The important impact of mesh size on numbers of fish impinged or entrained in power station cooling water systems

Richard Seaby

Pisces Conservation Ltd

01590 674000

pisces@pisces-conservation.com

Fish entering the cooling water system of a station have two possible fates - impinged or entrained

Impinged – stopped by the screens before passing through the station.

Entrained – passing through the screens and the station.

The size of the mesh on the screens determines the proportions of the fish which are impinged or entrained.

- Larger mesh size results in greater numbers of fish being entrained rather than impinged

- Small mesh size results in greater numbers of fish impinged rather than entrained

Historically, 10-mm square mesh has been used; in recent years, some stations have been constructed with 5 and 6-mm mesh screens

This presentation attempts to quantify the difference between 10-mm mesh and a 5-mm mesh.

The 5-mm site – Marchwood power station in Southampton Water

The site is on the south coast of the UK, at the upper end of Southampton Water, which is home to a wide range of marine and estuarine fish species.

The salinity is generally around 30-35 ppt

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Mesh size that retained 100% of fish

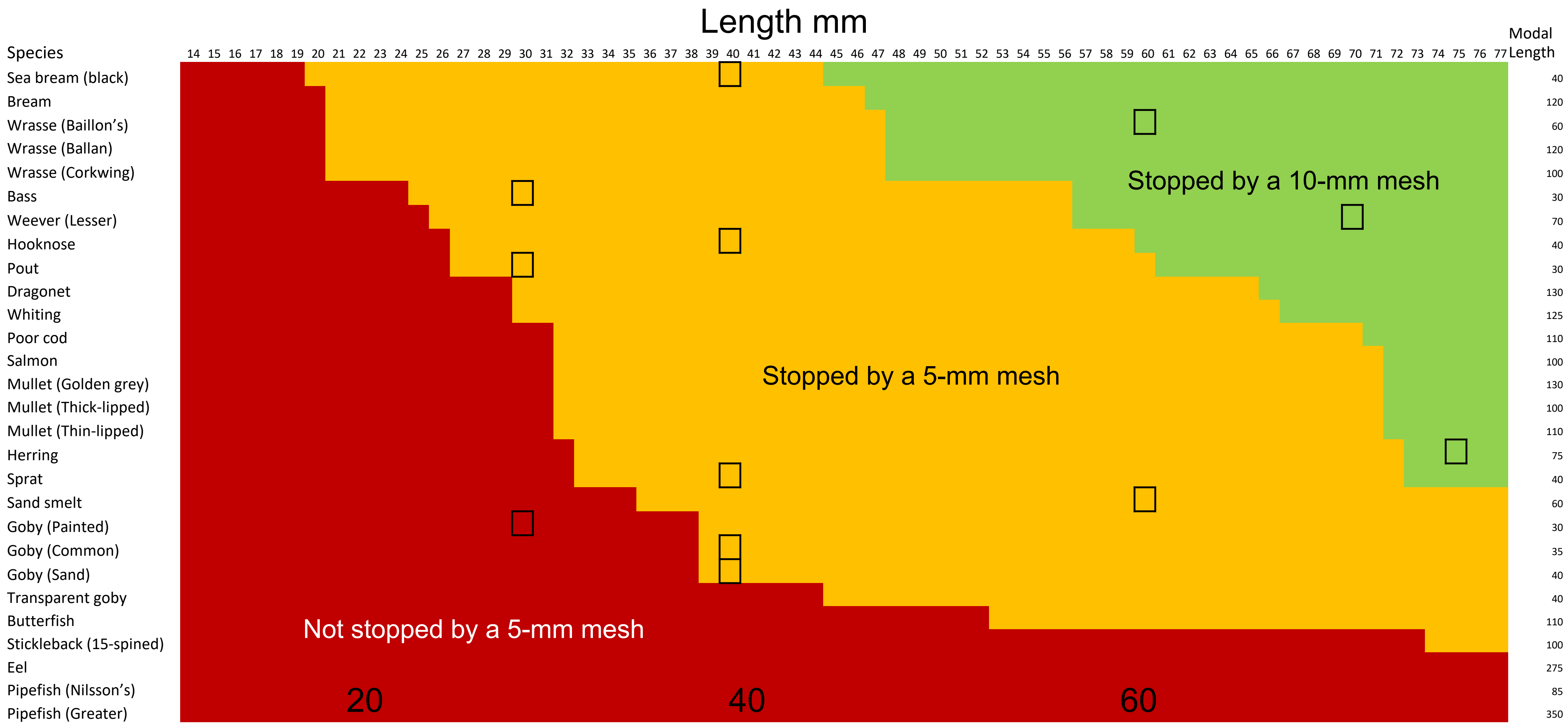
Turnpenny (1981) measured the size of square mesh needed to stop 100% of individuals of a fish species from passing through a screen. The equation is:

$$M = \frac{Ls}{0.0209Ls + 0.06564 + 1.999F}$$

where *M* = Mesh size in mm,
Ls is the standard length of the fish in mm, and
F, or Fineness, is the *Ls/D* where *D* is the greater of width and depth of the fish.

