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Fishing Vessel Design in a Regulation Driven Environment

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ABSTRACT

Many newly constructed and currently operating fishing vessels appear to have been designed with disregard for much of the naval architect's conventional wisdom as to what constitutes a sound, sensible and safe design. In this paper recent designs will be examined in the context of the rapidly changing regulatory and legislative framework that controls the fishing industry, and the difficulties in obtaining satisfactory stability characteristics will be considered. In analysing recent safety records no evidence is found to suggest that the new vessels are less safe than more traditional forms, but it is observed that turbulence in the regulatory framework in which they operate may be contributing to the lack of progress in improving safety.

Abbreviations

DETR:	Department of Transport Environment and the Regions
FISG:	Fishing Industry Safety Group
FQA:	fixed quota allocation
FAS:	formal safety assessment
ITQ:	individual transferable quota
MAFF:	Ministry of Agriculture Fisheries and Food
MAIB:	Marine Accident Investigation Branch
MCA:	Maritime and Coastguard Agency
SFIA:	Sea Fish Industry Authority (Seafish)
TAC:	total allowable catch
VCU:	vessel capacity unit

Introduction

Regulations that are intended to ensure the sustainability of the fish stock in European waters have resulted in new vessels that have some extreme characteristics. These 'rule beaters' appear to go against the natural instincts of the naval architect. The impact of rules on the design of vessels has often been unexpected. Rules and regulations designed with one aspect of performance in mind, can unwittingly lead to undesirable characteristics being favoured in other unrelated aspects. In his analysis of the Fastnet disaster of 1979 Marchaj [1] details how the rating rule applied to the yachts of the time unintentionally penalised stability, as a rule that was intended to ensure fair competition between racing yachts in practice compromised safety. This paper will consider how a similar phenomenon has developed in the fishing vessel fleet, and how it has influenced the stability characteristics of modern fishing vessels.

The Design of Fishing Craft and the Role of Regulations

In recent years the major factor impacting on the evolution of the design of fishing vessels in the UK has been the introduction of increasingly complex and demanding regulations for the control the fishing industry. Fishermen may work in dangerous waters, but it is turbulence in the regulatory framework that taxes the skill of the designers of these craft.

The latest additions to the UK fishing fleet are characterised by extreme length to beam ratios (often around 2.5 and on occasion as little as 2.1 in determined 'rule beater' designs) and exaggerated length to draught and depth ratios. The underwater form is exceptionally full, with the above water profile a towering rectangular slab above which perches the wheelhouse. These are the vessels that fishermen are having built today, so they must be successfully meeting their requirements. However they are a stark contrast to the traditional style of craft, and to new vessels being built in other parts of the world. In these vessels it is clear that the usual physical requirements driving the design process have been overwhelmed by the influences of the fishing regulations. When unconstrained by regulations the designer produces a hull that is moderate in all aspects: length to breadth ratios of between 3 and 4 and fine form coefficients minimise resistance when free running and enhance seakeeping performance, and a moderate superstructure height reduces windage and improves stability. Although the safety record of these vessels cannot be questioned without further work to produce relevant detailed data, it is clear that the crew of a vessel with poor seakeeping characteristics, and therefore high accelerations, will work less effectively than the crew of a more seakindly boat. In addition the working areas of these modern boats include the extreme ends of the vessels where the motions are greatest, areas that would normally be left void or used for storage in a more conventional craft. The control position is also at a far greater distance from the centres of rotation than on traditional craft, which must also impact on the crew's effectiveness. The skipper and crew would operate more happily, effectively and safely on a vessel that responded in a more orderly manner to the sea, and that was arranged with a higher priority on crew comfort.

These new style vessels are the result of an on-going tussle between the regulators, who impose the rules, and the fishermen who respond, often in unanticipated but strategically sound ways. It is the work of the naval architect to interpret these moves and counter moves as design constraints, with each new vessel being a record of the current state of play and an indicator as to the extent to which the design of fishing vessels is being driven by politically and environmentally inspired regulations rather than by physical requirements.

