Antonello Sala,
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Pilot project catch and discard composition including solutions for limitation and possible elimination of unwanted by-catches in trawl net fisheries in the Mediterranean (DISCATCH)

Experimental and theoretical size selectivity

Introduction and material and methods

Specific objectives

To predict the expected size selectivity of a range of species for many different codend designs (e.g. mesh sizes, mesh type, twine thickness);

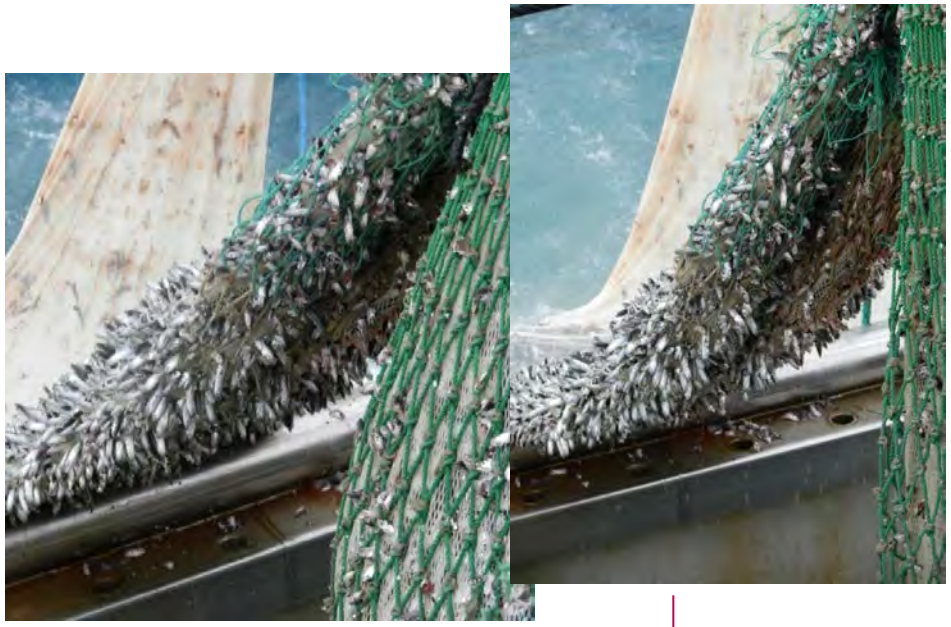
To validate the model results using selectivity data from both the pelagic- and demersal fisheries.

Proposed fisheries and species being investigated

Use of FISHSELECT simulation tools for trawl design guides

- OTB: quantification of the size selective properties of meshes of different shape and size for the species being investigated.

- OTM, PTM: mitigation of the sticking problems, judgement of the risk for stickers (fish which due to the impossibility of going completely through, become enmeshed while trying to pass through the netting) in different parts of a trawl.