Turnpenny, A. (1981). *An Analysis of Mesh Sizes Required for Screening Fishes at Water Intakes.* Estuaries, Vol. 4, No. 4, pp 363 – 368.

Fish length (SL mm) with 100% retention by a 5- and 10-mm screen



Modal sizes of fish impinged at Marchwood marked as a black square

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Initial approach for sprat

- Sprat was chosen, as it is one of the commonest species caught in the UK, and is present from larval to adult fish.
- We have several datasets that include good length data for impinged fish.

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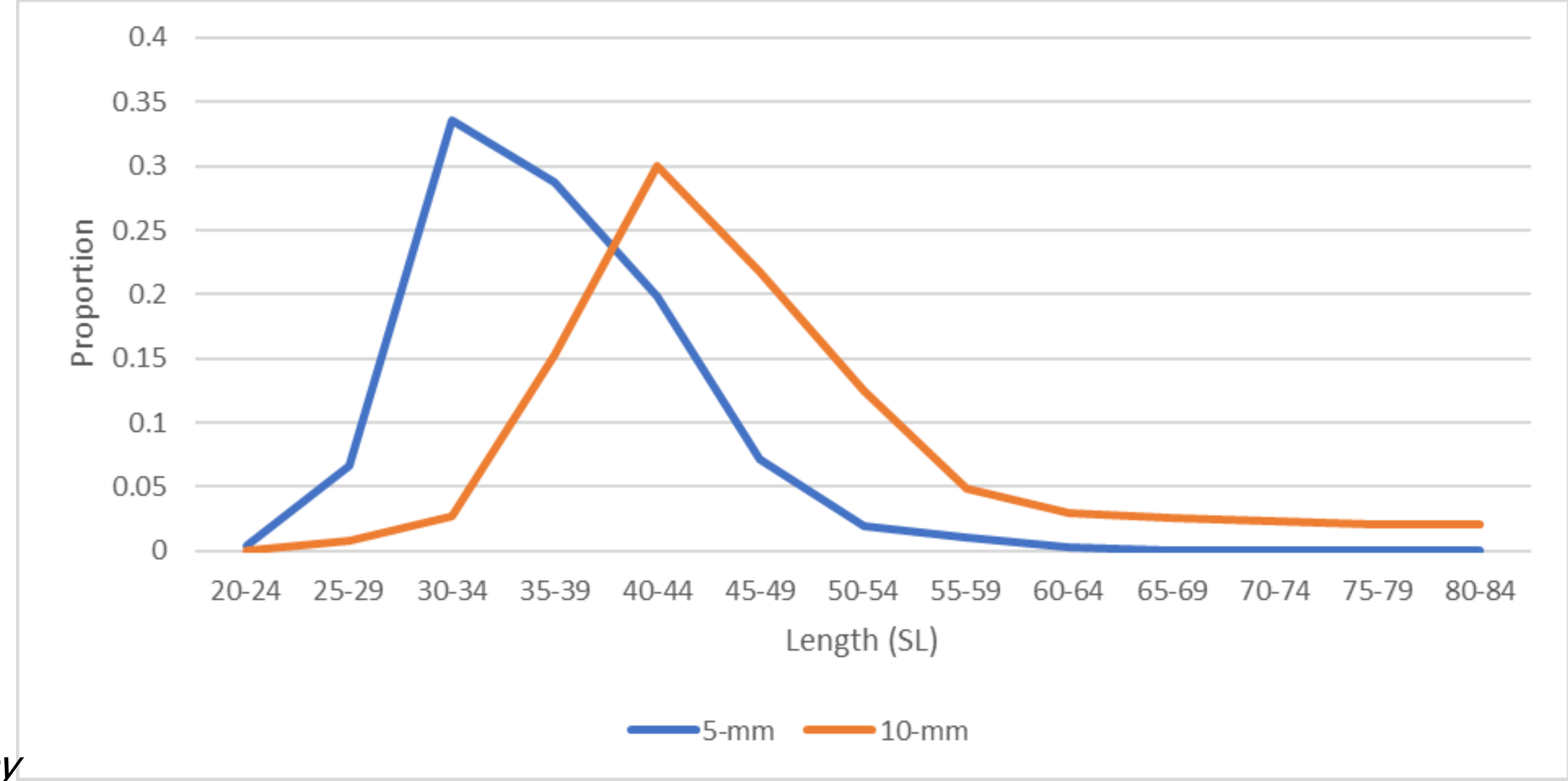
Plot of the proportion of sprat impinged in each 5-mm size class at Marchwood (5-mm mesh) and at sites with a 10-mm mesh

