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# OBSERVATIONS ON THE CAPTURE EFFICIENCY OF A TWO-METRE BEAM TRAWL FOR JUVENILE FLATFISH

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## ABSTRACT

**A standard two-metre beam trawl, frequently and commonly used in surveys of young flatfish, was modified to increase its catch efficiency by replacing the tickler chains with heavy, spiked chains. Catches of 0-group plaice were improved by a factor of almost two, and catches of 0-group sole and dab by a factor of almost five. Differences in catchability were found between the three species, and behavioural factors were suggested which could account for such variation.**

## 1. INTRODUCTION

Estimates of the absolute abundance of fish species taken in trawl surveys require information on the efficiency of the gear. Beam trawls are regularly used to survey young flatfish populations, but few authors have presented efficiency data, largely because of the practical difficulties involved in their estimation. Where estimates have been made, they refer only to the plaice, *Pleuronectes platessa*. For this species, taken with a 4-m beam trawl, values range from 33% for newly-metamorphosed fish (10 mm), from 57% for juveniles in August and September (50-60 mm) and from 46% for fish during November (70 mm) (RILEY & CORLETT, 1965). For a 2-m beam trawl, gear efficiencies have been estimated at 25% to 35% for 15-65 mm 0-goup plaice (EDWARDS & STEELE, 1968), and 22% to 45% for plaice of 100-150 mm (KUIPERS, 1975).

Modification of the beam trawl to increase catch efficiency for flatfish has been attempted with some success by CHRISTENSEN (1969) using a rake trawl, and by DE GROOT & BOONSTRA (1970) using an electric tickler chain. This paper describes a simple modification to a standard 2-m beam trawl (RILEY *et al.*, 1986) which catches greater numbers of 0-group plaice, sole *Solea solea*, and dab *Limanda limanda* than the unmodified trawl. From the catch data an estimate is made of the maximum gear efficiency for these species.

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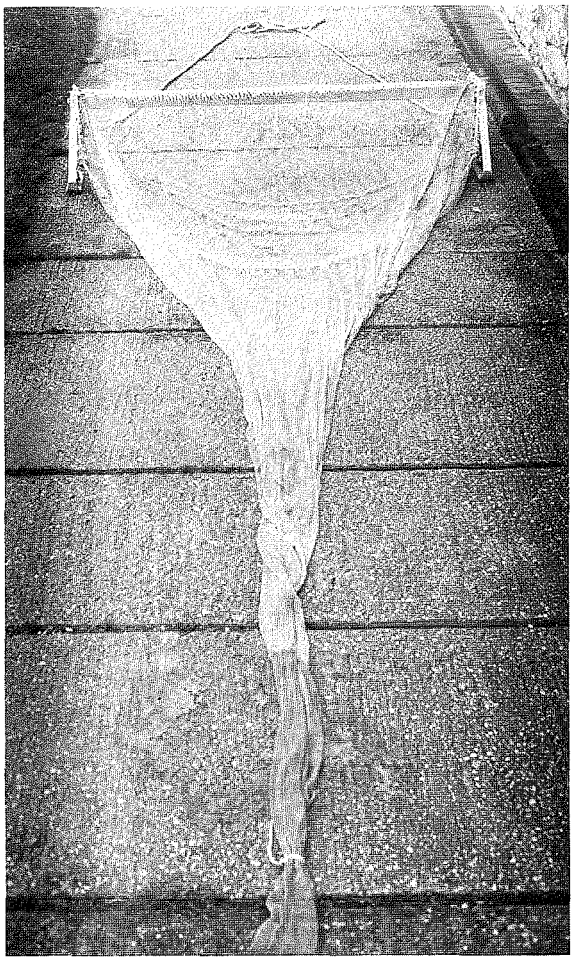
## 2. MATERIALS AND METHODS

Two types of trawl were used: a standard 2-m beam trawl (RILEY *et al.*, 1986), as used in many flatfish surveys (RILEY & CORLETT, 1965; EDWARDS & STEELE, 1968; LOCKWOOD, 1974) (Fig. 1a), and a modified version of the same gear. In the modified gear, the 3 tickler chains were replaced by heavier, spiked chains. The chains were made up of 65 mm x 20 mm links of 5-mm mild steel, with a 50 mm x 10 mm x 10 mm spiked bar through each link (Fig. 1b). A 2.5-m length ran between the eyes on the forward end of each trawl shoe, and another between the after eyes, with a 3.0-m chain also between the after eyes. All tickler chains were joined perpendicularly by 4 equally- spaced, shorter chains (Fig. 1c).