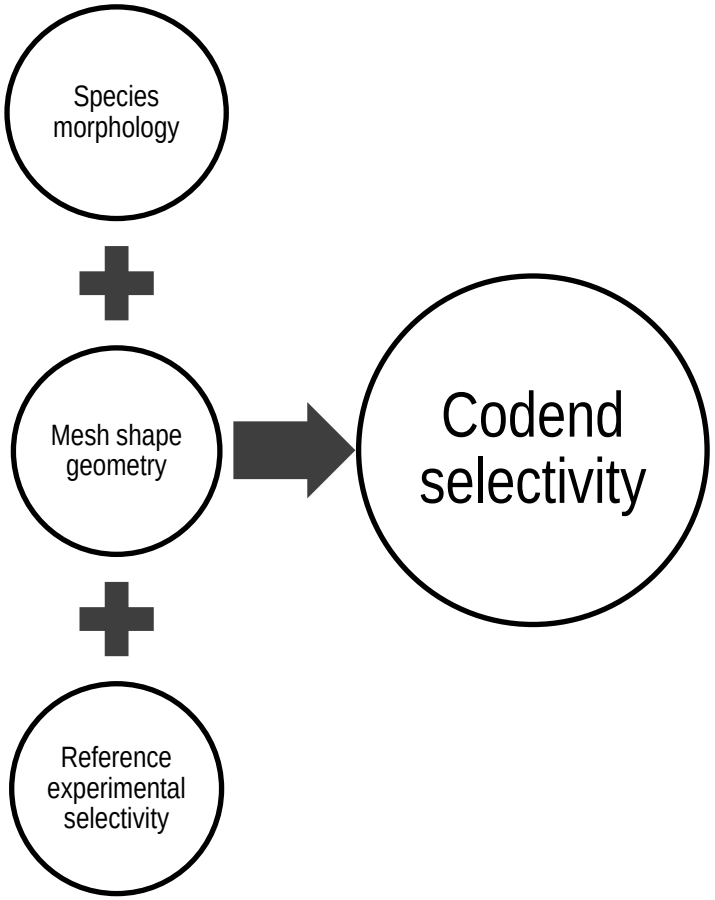


- ✓ Assessment of the morphological conditions of different fish and crustaceans in the process of mesh penetration in towed gears;
- ✓ Based on comparison of cross-sectional geometry of individual animal and the geometry of the mesh;
- ✓ Prediction of the selectivity properties of multiple codend types.

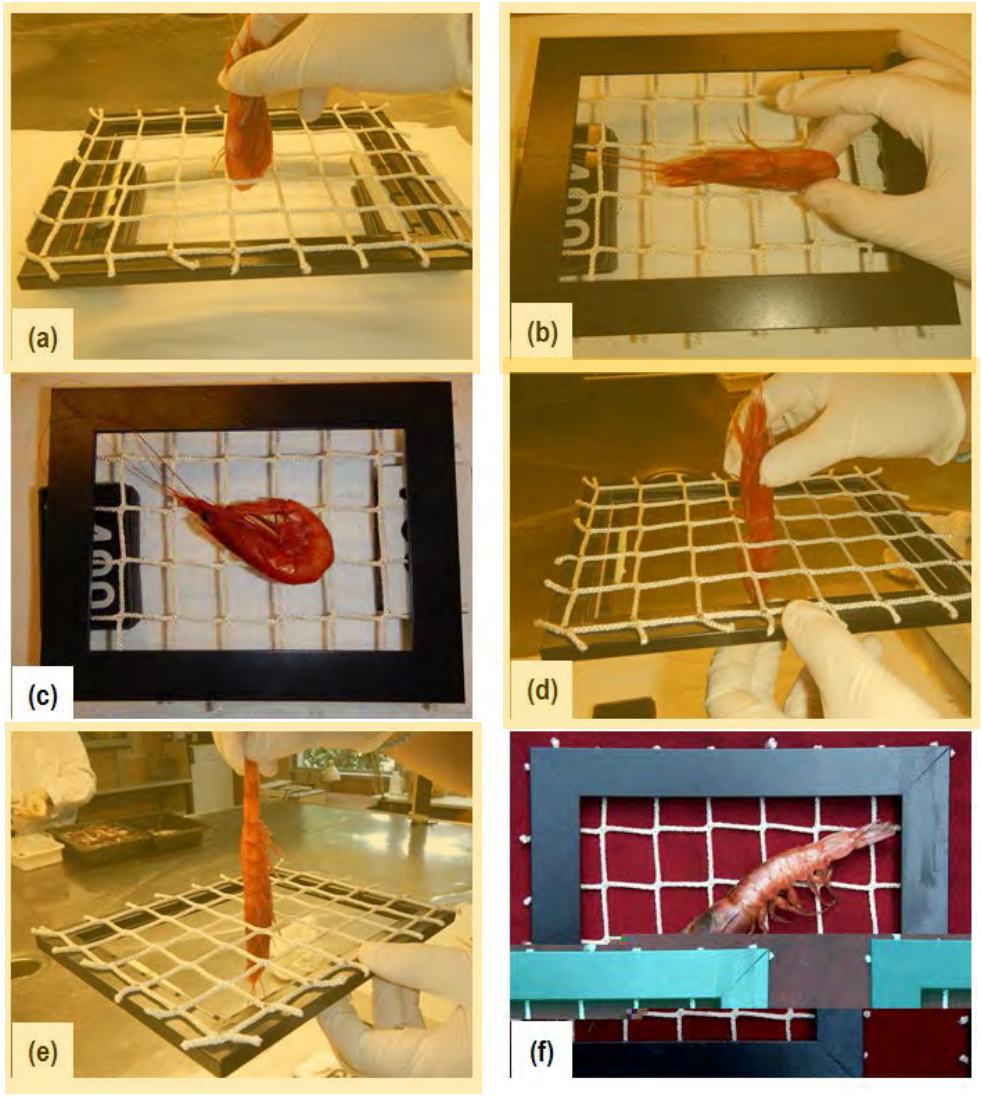
Types of information needed in the selectivity simulation