Data for July to September



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Number of sprat per size class at Marchwood (5-mm mesh) and sites with 10-mm mesh

Data from
July to September

Sprat	Number of sprat		
Size class (SL in mm)	Marchwood (5-mm)	Other sites (10-mm)	Other sites adjusted to 5-mm mesh
20	278	0	624
25	4,174	30	9,387
30	21,234	107	47,755
35	18,126	601	40,765
40	12,580	1,177	28,292
45	4,562	857	10,260
50	1,238	489	2,785
55	647	191	1,455
60	196	119	440
65	66	100	148
70	54	93	122
75	24	82	55
80	14	82	33
Total	63,192	3,928	142,121
% of fish not observed on the 10-mm site			97.2%

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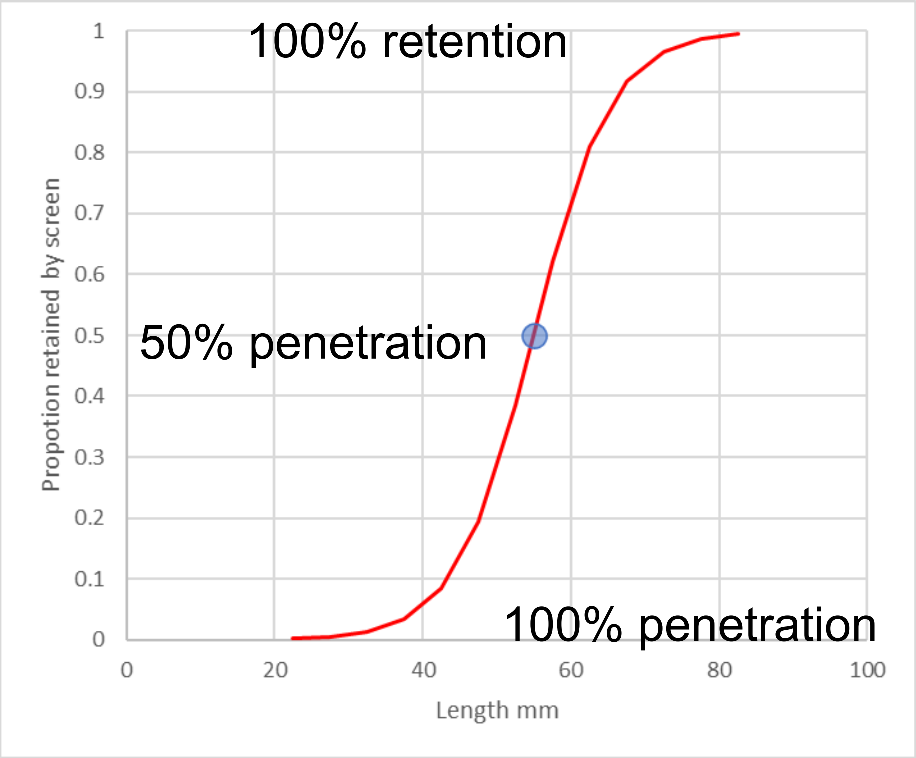
Finding the relationship between 5-mm and 10-mm impingement data for sprat

The equation used was a standard logistic curve, defined by the inflection point (*L50*) and a slope.

The equation is (all standard lengths)

$$p = \frac{1}{1 + \exp\left(-S * (L - L50)\right)}$$

where *p* is the probability of penetration,
S is the slope,
L is the fish length (SL)
L50 is the inflection point, where 50% penetration occurs



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Finding the parameters for the sigmoid curve