The standard and modified trawls were towed simultaneously on separate warps from the stern of a 10-m commercial fishing vessel, such that they fished for the same length of time, abreast of each other, and no further apart than 1 m. The tickler chains of each gear were swapped at intervals during the survey to reduce the possibility that some other factor of gear design would influence catch efficiency. There is no reason to believe that the substrates over which the trawls were towed differed consistently. Eight stations were chosen within a 24-km$^2$ area off the north-Wales coast centred on 53°19′ N, 3°33′ W. Fishing was carried out during daylight at, or near, the time of high tide, and in water depths of 4 m to 15 m. The paired tows were of 5-min duration and approximately at the speed of 35 m·min$^{-1}$ recommended by RILEY & CORLETT (1965); the distance travelled over the ground was recorded by a hodometer attached to the standard trawl (RILEY *et al.*, 1986).

The trawl stations were fished at spring tides on 5 separate occasions: on 7 September, 23 September, 12 October and twice on 6 November 1987. At each station the catch from each gear was sorted, and all



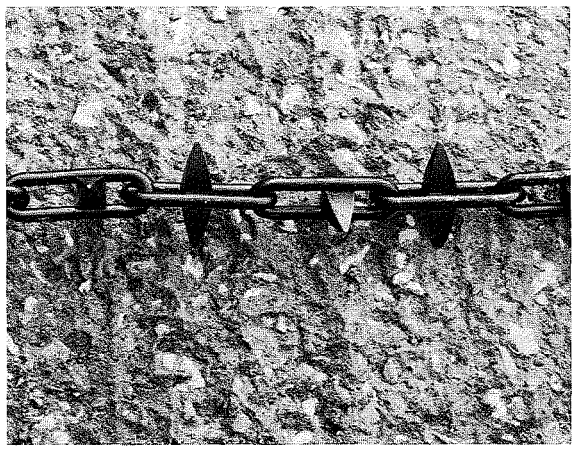


Fig. 1. The standard two-metre beam trawl (a), modified so that the tickler chains are replaced with spiked chain (b, c).

TABLE 1

The catch (numbers per 1000 $m^2$) at valid stations, of 3 species of 0-group flatfish, using standard (C) and modified ($C_1$) beam trawls, on 7 September (1), 23 September (2), 12 October (3) and 6 November (4) 1987. The absolute population density for plaice at 35% gear efficiency using the standard catch is shown as $C_2$.