To predict size selectivity of codends three types of information are needed:

1. Cross-sectional morphology of the species being investigated;
2. Mesh codend shape during fishing;
3. Experimental size selectivity of a reference mesh type.



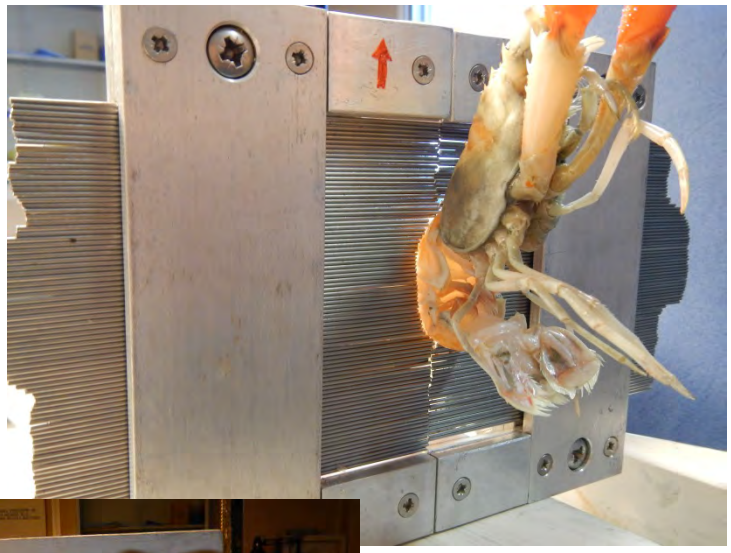
Cross-sectional morphology data of the species being investigated

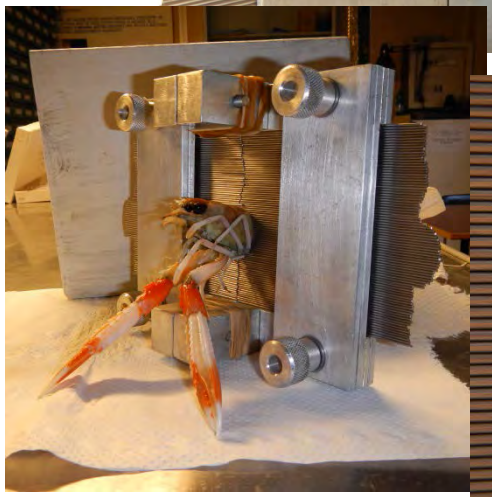


Preliminary contact modes test

In the subsequent cross-sectional morphology experiments only three modes (a), (d) and (b)(e) have been considered.

