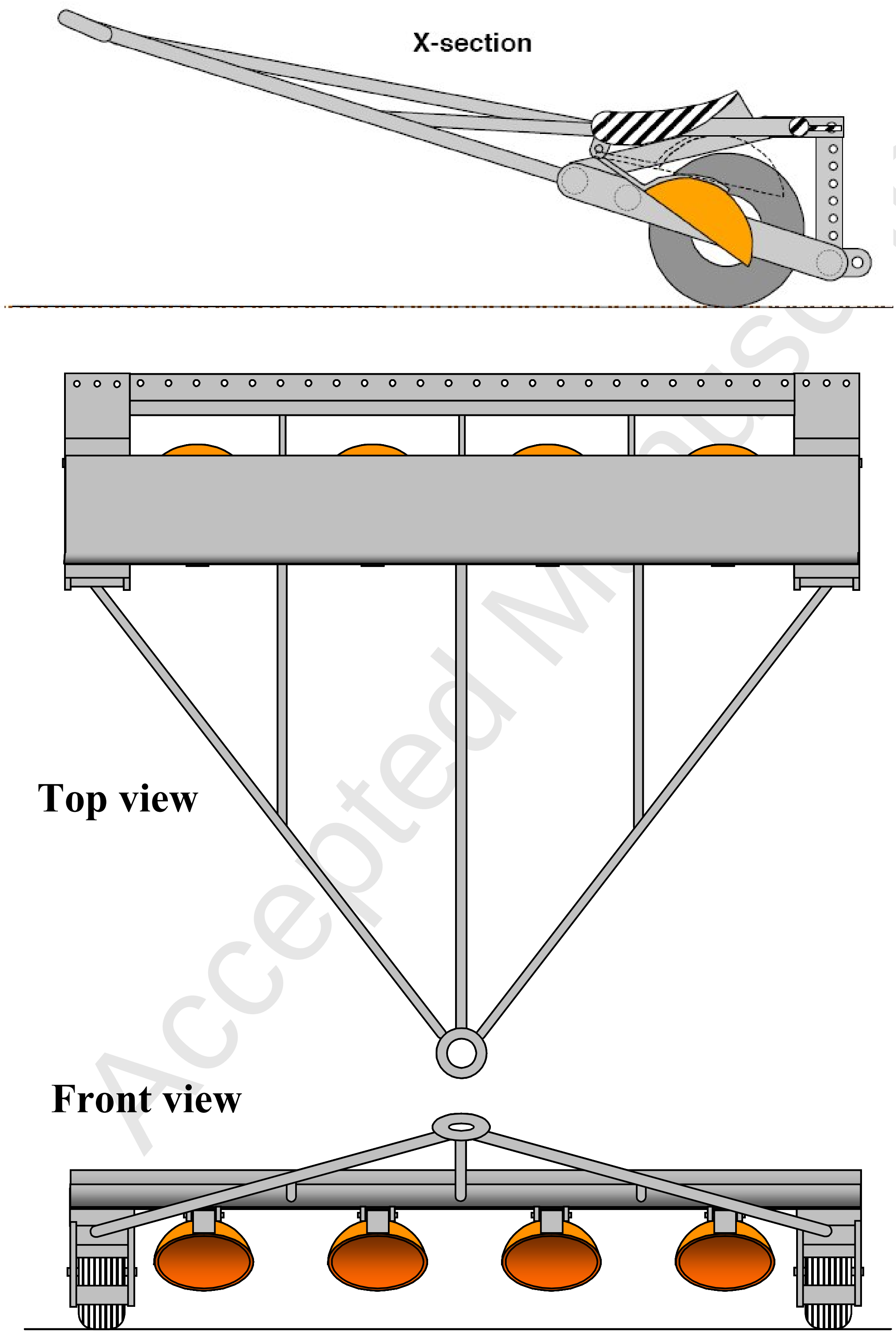

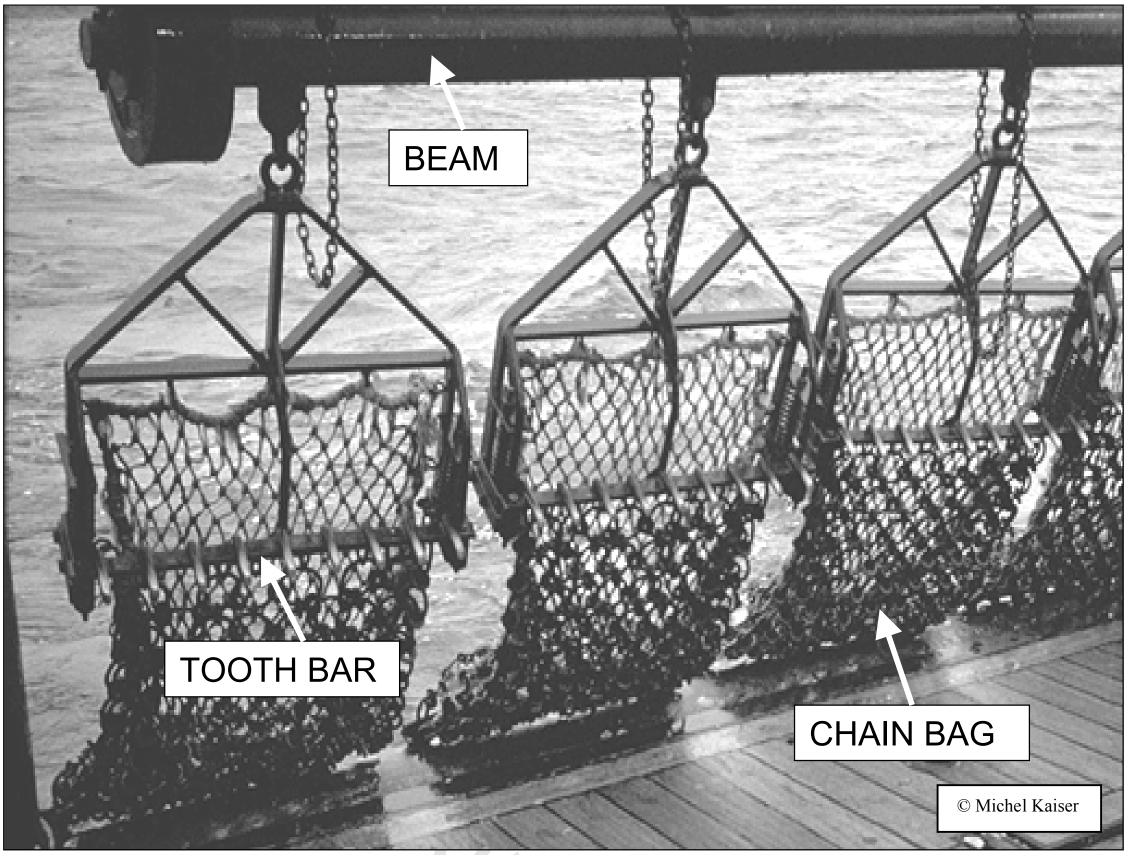