The Regulatory Control of the Fishing Industry

Fisheries are a totally free naturally occurring resource. Experience has demonstrated that the un-restricted use of such a common resource will lead to its over use and gradual decline, defined by Hardin as 'the tragedy of the commons' [2]. He states that each fisherman will consider their own interests and forsake the broader social costs, with the inevitable result being over capitalisation in the industry, excessive harvest and eventually stock depletion. A similar sentiment was outlined by Gordon [3]: "There appears to be some truth in the conservative dictum that everybody's property is nobody's property. Wealth that is free for all is valued by no one because he who is foolhardy enough to wait for it's proper time of use will only find that it has been taken by another… The fish in the sea are valueless to fishermen, because there is no assurance that they will be there for him tomorrow if they are left behind today". The truth of these observations made in the middle of the last century are self evident today, and the fulfilment of the prophecies is quite simply that we have too many fishing boats chasing too few fish.

If the seas are to be fished in a sustainable way then the organisation of the industry, the number and types of vessels, the way they are operated, and the way the catches are processed and monitored will all have to change. The regulations are therefore concerned with an orderly process of change management. Such a process will always be criticised as it is impossible to satisfy all parties in a time of transition, and it may even be impossible to completely satisfy any party. Given the fragmented nature of the problem it is not surprising that attempts to regulate this industry have been complex, and often unpopular with sections of it. A broad overview of the current regulatory framework can be found in the references [4], with the briefest of summaries provided here.

As with other vessels of all types fishing vessels have a long established procedure for validating that they are built and operated to recognised standards of safety. In the UK two bodies, the SFIA and the MCA, oversee the three safety elements of vessel structure, equipment and crew competence. In recent decades these safety-orientated regulations have been augmented by the measures intended to ensure the sustainability of the fisheries, and to manage the changes necessary to achieve that end. Two types of control have therefore been introduced, those to limit the total catch and so ensure conservation of stocks, and those to manage the reduction in fishing effort and so minimise the social and economic disruption due to the structural changes necessary in the industry. Both of these types of control are the responsibility of the MAFF. Here the way in which these three organisations regulate the industry will be examined in broad terms as the complexity and dynamic nature of the controls makes a detailed description inappropriate here. It is also unnecessary as the intention is not to describe the controls themselves, but to examine their nature and so obtain some insight into their interaction with the safe design of fishing vessels, and in particular the impact in their stability characteristics.

In the context of safety the SFIA acts as a Classification Society for the construction of fishing vessels, publishing scantling rules and employing surveyors to oversee the construction of fishing vessels. These guidelines cover both the hull construction and essential equipment. It also promotes crew training through the development of courses and the provision of bursaries [5]. The Maritime and Coastguard Agency (MCA) is concerned with all aspects of marine safety. It has a long standing Code of Practice for Fishing Vessels over 12 metres and recently created a Code of Practice for vessels under 12 metres. These Codes consists of a checklist of safety equipment plus a written risk assessment that covers the operation of the vessel, watertight and weather tight integrity, stability, machinery, fire protection and fire prevention. The under 12 metre Code allows for self-certification by the owner but also requires a regular verification inspection by the MCA. The Ministry of Agriculture Fisheries and Food, MAFF, controls both the total amount of fish caught, and the catching capability of the fleet, through a license scheme. The right to fish is dependent upon possession of a licence appropriate to the type of vessel and the species targeted. The licensing scheme has developed considerably in breadth and complexity and the current licence structure limits not only the total number of vessels but also their size and power and the extent to which effort can be shifted between target stocks and between fishing methods. The licences have three elements: the authorisation to fish; the catch entitlement, or quota; and the allowable fishing capability expressed in vessel capacity units, VCUs. Since licence entitlements are transferable between ownerships and are restricted in number an active market in all three elements of the licences has developed [6].