Cross-sectional morphology data of the species being investigated

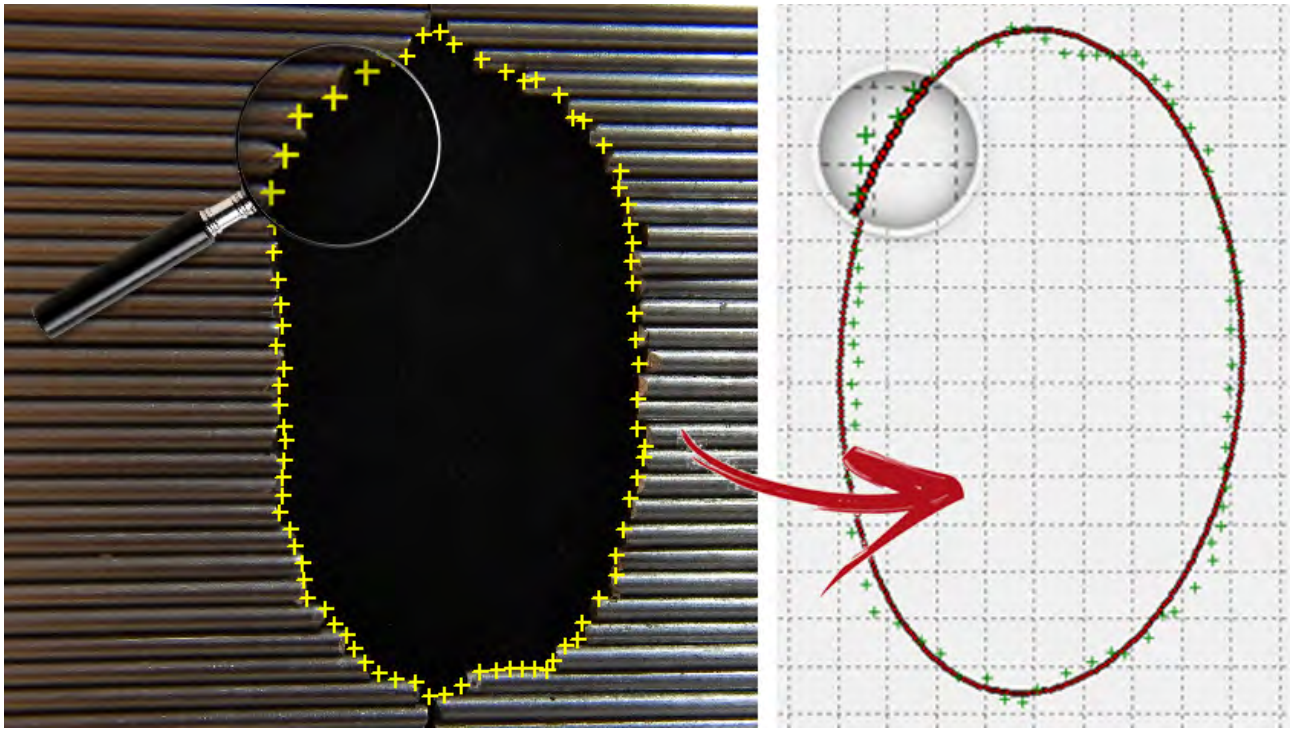




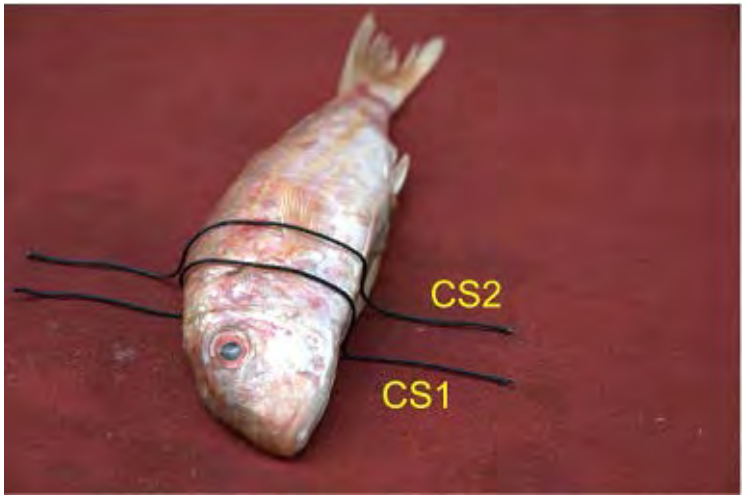
Mathematical descriptions for the two functions, f(t) and g(t) with $t \in [0\text{-}360]$, to represent the cross sections of the fish and crustaceans.