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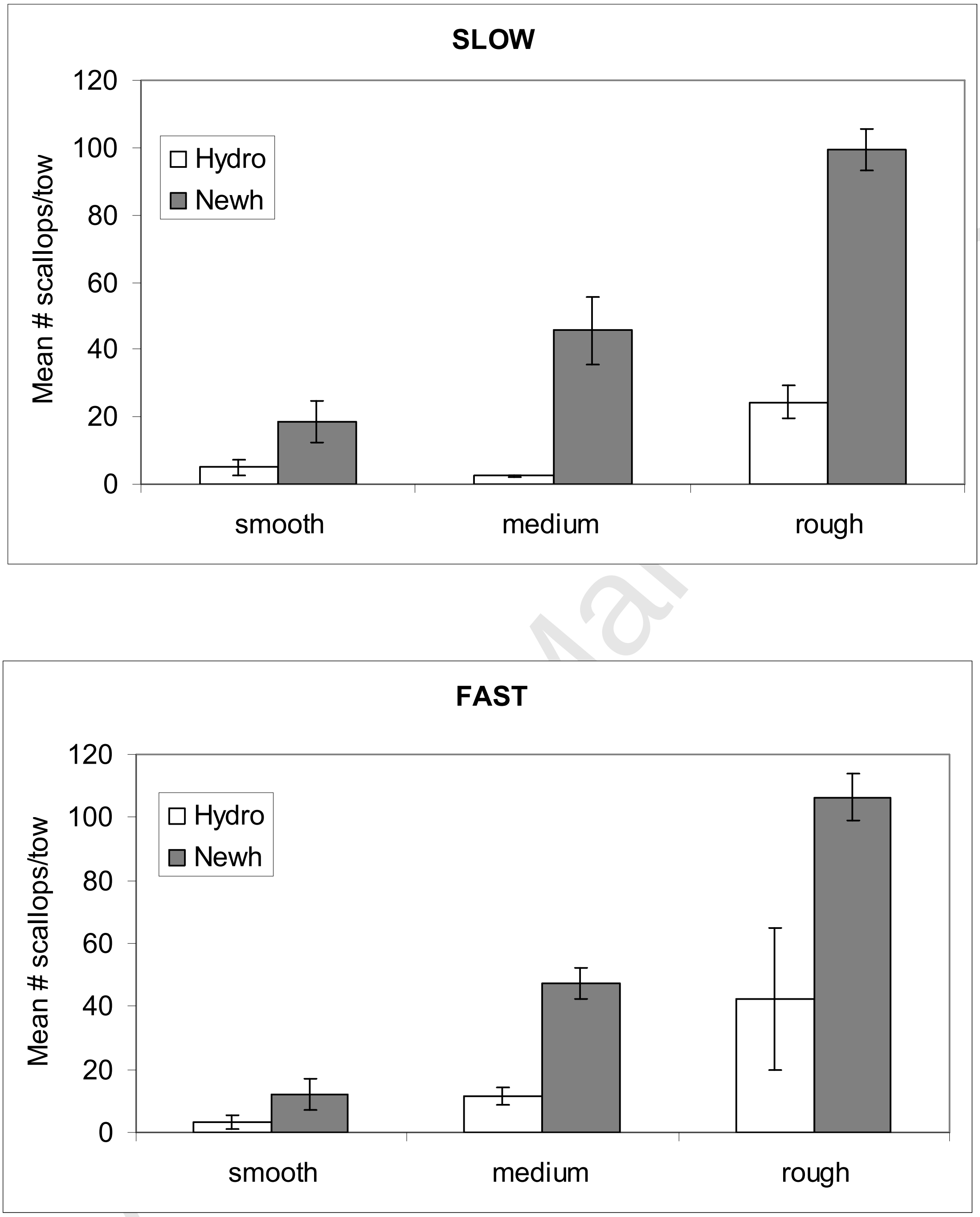

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