Before exploring how the various regulations have impacted on the design of fishing vessels both the quota concept, and the measure of fishing capability (the VCU) can be considered further. The quota associated with a license is one small part of the total allowable catch (TAC) agreed by the EU for the waters of the member states of the EU. The Community shares fishing opportunities in the form of quotas among Member States [7]. Member states allocate their national quota in different ways, the UK having moved from an allocation based on a vessel's track record to a fixed quota allocation (FQA) that can be traded to a limited extent. (An alternative procedure referred to as the individual transferable quota (ITQ) has been introduced successfully in both New Zealand [8] and Iceland [9]. ITQs effectively make the fishermen owners of a share of the resource and so they encourage the fishermen to regulate fishing effort and protect stocks as they have an annual claim on the harvest. Catching rights expressed by ITQs are analogous to territorial interests held by farmers and their tenants in that they form part of their property [10]. The advantages and disadvantages of the various methods of quota allocation are discussed in detail by Symes [11].)

The measures of fishing capability, or capacity, vary between the member states, some adopting the units used at the EU level, these being a combination of engine power and tonnage. In the UK a system based on length was replaced by the vessel capacity unit, the VCU, in 1990. This followed research by the SFIA aimed at identifying the most appropriate measure of fleet capacity, and concluding that the unit should comprise the sum of the deck area and a percentage of the engine's maximum continuous rating [12], calculated thus:

$$\text{VCU} = \{\text{length (m)} \times \text{breadth (m)} + 0.45 \times \text{engine power (KW)}\}$$

Fishing craft designed to maximise their fishing capability while minimising the measured VCU are referred to as 'rule beaters'. Both halves of the above equation impact on the design of such craft. The dimensional constraints have a significant impact on the appearance of these craft, and on their stability characteristics.

Design Impact of the Licensing System

'Rule beaters' are vessels designed to flout the spirit of a set of rules, but succeed in being both legitimate and profitable by strictly following the letter of the regulations. The classification societies, and others concerned with safety-focussed rules, have long been aware that any specified requirement is not treated as a minimum, but as a design target. Similarly where different sets of rules apply to different classes of vessel it is common practice to try to gain advantage by squeezing a vessel into the most economical class, even if it is inappropriate for the vessel's true function. In the regulation of fishing vessels both of these phenomenon have long been apparent. Fortunately the robust scantlings required of these workboats have negated the impact of any tendency to 'design down'. The application of different sets of rules to different sizes of vessels has however caused a noticeable bunching of the fleet at the relevant break points, whether they be specified in terms of length or displacement, with many more vessels being built just below the defined break points (such as 12 meters and 24 meters for the scantling rules) and almost none being built in a range above these points. Some of the vessels built just below such break points could be defined as rule beaters, but in these cases the financial savings made by staying in a lower class are limited, and other efficiency losses soon outweigh them. The imposition of these rules therefore distorts the fleet profile, but does not have a significant impact on the design of individual vessels.

This contrasts markedly with the impact of regulations intended to control the catching capability of individual vessels, and of the fleet, and with the impact of the alternative methods of enforcing individual, local and national quotas. In these cases the break point between different regulations may not simply result in an increase in equipment and manning costs, but may determine where, when and how the fisherman is allowed to fish, or even if he can fish at all. The impact on the earning ability of the vessel can be dramatic, or even catastrophic. In this environment it is not surprising that rule beaters are not simply pushing the limits of conventional design, but dramatic departures that test the expertise and integrity of the naval architect.

The introduction of the VCU as a measure of fishing capacity, and as a way to control the overall fishing effort of the UK fleet is the prevailing design driver of the present time. However the regulatory framework is in a constant state of development, or evolution, with significant changes anticipated in 2002 [13], so the lessons to be learned from the present case are essentially concerned with regulation development, not vessel design. Measuring fishing effort with the current VCU formula has resulted in an unanticipated development of the fishing vessel form. Constrained by the 'deck area' (defined as length by breadth) the designer seeks to maximise the displacement and volume of the vessel. Maximising displacement enables heavier equipment to be installed, and more fuel and fish to be carried, while maximising volume allows an increase in accommodation and areas for working with the gear and catch. As a result the actual catching capability can be considerably greater than that indicated by the measured VCUs. As neither depth nor draught are controlled displacement is maximised by increasing draught and increasing the fullness of the form, especially forward. Volume is maximised by increasing freeboard and making the actual deck area fill as much of the measured area as possible, so wide transoms and exceptionally bluff bows are used. In some cases the entire deck, from transom to stem, is utilised as the working area, with no forecastle and with the wheelhouse located over the working deck, the nets being hauled forward beneath it. The dimensional constraints are only one half of the VCU formula, with the other half being the engine power. Rule beating in this area results in maximising the diameter of the propeller and placing it in a nozzle, and introducing additional power packs for auxiliary requirements, so reserving all the rated power from the main engine for driving the vessel. De-rating the engine is also practiced, but if this is to be effective the engine must be returned to full power after measurement, which is clearly an illegal case of cheating the rules, and not a legitimate rule beating procedure.