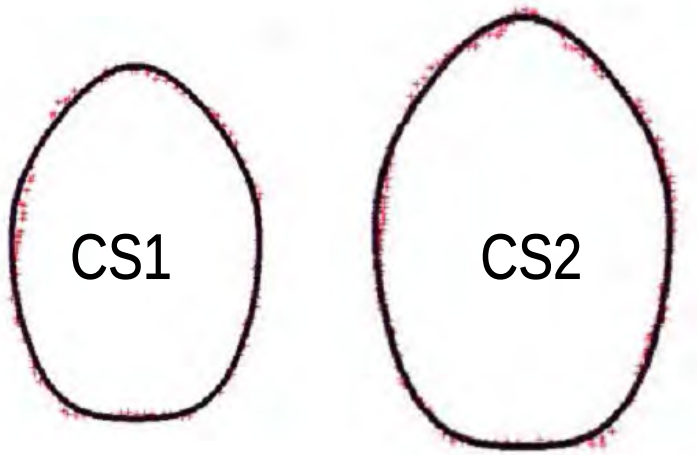
Model	*f(t)*	*g(t)*
Ellipse	$c_1 \times \cos\left(\pi \frac{t}{180}\right)$	$c_2 \times \sin\left(\pi \frac{t}{180}\right)$
Bottle	$c_1 \times \sin\left(\pi \frac{t}{180}\right) + c_1 \times c_3 \times \sin\left(\pi \frac{t}{90}\right)$	$-c_2 \times \cos\left(\pi \frac{t}{180}\right) + c_1 \times c_3 \times \cos\left(\pi \frac{t}{45}\right)$
Flex_1	$c_1 \times \sin\left(\pi \frac{t}{180}\right) + c_1 \times c_3 \times \sin\left(\pi \frac{t}{30}\right)$	$c_2 \times \cos\left(\pi \frac{t}{180}\right) + c_2 \times c_3 \times \cos\left(\pi \frac{t}{90}\right)$
Flex_drope	$c_1 \times sin\left(\pi \frac{t}{180}\right) + c_3 \times sin\left(\pi \frac{t}{90}\right)$	$-c_2 \times \cos\left(\pi \frac{t}{180}\right)$
Flex_drope_2	$c_1 \times \sin\left(\pi \frac{t}{180}\right) + c_1 \times c_3 \times \sin\left(\pi \frac{t}{90}\right)$	$-c_2 \times \cos\left(\pi \frac{t}{180}\right)$
Flex_ellipse_1	$c_1 \times \sin\left(\pi \frac{t}{180}\right)$	$-c_2 \times \cos\left(\pi \frac{t}{180}\right) + c_3 \times \cos\left(\pi \frac{t}{90}\right)$
Ship	$c_1 \times \sin\left(\pi \frac{t}{180}\right)$	$-c_2 \times \cos\left(\pi \frac{t}{180}\right) + c_3 \times \cos\left(\pi \frac{t}{45}\right)$

- Example of a scanned Morphometer image with a mechanical replica of the outer cross-section contour of a red mullet;
- the crosses are digitized points along the contour detected by contour acquisition routines implemented in FISHSELECT.



Cross-sectional morphology data of the species being investigated





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Experimental and theoretical size selectivity

Selectivity simulation of the demersal fish species

Statement from one stakeholder from the 1st DISCATCH stakeholder meeting held in Split:

„I am not convinced that laboratory simulations can really give good results because the conditions at sea are constantly changing and fishermen don't know how the mesh is going to behave, given that there are many uncontrollable factors during fishing.”

Proposed fisheries and species being investigated

Demersal trawl fisheries		
Country	Sub-region / fisheries	Species
Italy	Continental shelf and the upper slope in the Strait of Sicily (GSA16)	ARS, DPS, HKE
Italy	South Adriatic (GSA18)	DPS, HKE, HOM, MUT, NEP
Spain	Continental shelf and the upper slope off Iberian Peninsula (GSA1, GSA6)	ARA, HKE, MUT
Spain	Balearic Islands (GSA5)	ARA, HKE, MUR
Greece	Aegean Sea (GSA22)	DPS, HKE, HOM, MUT,
Pelagic trawl fisheries		
Italy	North-Central Adriatic (GSA17)	ANE, PIL
Italy	Central-Southern Tyrrhenian Sea (GSA10)	ANE

ANE: anchovy (*Engraulis encrasicolus*); ARA: red shrimp (*Aristeus antennatus*); ARS: giant red shrimp (*Aristaeomorpha foliacea*); DPS: deep-water rose shrimp (*Parapenaeus longirostris*); HKE: hake (*Merluccius merluccius*); HOM: horse mackerels (*Trachurus spp*); MUR: striped red mullet (*Mullus surmuletus*); MUT: red mullet (*Mullus barbatus*); NEP: Norway lobster (*Nephrops norvegicus*); PIL: sardine (*Sardina pilchardus*).