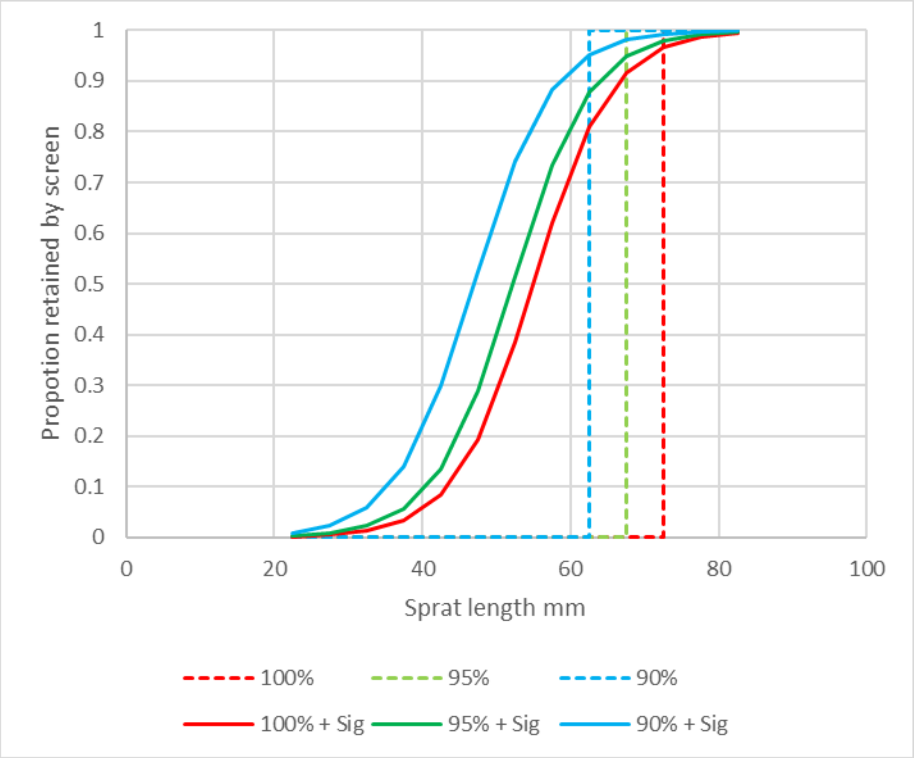
The Marchwood data were adjusted using a sigmoid curve, with a non-linear solver to adjust the parameters of the curve to fit the data found at 10-mm sites.

For sprat, the maximum length at which mesh penetration would occur on a 10-mm screen was found to be 71.09 mm – this is known as the 100% retention length.

By minimising the square of the difference between the two datasets, the best fit to the curve was

- *S* (slope) of 0.1914,
- *L50* of 54.9 mm.

The *L50* was therefore at 77.29% of the 100% retention length.



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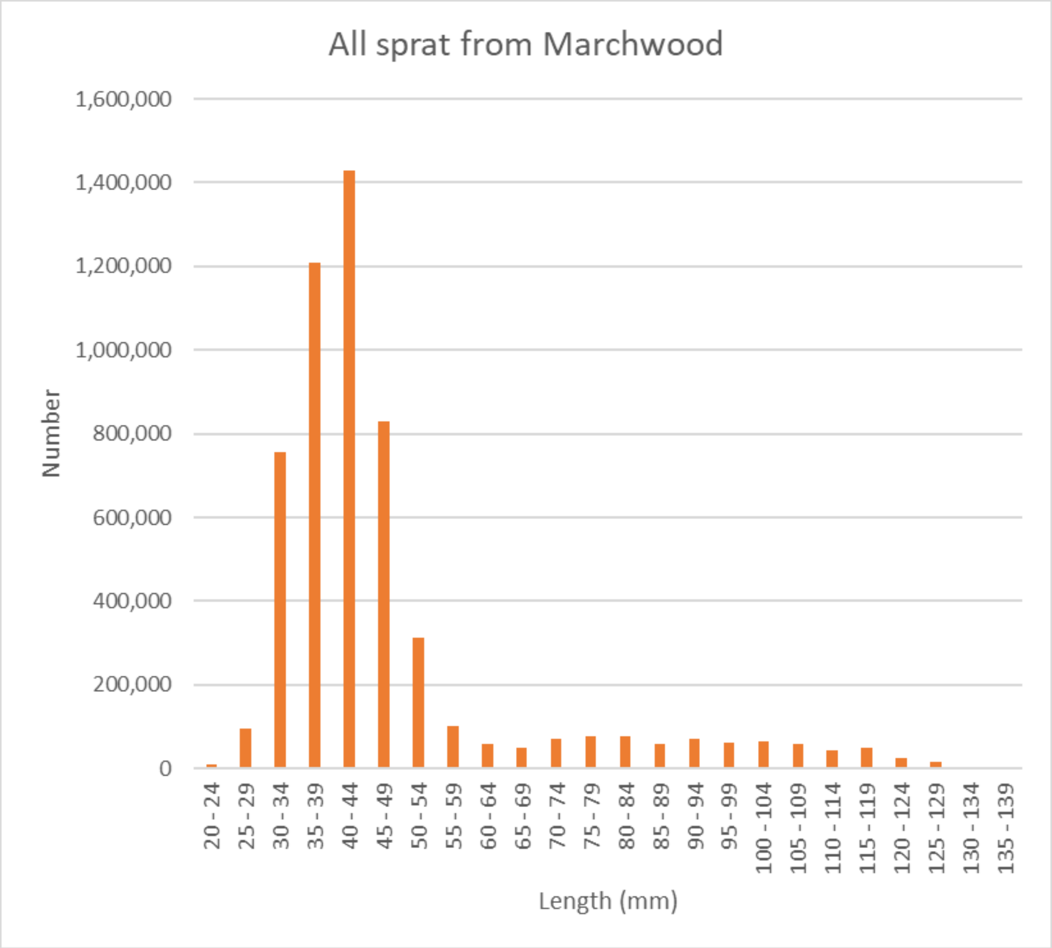
A model to calculate the fish impinged on a 5-mm screen and 10-mm screens