| *Date* | *Plaice* | | | *Sole* | | *Dab* | |
|---|---|---|---|---|---|---|---|
| | *C* | $C_2$ | $C_1$ | *C* | $C_1$ | *C* | $C_1$ |
| 1 | 39.4 | 112.6 | 78.8 | 0.0 | 1.9 | 39.4 | 121.2 |
| 1 | 14.2 | 40.6 | 79.8 | 0.0 | 8.5 | 5.7 | 48.4 |
| 1 | 278.3 | 795.1 | 335.2 | 0.0 | 0.0 | 58.8 | 58.8 |
| 1 | 24.6 | 70.3 | 21.1 | 3.5 | 0.0 | 0.0 | 0.0 |
| 1 | 6.2 | 17.7 | 12.5 | 0.0 | 6.2 | 6.2 | 3.1 |
| 1 | 8.7 | 24.8 | 162.9 | 11.6 | 78.6 | 174.6 | 282.3 |
| 1 | 40.5 | 115.7 | 58.2 | 10.1 | 70.8 | 141.7 | 543.9 |
| 2 | 37.7 | 107.7 | 99.1 | 0.0 | 9.4 | 35.4 | 210.0 |
| 2 | 78.7 | 224.8 | 80.6 | 1.9 | 3.8 | 28.8 | 36.5 |
| 2 | 48.2 | 137.7 | 129.4 | 0.0 | 12.0 | 24.1 | 63.2 |
| 2 | 131.2 | 374.8 | 97.2 | 4.8 | 43.7 | 36.4 | 456.8 |
| 2 | 16.8 | 48.0 | 94.1 | 16.8 | 127.7 | 154.5 | 816.5 |
| 2 | 2.2 | 6.3 | 6.7 | 2.2 | 15.7 | 33.6 | 315.8 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 5.7 | 20.0 | 71.5 |
| 2 | 3.9 | 11.1 | 3.9 | 0.0 | 0.0 | 15.7 | 180.3 |
| 3 | 14.3 | 40.8 | 9.6 | 7.2 | 11.9 | 28.7 | 124.3 |
| 3 | 74.8 | 213.7 | 261.8 | 2.2 | 0.0 | 0.0 | 6.6 |
| 3 | 69.3 | 198.0 | 217.5 | 0.0 | 2.4 | 16.7 | 179.2 |
| 3 | 37.1 | 106.0 | 113.4 | 10.9 | 80.6 | 26.2 | 259.4 |
| 3 | 8.5 | 24.3 | 5.7 | 0.0 | 2.8 | 5.7 | 125.4 |
| 3 | 6.1 | 17.4 | 18.4 | 3.1 | 30.6 | 6.1 | 113.2 |
| 3 | 4.2 | 12.0 | 4.2 | 4.2 | 12.7 | 8.5 | 182.7 |
| 3 | 8.5 | 24.3 | 0.0 | 17.0 | 34.0 | 76.5 | 119.0 |
| 4 | 5.7 | 16.3 | 5.7 | 0.0 | 23.4 | 45.9 | 106.2 |
| 4 | 21.8 | 62.3 | 56.7 | 0.0 | 0.0 | 2.2 | 8.7 |
| 4 | 80.1 | 228.8 | 45.7 | 2.8 | 0.0 | 0.0 | 8.6 |
| 4 | 17.2 | 49.1 | 0.0 | 28.6 | 74.3 | 91.5 | 88.6 |
| 4 | 0.0 | 0.0 | 4.1 | 4.1 | 31.0 | 2.1 | 6.2 |
| 4 | 0.0 | 0.0 | 3.2 | 0.0 | 3.2 | 3.2 | 0.0 |
| 4 | 0.0 | 0.0 | 0.0 | 4.6 | 6.9 | 0.0 | 4.6 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 9.7 | 1.9 | 19.5 |
| 4 | 0.0 | 0.0 | 17.3 | 0.0 | 20.2 | 31.8 | 106.9 |
| 4 | 3.7 | 10.6 | 22.5 | 0.0 | 0.0 | 0.0 | 1.8 |
| 4 | 268.8 | 768.0 | 311.7 | 2.8 | 2.8 | 131.5 | 105.8 |
| 4 | 6.0 | 17.1 | 21.1 | 18.1 | 99.6 | 3.0 | 66.4 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 18.6 | 0.0 | 14.5 |
| 4 | 0.0 | 0.0 | 14.8 | 0.0 | 4.9 | 0.0 | 9.8 |
| 4 | 0.0 | 0.0 | 2.3 | 0.0 | 4.6 | 0.0 | 2.3 |
| 4 | 0.0 | 0.0 | 3.9 | 3.9 | 7.8 | 1.9 | 15.6 |

0-group plaice, dab and sole were measured and counted. During the period of sampling the size of fish captured ranged from 42 mm to 120 mm total length (TL). Catches were expressed as numbers of each species caught per 1000 $m^2$ for each gear. The frequency distribution of fish caught in a large number of tows is not normally distributed, thus the mean catch per 1000 $m^2$ for each gear, over the entire 9-week period, was calculated from logarithmically-transformed data (SOKAL & ROHLF, 1981):

$$\bar{C} = (\text{antilog } \Sigma \ln(C+1)/n) - 1 \quad (1)$$

where $\bar{C}$ = geometric mean number of fish caught (by species)
C = number of fish caught per 1000 $m^2$
n = total number of valid tows

The 95% confidence limits for the logarithmically-transformed catch were also calculated:

$$\text{c.l.} = \bar{C} \pm t_{0.05} \cdot s/\sqrt{n}$$

The mean catch of each species by the standard gear was expressed as a percentage of that made by the modified gear. This provided an estimate of the maximum possible gear efficiency of the standard 2-m beam trawl, assuming that the modified gear was 100% efficient. Following this assumption, the catches from the modified trawl provide a direct estimate of mean population density of plaice ($\bar{C}_1$ per 1000 $m^2$). Similarly, the mean population density can also be estimated from the standard trawl catches ($\bar{C}_2$ per 1000 $m^2$), assuming a mean trawl efficiency of 35%, the efficiency estimate most appropriate to this particular trawl and size range of fish (EDWARDS & STEELE, 1968).