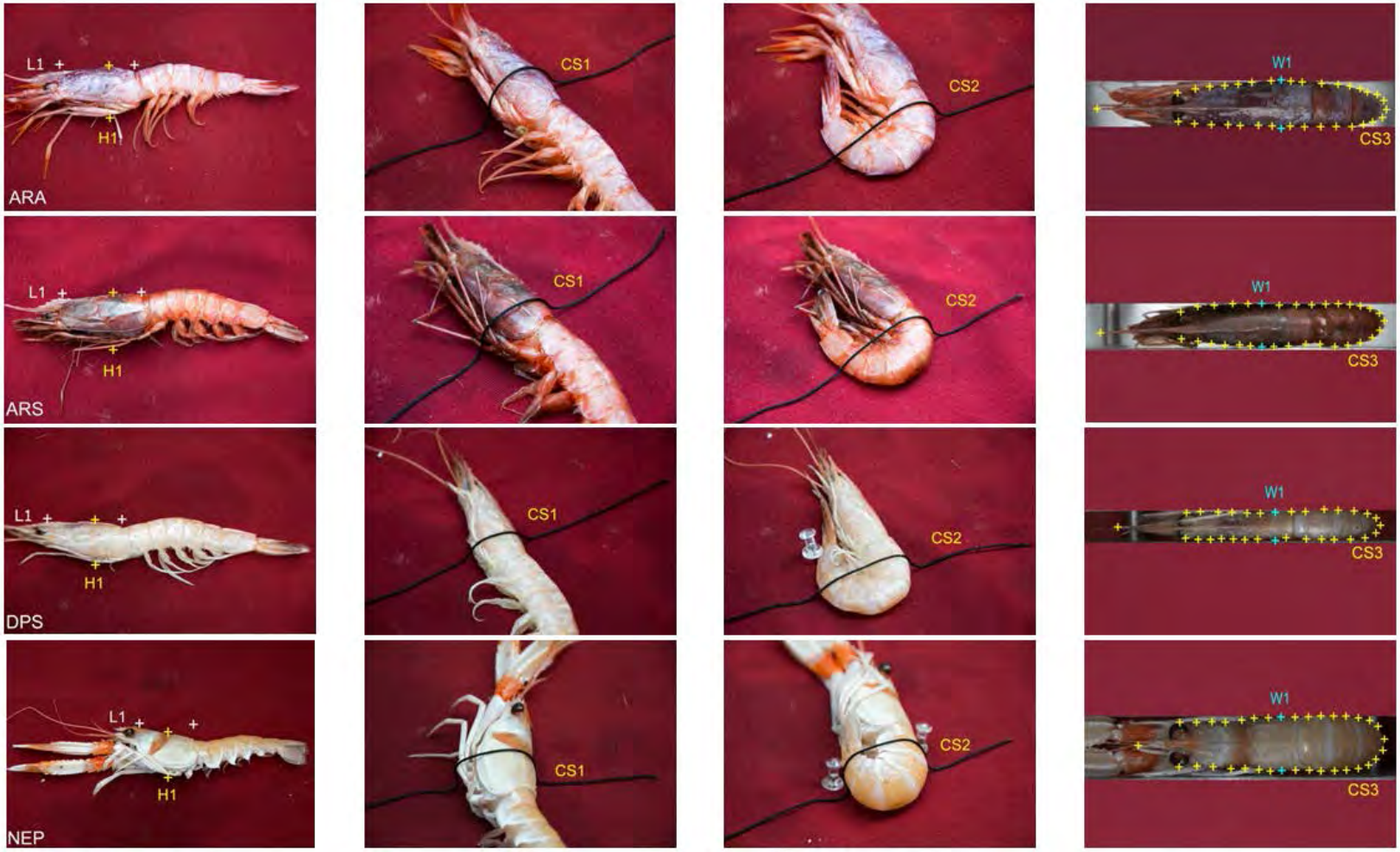
Why do we need the theoretical selectivity studies?