Known facts:

- The abundance and size distribution of fish at Marchwood (5-mm mesh)
- The sizes of fish stopped by different-sized meshes
- The shape of that relationship for sprat on a 5-mm and 10-mm screen



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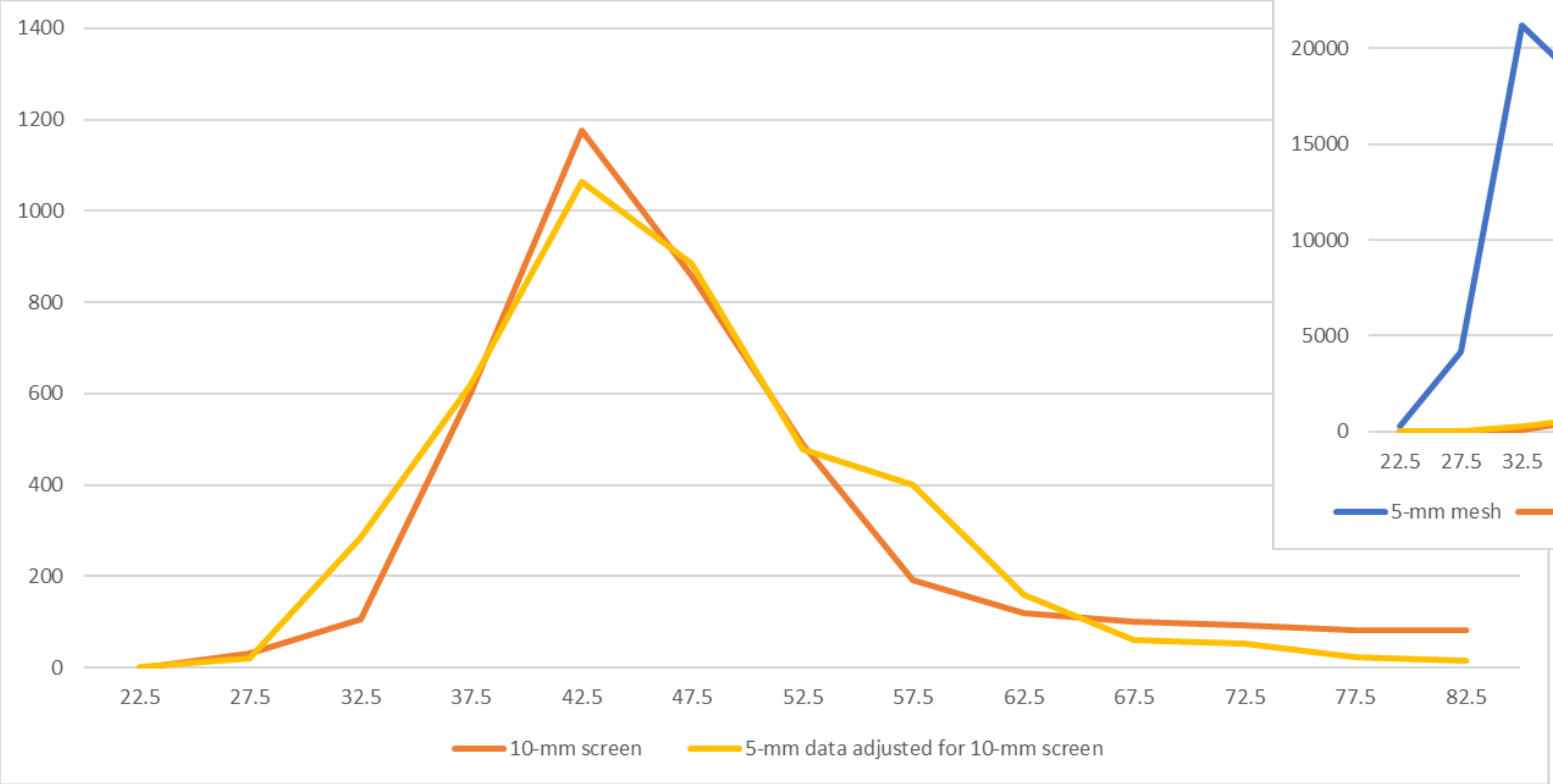
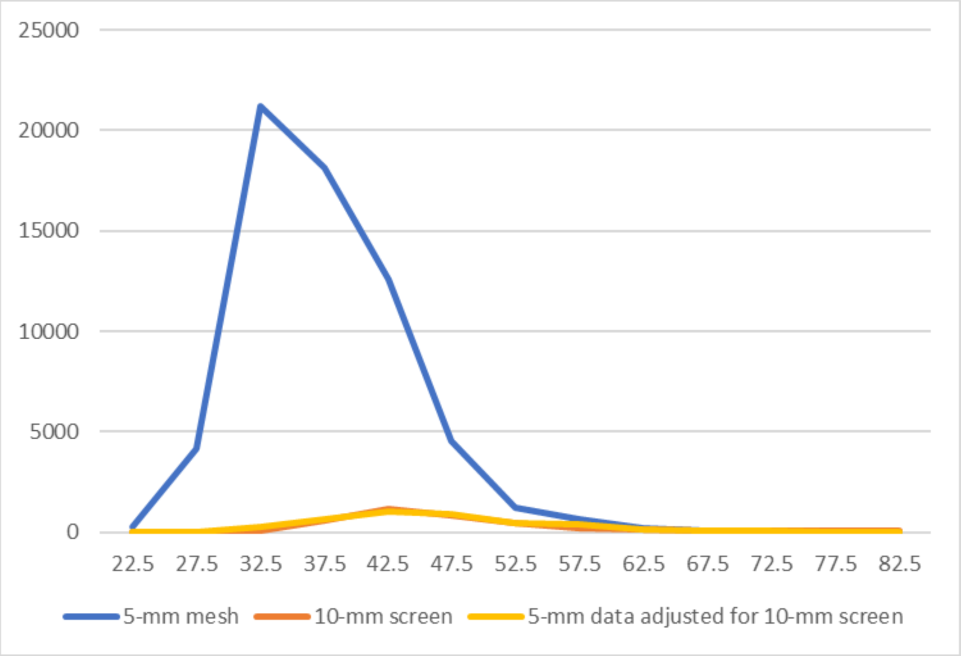
Fit of the model to the data. Sprat length frequency, from the 5-mm mesh (blue), the actual 10-mm data (orange) and the predicted 5-mm values with a 10-mm screen (yellow).