The difference between $\bar{C}_1$ and $\bar{C}_2$ was tested for significance by using a paired 't' test. On the assumption that 35% is an accurate measure of standard trawl efficiency, no significant difference would imply that the modified trawl was 100% efficient at catching 0-group plaice. In this test the null hypothesis assumes that there is no difference between the two groups, *i.e.* $\bar{C}_1 - \bar{C}_2 = 0$.

Then:

$$t = \frac{D}{s/\sqrt{n}} \qquad (2)$$

(SOKAL & ROHLF, 1981; Box 11.3)

The value $(\ln C_2 + 1)$-$(\ln C_1 + 1)$ was calculated for each of the paired tows, and the mean of these values for all stations was determined (D); s = standard deviation. The ratios of each of the paired trawl catches were specific to a certain time and place, and therefore the differences shown were only those between gears. The log. catch ratios showed an approximate normal distribution, conforming with the requirements of the 't'test.

Catch records were also kept of the infaunal bivalve mollusc the edible cockle, *Cerastoderma edule*, which is abundant in the area, as an indicator of the different fishing characteristics of the two types of tickler chains.

TABLE 2

The geometric mean catch of three 0-group flatfish species using standard gear (C), and modified gear ($C_1$) (numbers per 1000 $m^2$), ±95% confidence limits. Number of valid observations=39.

| *Gear* | *Plaice* | *Sole* | *Dab* |
|---|---|---|---|
| Standard $\bar{C}$ | 9.1 (4.7 – 16.7) | 1.7 (0.9 – 2.8) | 10.2 (5.5 – 18.3) |
| $\bar{C}_1$ | 17.6 (9.3 – 32.6) | 8.4 (4.7 – 14.1) | 44.3 (24.6 – 78.9) |
| $\bar{C}/\bar{C}_1 \times 100$ | 51.7 | 20.3 | 22.9 |
| t(df = 38) ($p < 0.05$) | 3.28 | 6.69 | 8.21 |

TABLE 3

The catch of cockles *C. edule* (numbers per 1000 $m^2$) using standard (S) and modified (M) gears on 3 occasions. (– = no data)

| | *Live* | | *Dead* | |
|---|---|---|---|---|
| *1987* | *S* | *M* | *S* | *M* |
| 12 Oct | 20 | 575 | 93 | 77 |
| 6 Nov | 54 | 741 | – | – |
| 6 Nov | 23 | 422 | – | – |

## 3. RESULTS

The catches of 0-group plaice, sole and dab from each station (numbers per 1000 $m^2$) between 7 September and 6 November 1987 are shown in Table 1. The mean catch by each gear, in all surveys combined (Table 2) shows differences between species. In particular, the lowest mean catch for standard gear was that of sole with 1.7 fish per 1000 $m^2$, while those of plaice and dab were 9.1 per 1000 $m^2$, and 10.2 per 1000 $m^2$ respectively. Also, paired 't'tests indicate that the mean catch per unit area of the standard gear was significantly lower than that of the modified gear, for each of the species (Table 2). The highest mean catch rate using modified gear was that of the dab, with 44.3 fish per 1000 $m^2$.

The mean catch of the standard trawl, when expressed as a percentage of the mean catch of the modified trawl, for each species, indicates the maximum possible efficiency of the standard trawl in relation to that of the modified trawl. The ratios suggest that the maximum value for plaice would be 51.7%, for sole 20.4%, and for dab 22.9% (Table 2).

As a result of the gear modification, mean catches of the 3 species were greatly improved. For plaice, this increase suggests that the new gear efficiency was greater than the 35% value previously assumed, and could even be tested for 100% efficiency. The mean density of plaice, taken directly from the modified trawl catch data, was not significantly different from the mean density ($\bar{C}_2$) calculated from standard trawl catch data and using an assumed gear efficiency of 35% ($t = 0.59$; $df = 38$; $P < 0.05$).

Catch records of live *C. edule* (length range 15-35 mm) show how catches of this infaunal bivalve were affected by the action of the modified gear (Table 3). At one fishing station the catch of cockles was recorded on 3 separate occasions. The catch of live animals using modified gear was considerably greater than that using standard gear. The empty shells of dead animals on the surface of the

substrate were caught in approximately equal proportions, 77 per 1000 $m^2$ using modified gear, and 93 per 1000 $m^2$ using standard gear, while catch rates of live animals differed by a factor of 14 or more (Table 3).