The current type of rule beater is found at its most extreme in the smallest vessels, with a measured length of less than 10 meters. This is because the artificial constraints imposed by the VCU system have been further exaggerated in recent years by the system of allocation of quota. Vessels below this break point have not been allocated an individual quota, but have been free to fish until such time as the allowable catch was reached nationally, at which point the fishery was closed, even to these vessels. This regulatory regime encouraged fishermen to nominally down size from larger vessels in order to enter this relatively unregulated sector of the fleet. The resulting vessels have the capability in terms of crew size, gear handling, endurance, and stowage, of a more traditional vessel of perhaps 15 meters. A schematic of the type is shown in Figure 1, with the extreme geometry associated with these vessels demonstrated by way of a computer model in Figure 2.

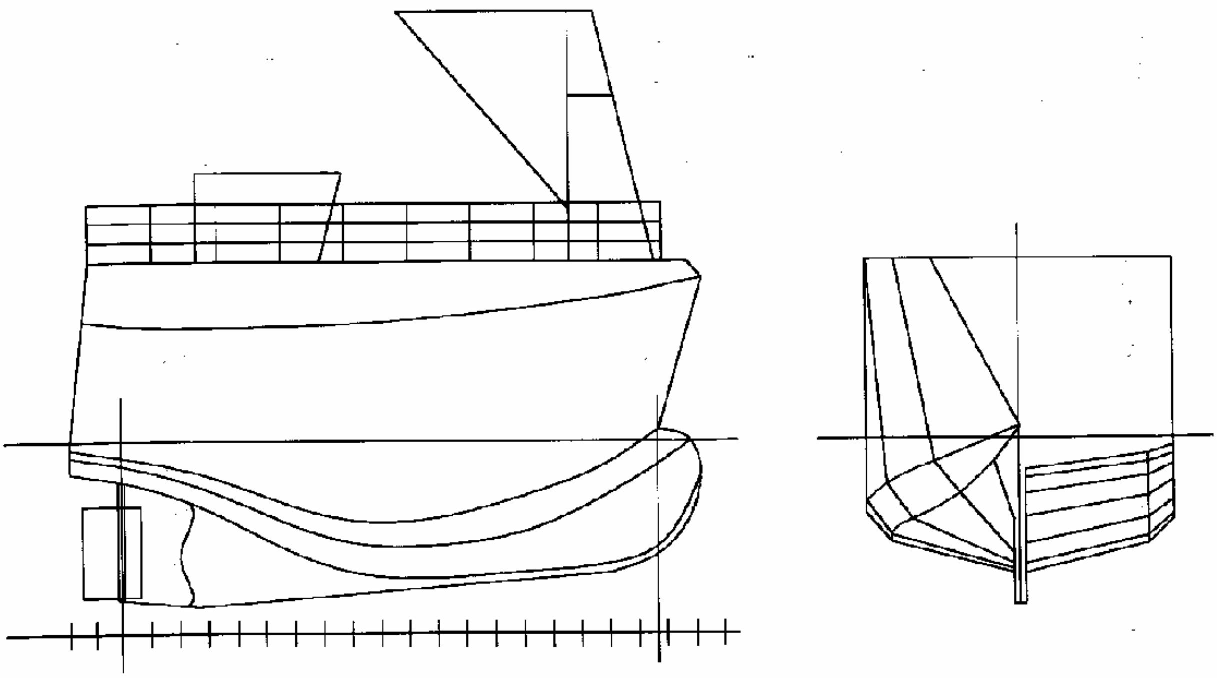

Figure 1: Sketch of under 10 meter Rule Beater

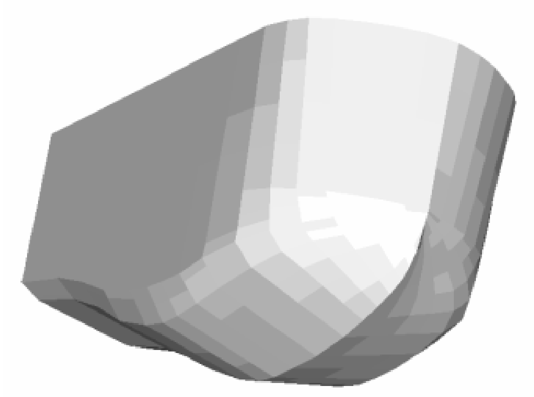

Figure 2: Computer model of under 10 meter Rule Beater

Stability Implications

Fishing vessels intended to have maximum fishing capability for the minimum of measured VCU, ‘rule beaters’, are designed to have the largest possible displacement and enclosed volume while constraining their planform area, as given by the product of length and breadth. This combination of design goal and constraint inevitably leads to an increase in the depth of the vessel, as once the ends of the vessel have been filled out the only way to increase volume is by enlarging the vessel vertically. This is one of the distinctive characteristics of these designs, their high profile and raised control position.

Increasing the depth inevitably raises the centre of gravity of the vessel, but this is further exaggerated as much of the heavy equipment necessary for fishing operations is located on the main working deck. Raising this deck moves items such as the winches, power block and net storage higher on the vessel. The inevitably high vertical centre of gravity forces the designer to increase the beam of the vessel in order to regain an acceptable value for GM, so giving rise to the second distinctive characteristic of the rule beater designs, their very low length to beam ratio. However the designer may find that simply increasing the beam of the vessel is not an adequate solution to the stability difficulties caused by the high vertical centre of gravity. In the first place there is a limit