Data from
July to September

$R^2 = 0.94$

Analysing the other species

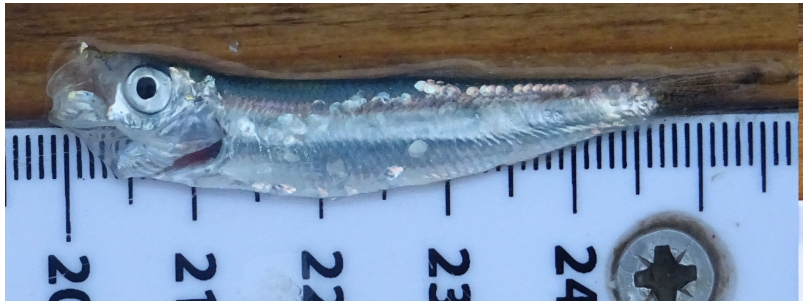
Using length and depth data for the fish species present at Marchwood, and the sigmoid curve, the model was run for each year of data.

There are two possibly problematic assumptions implicit in the calculation:

- most data used in the fineness ratio calculations come from adult fish data, when it is possible that young fish have different proportions to adult fish;

- that the retention curve for sprat is assumed applicable to other species – this may not in fact be the case.

At Marchwood, most of the fish caught are sprat, transparent goby and sand smelt, which have similar fineness ratios, and the juveniles are similar to the adult form.