## 4. DISCUSSION

When the standard 2-m beam trawl is modified by incorporating heavier, spiked tickler chains, the catches of 0-group flatfish increase by a factor of almost 2 for plaice, and a factor of almost 5 for sole and dab. The catches of live cockles and dead shells made at one particular station suggest the way in which these higher catch rates are achieved. Both trawls caught approximately the same number of dead shell while the modified trawl took approximately 20 times as many live animals (Table 3). This suggests that the modified tickler chains are able to dig in to the substrate and disturb the partially-buried cockles, whereas the standard tickler chains skim the surface of the sea bed, largely freeing only the dead shells. It is assumed that it is this deeper-digging action which disturbs the fish.

From the higher catch rates of 0-group flatfish, it is clear that the modified trawl is significantly more efficient than the standard trawl but, as yet, the absolute level of efficiency has not been estimated. The assessment presented here is based entirely on the assumption that the standard 2-m beam trawl is 35% efficient when fishing for 0-group plaice (EDWARDS & STEELE, 1968). This estimate is not dissimilar to that found and used in other quantitative studies of 0-group plaice (RILEY & CORLETT, 1965; KUIPERS, 1975; LOCKWOOD, 1980a), but the estimate made by EDWARDS & STEELE (1968) was with a 2-m beam trawl, the same model as used in these studies and elsewhere (RILEY *et al.*, 1986), and was calculated for 0-group plaice of the same size range as that recorded in this study. Thus, as a first approximation to estimating the efficiency of the modified trawl, it is most appropriate to compare it with the standard trawl efficiency estimate of 35%.

The standard trawl catches of 0-group plaice, raised by the efficiency factor ($C_2$, Table 1), and the unamended catches from the modified trawl ($C_1$, Table 1), were not significantly different; notionally therefore, this gear is 100% efficient at catching 0-group plaice. Although this may be a logical assumption the practical aspects of fishing suggest that it is unlikely. However, if standard 2-m beam-trawl catches are to be raised by a factor equivalent to 35% efficiency to estimate absolute population density of 0-group plaice, it can be no less acceptable to take un-amended catches from the modified trawl for the same purpose.

An alternative method of comparing the catches from the two trawls draws a different conclusion. The average catch of plaice in the modified trawl is double that in the 35% efficient standard trawl (Table 2), which implies that the modified trawl is about 70% efficient when fishing for 0-group plaice. Conversely it might be argued that if the modified trawl is close to 100% efficient and catches approximately double the number of plaice of the standard trawl, the standard trawl has an efficiency of about 50%. This later value is within the range of estimates made by RILEY & CORLETT (1965) using a 4-m version of the same net, and close to the maximum estimate of KUIPERS (1975), but for larger fish (100-150 mm).

There are, as yet, no comparable gear efficiency estimates for 0-group sole and dab. When gear corrections have been used they have been based on the assumption that 0-group plaice efficiency factors are equally applicable for other species (*e.g.* dabs; EDWARDS & STEELE, 1968). Behavioural differences between the 3 species, however, suggest that their catchability is likely to show distinct variation. For the plaice, both dietary studies (EDWARDS & STEELE, 1968; LOCKWOOD, 1980b), and diurnal variation in trawl catches (DE GROOT, 1971), indicate that they are more active on or near the sea bed in the hours of daylight. In contrast, soles move and feed at night and remain buried, and relatively inactive during the day (KRUUK, 1963; BOEREMA, 1964). There is also evidence for nocturnal activity and feeding of dabs (HALL, 1987) although this conflicts with data presented by DE GROOT (1971) and suggests that activity can occur during the day and night. Species differences in catchability, or vulnerability, are also indicated by the greater increase in dab and sole catch rates with the modified trawl when compared with the increased catch rates for plaice (Table 2).

While modification of the 2-m beam trawl improves the catch rate of plaice, and significantly increases the catches of 0-group sole and dab, these data provide no information on absolute values of gear efficiency for sole and dab. However, they do show that, regardless of the efficiency of the modified gear, the efficiency of the standard gear for these species can be no more than about 20% (Table 2), if the modified gear has an efficiency of 100% as it notionally has for plaice.

The principal conclusion which may be drawn from this paper is that significant improvements can be made to catch rates by a very simple modification of the tickler chains. This modification may raise the catching efficiency for 0-group plaice to a level between 70 and 100%. Even greater improvements in 0-group sole and dab catch rates have been achieved but little advance has been made in expressing these as efficiencies, other than as maximum values for the standard gear, and in showing that current plaice efficiency factors are not applicable to dab or

sole. In this respect further studies are required to estimate beam-trawl catching efficiencies for 0-group flatfish.

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