to how low the length to beam ratio can be allowed to go. In the under 10 metre vessels extreme cases can be found of 2.1, but for larger vessels this would impact too severely on the powering requirement for the vessel. However even if other factors do not restrain the designer from increasing the beam even further stability derived in this way enhances stability at low angles of heel, but reduces it at moderate and high angles. The resulting GZ curve is typical of form stable craft, with the maximum value of GZ at a very low angle. Fishing vessels relying on beam to compensate for their high vertical centre of gravity have difficulty in satisfying the IMO stability criteria, due to the reduction in righting lever as heel angles increase.

The only solution for the designer in this case is to moderate the characteristics of a form stable craft by adding ballast, so bringing back down the centre of gravity until a satisfactory GZ curve can be obtained. This is a most unsatisfactory solution as the designer wishes to reserve all the available displacement for increasing the size of machinery and other equipment, for carrying fuel, and of course for maximising size of catch that can be stored. Placing permanent ballast in the box keel reduces the deadweight of the vessel, but even so up to 10% of the displacement is utilised for ballast on some of these vessels, this being the only way to obtain satisfactory stability characteristics. This design path is not always successful. Increasing ballast increases the draft of the vessel, which inevitably reduces the height of the metacentre, and may also force the designer to increase the height of the decks yet again, so entering a spiral that moves ever further from an acceptable design solution.

However when convergence is achieved the result is the current extreme form of rule beater design, with a low length to beam ratio, a high above water profile, and a deep draft, that includes a large amount of permanent ballast in the keel. Such designs have one further characteristic that can be commented upon. The masses of the vessel are concentrated at either end of the vessel's extreme depth. Ballast and the main engine (which is itself large for the size of vessel due to poor resistance characteristics and the desire to tow the largest possible nets) are located low down in the vessel, while much other heavy equipment, such as the winches and stored nets, are located high up on the working deck. This polarisation of the location of the main masses on the vessel results in a high mass moment of inertia in roll.