- Experiments are very expensive and time consuming
- Number of different gear designs that can be tested is limited
- Problems with observing fish behaviour inside the trawl

Cross-sectional morphology data of the species being investigated

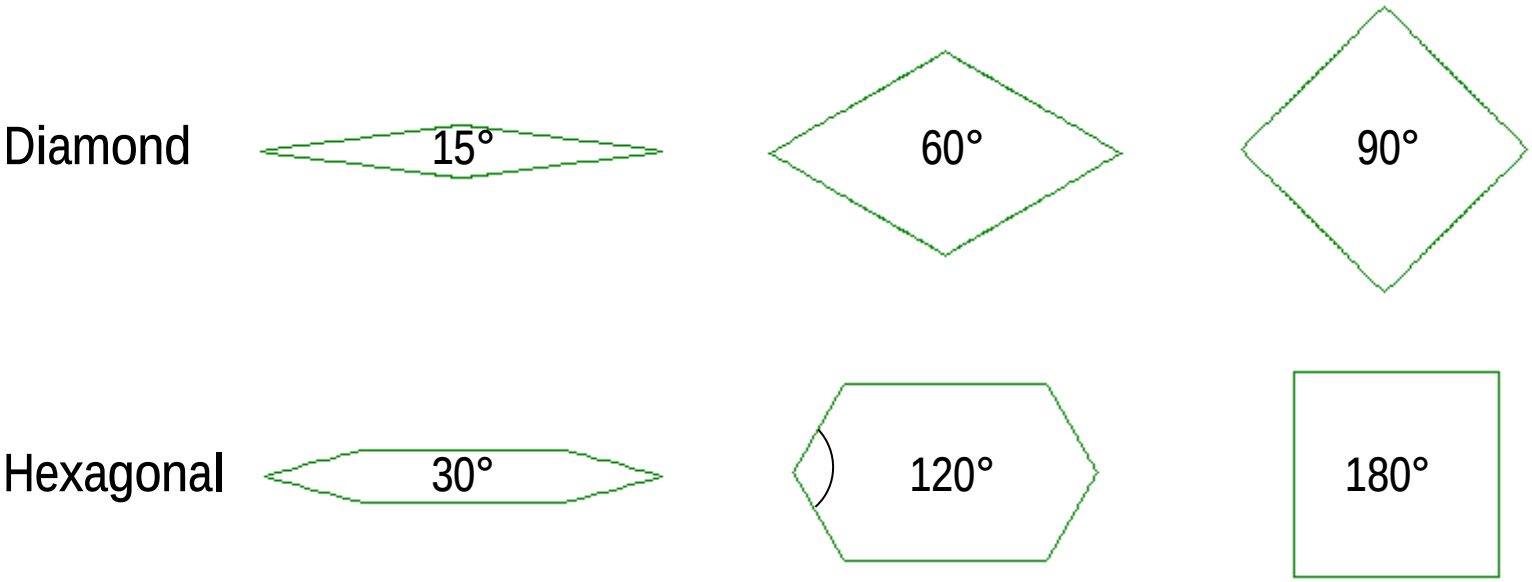
Cross-sectional morphology data of the species being investigated