The 10 most abundant species impinged at Marchwood (5-mm screen), and the percentage of those fish which would have been impinged on a 10-mm screen

Species	Average catch 2010-2018 5-mm screen	Estimated catch on 10-mm screen	The estimated percentage of the fish impinged on the 5-mm screen that would have been impinged on a 10-mm screen.
Bass	15,222	6,578	43%
Common goby	4,837	82	**2%**
Herring	25,715	22,859	89%
Pout	12,741	10,004	79%
Rock goby	6,447	1,102	17%
Sand goby	83,903	1,856	**2%**
Sand smelt	175,826	74,998	43%
Sprat	560,382	137,261	24%
Transparent goby	240,202	333	**0%**
Whiting	7,285	7,278	100%
Grand total (inc. all species)	**1,147,401**	**273,217**	**24%**

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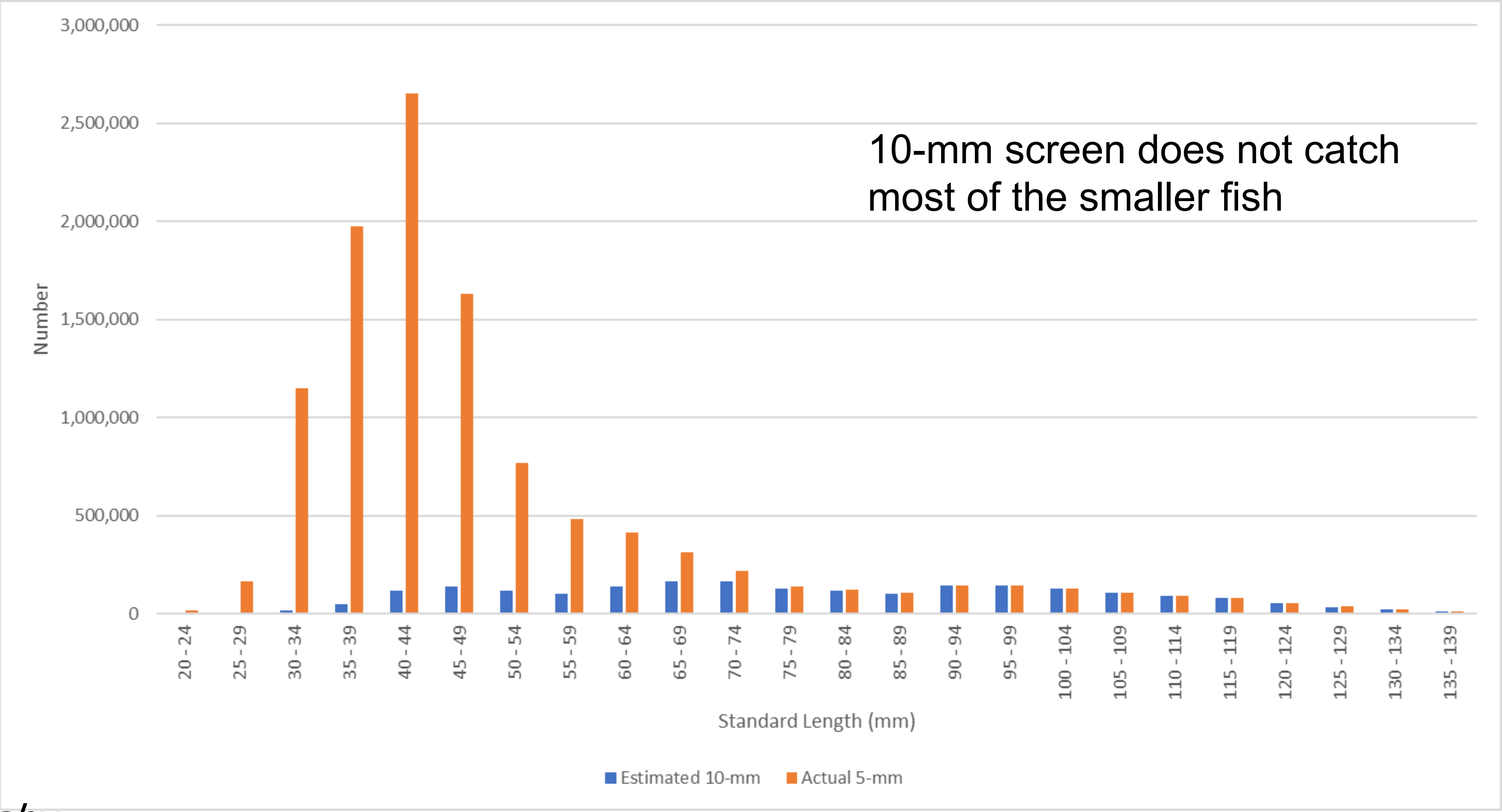
The actual (5-mm mesh) *vs* predicted catch on 10-mm mesh at different sizes at Marchwood for all species

Data for all years



Does the entrainment number go down to compensate for the increased impingement?

At Marchwood the number of fish entrained is 1 – 2 orders of magnitude higher than the number impinged.

So no, not really!

Therefore, increasing the impingement from 250 thousand to 1 million fish will only reduce the entrainment by a few percentage points, as the entrainment is predicted to be more than 10 million fish. This would not be noticeable with the high variability of entrainment data.