Rule Beaters and Safety

To interpret the statistics that are available for fishing vessel incidents [14] in terms of the impact of regulatory distortion on fishing vessel design is not possible. As the impact of the regulations has been manifest in its most extreme form in the smallest sizes of vessel it seems logical to look to the incident rate for different length groups. The figures for losses in 1999 are given in Table 1, and a graphical presentation of all incidents for the same year in Figure 3. In both cases the data suggests that the under 12 meter fleet, where the rule beaters are most extreme, is the safest sector of the fleet. It should be noted that these figures are presented as a percentage of the registered vessels in the relevant fleet and do not take account of the degree of utilisation of the vessels, the actual hours spent at sea. If a utilisation factor were introduced it would clearly present the smallest class in a less favourable light. It is also likely that minor incidents have been under reported for the smaller vessels where record keeping is less rigorous than the formalised procedures implemented on the large crewed vessels. But even if the figures were adjusted in this way little could be concluded with regard to the impact of the safety record of rule beating vessels as these are not differentiated from the more conventional designs.

Fishing Vessel Losses in 1999			
Length	No. Registered	No. Lost	Percentage lost
Under 12 meters	6163	17	0.28
12 – 24 meters	1002	10	1.00
24 meters and over	295	6	2.03
Total Fleet	7460	33	0.44

Table 1: Fishing Vessel Losses in 1999

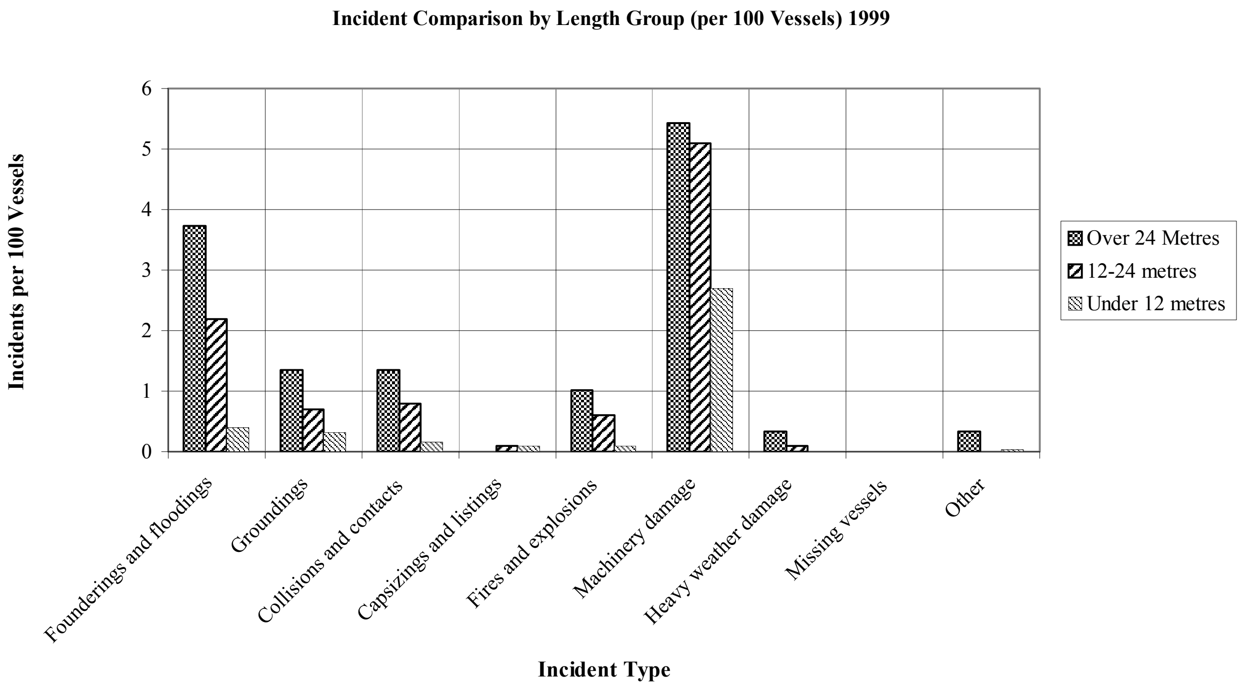

Figure 3. Fishing vessel incidents in 1999

Fishing Vessel Losses Since 1992			
Year	**Total Lost**	**Total on register**	**% Lost**
1992	32	10,953	0.29
1993	38	11,108	0.34
1994	43	10,296	0.42
1995	33	9,337	0.35
1996	26	8,064	0.32
1997	23	7,779	0.30
1998	21	7,605	0.28
1999	33	7,460	0.44