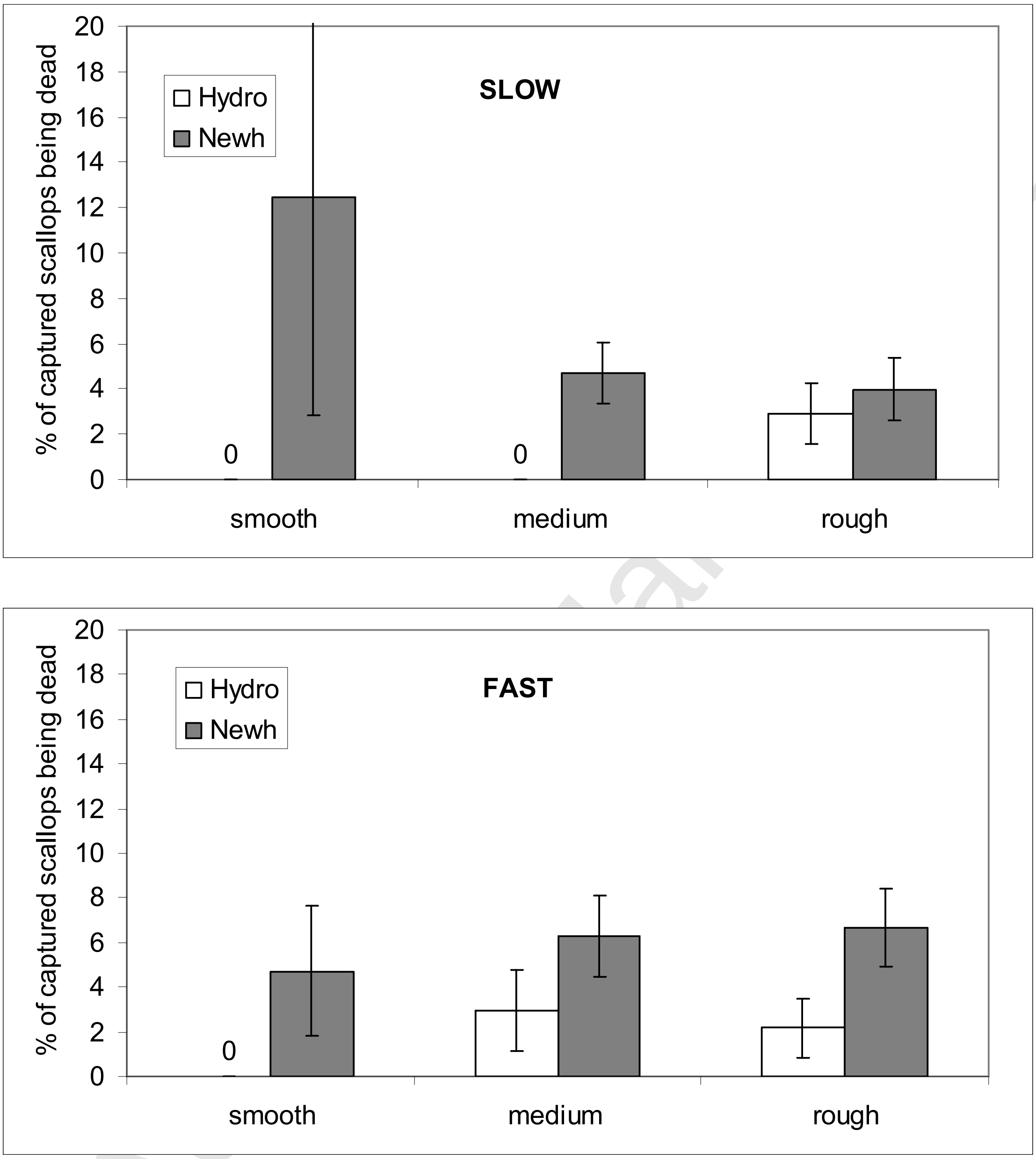

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