These small-sized fish are under-sampled generally – they are too small for general trawls and too large for plankton nets.

Expectation of the number of fish impinged should be higher at stations with smaller mesh sizes.

Summary

The effect of mesh size on impingement number is variable by species but can be very large.

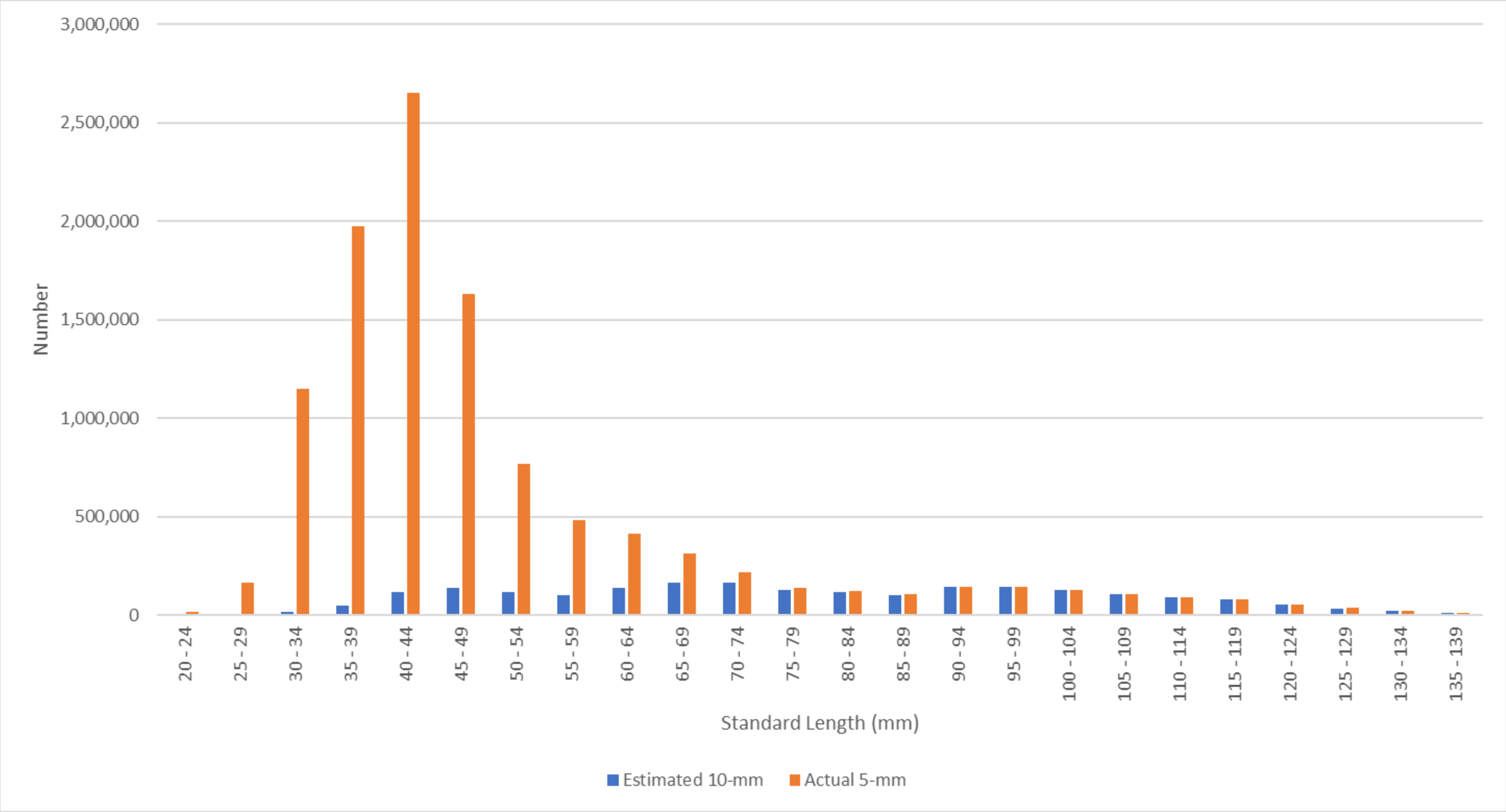
Some small species are not effectively retained on a 10-mm mesh, and small species are very common.

The impact on numbers impinged will depend on the species and size distribution of the fish vulnerable to impingement.

At a site where fish entrainment is an order of magnitude, or more, above the impingement numbers, the increased impingement with reduced mesh size does not measurably affect the numbers entrained.

These small fish are difficult to sample and estimate but are highly abundant and ecologically important.

Mesh size differences need to be considered when using historic data



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