Table 2: Fishing Vessel Losses, 1992-1999

In the fishing industry the imposition of regulatory controls in the form of licenses with catch and capability limits attached, has influenced the fleet in two ways. Firstly, as examined in some detail in this paper, the design of fishing vessels has been driven in unexpected directions. The second effect, which has not been mentioned thus far, is that fishermen have been discouraged from building new vessels. This is because the regulations penalise fleet renewal, whether it be new building to replace older vessels or to aggregate license entitlements (i.e. two smaller vessels are replaced by one larger one). In both cases in order to force a gradual contraction of the total capacity of the fleet a reduction of the VCUs allocated to the license is imposed. Clearly this encourages the fishermen to continue working with older boats for as long as possible as can demonstrated by an analysis of the age of the vessels in the fleet. Over 28% of the fleet is over 25 years old, with the average age of the under 12 meter boats being

28 years, of the 12 to 24 meter boats being 36 years, and of the over 24 meter boats being 40 years [15]. Not only is the fleet old, but it is still aging as the rate of new building is less than half that required to prevent the average age of the fleet increasing further.

The data presented in Table 2 indicates that during the last eight years there is no sign of any improvement in the safety of the fishing fleet. While this could be attributed to many causes it is not unreasonable to suggest that a regulatory regime that discourages the building of new vessels, and encourages the development of extreme characteristics in those vessels that are built, could be one of the main contributors to the safety record.

Conclusion

In this paper the link between the regulations imposed on fishermen and the design of fishing vessels has been examined, and it has been demonstrated that the regulations are driving the evolutionary process in a direction that is unsatisfactory. Without the artificial regulatory constraints vessels could be designed that are fundamentally more appropriate for their purpose. However the fishing industry has to change as it is an undeniable fact that there are too many boats competing to catch too few fish. The industry must recognise that the mission of all fishing vessels has changed, and that they are no longer hunters, but harvesters of a crop. Farmers can reap the corn with a combine harvester, or a tractor, or simply use a scythe, and in different parts of the world all methods can be found. The appropriate technology has to be identified to harvest the resources of the sea in the waters of the UK and Europe. The rules that are regulating the size of the catch, and that are managing the structural changes in the industry, are in a continual state of development due to the complexity of the political, technical and ecological environment in which they operate. If future developments of these rules can be framed in a permissive format, the development of the fleet in future may not conflict with established naval architectural practice [16].

It is surprising that the type of craft described in this paper are economically viable, as the lower fuel efficiency (due to non-optimal hull forms and excessive windage) combined with the potentially reduced opportunity for fishing (due to non-optimal seekeeping characteristics) should be detrimental to the vessels profitability. However the popularity of the under 10 meter rule beaters attests to their commercial success. One reason for this is that these particular boats have been operating in a quota regime that does not include an allocation to each individual boat. A skilful fisherman with a highly efficient vessel can therefore take a disproportionate percentage of the total catch. Expensive but effective fishing operations undertaken over a brief period are more profitable than a more economical less intensive operation if there is effectively a race to grab the allowable catch. Once the fishery is closed both types of vessel are tied up, or turn to alternative sources of income.

It should not be forgotten however that the economic environment that favours all the rule beater designs is entirely artificial, and could be turned on its head by the introduction of slight modifications to either the regulations for capacity measurement, or for quota allocation. With their inefficient use of human and fossil resources an accurate cost benefit analysis of the contribution that these vessels make to society would demonstrate that short term individual benefit continues to dominate long term societal interests. If the result of this skewed logic is simply that excessive fuel is being used to catch the permitted quantity of fish, or that expensive capital equipment is unused for extended periods of time, perhaps it is an acceptable price to pay for ensuring that the structural changes necessary in the fishing industry occur in a relatively orderly fashion. But if the cost of structural change is also being paid in the form of reduced safety standards, then no one in the industry can afford to be complacent. Clearly further research is needed to compare in detail the safety performance of conventional and rule beating designs.

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