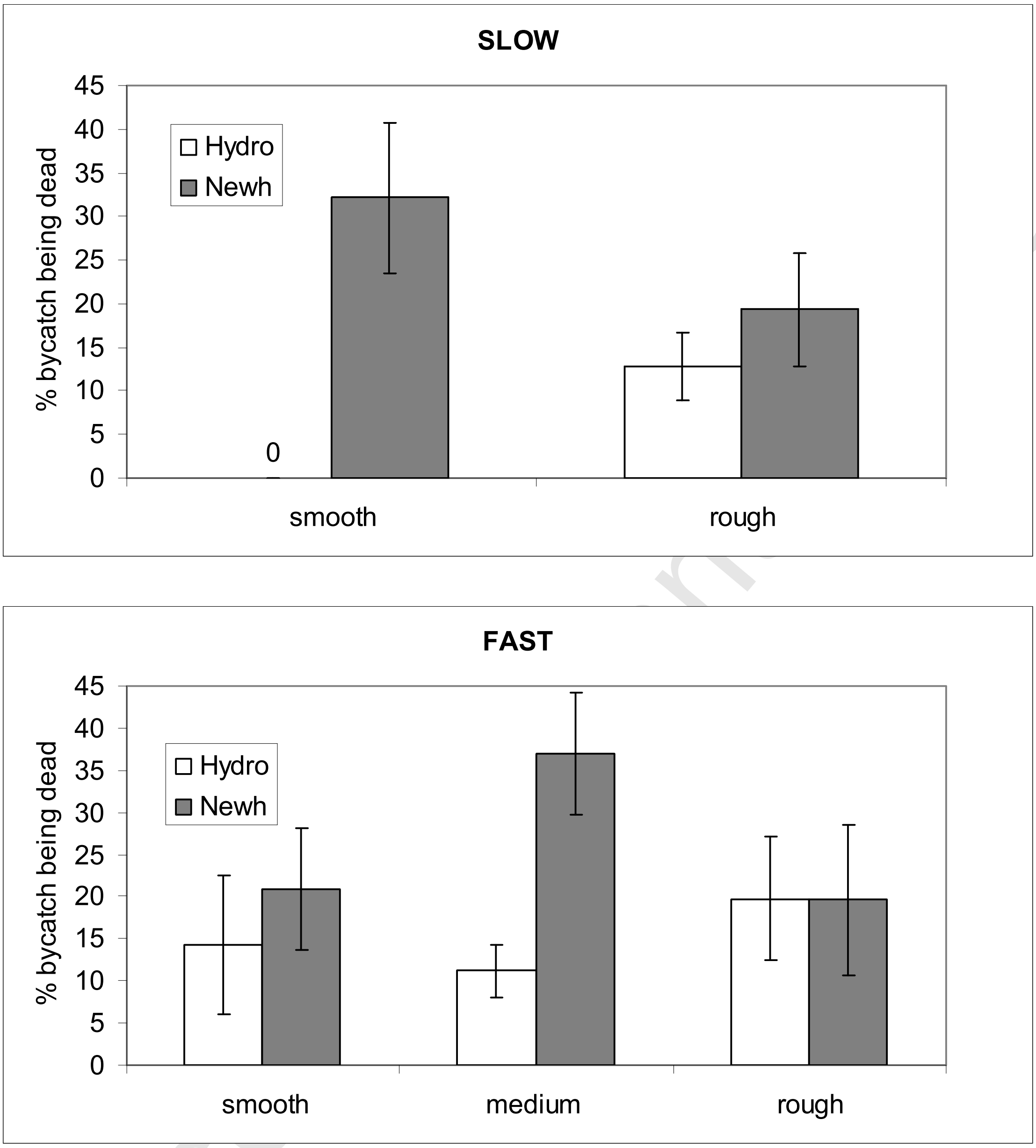

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