Cross-sectional morphology data of the species being investigated



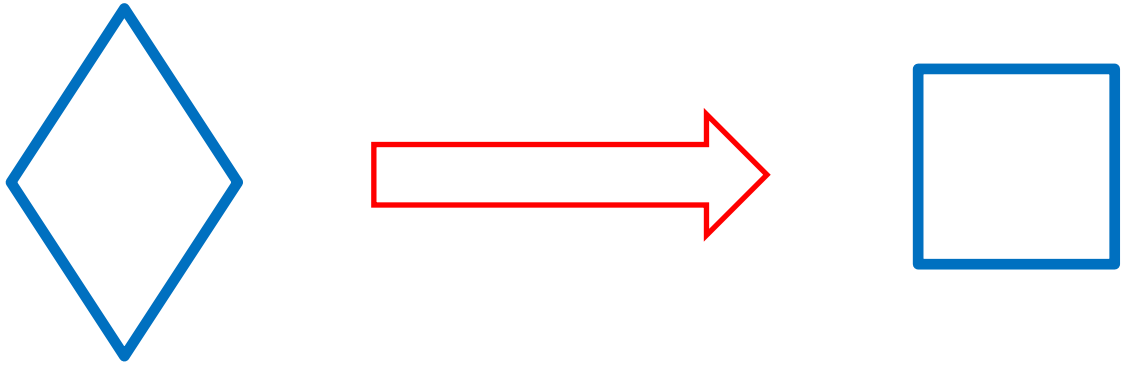
Assessment of codend mesh shape: demersal and pelagic fish

Mesh type	Openness	Stretched mesh size [mm]	
		Demersal	Pelagic
Diamond	15-90°	30-60	15-30
Hexagonal	30-180°	15-30	7.5-15

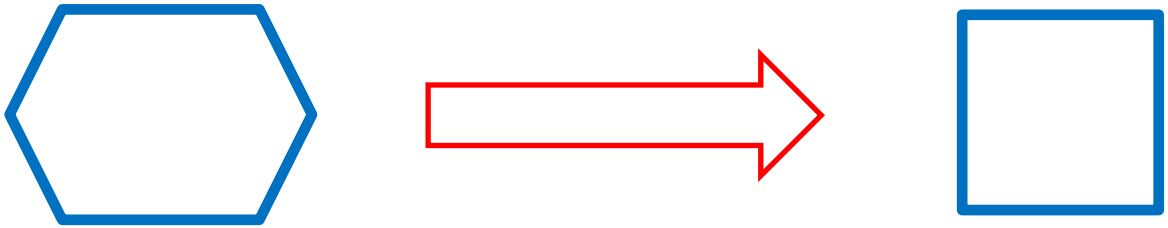


Where is the square mesh?

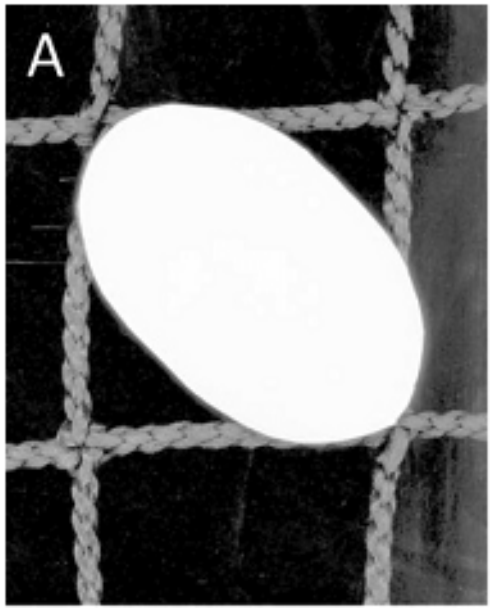
Opening angle in diamond mesh = 90°

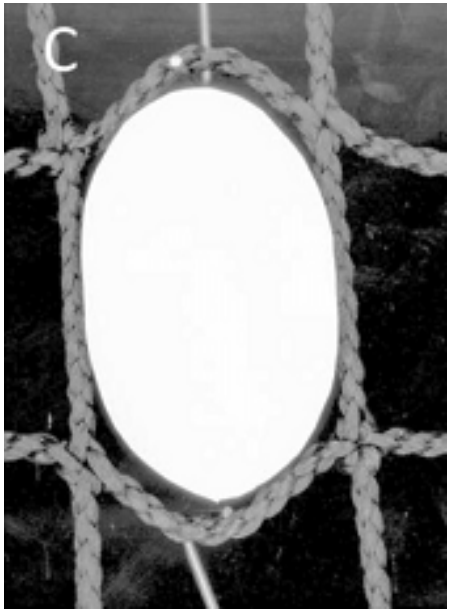


Opening angle in Hexagonal mesh = 180°



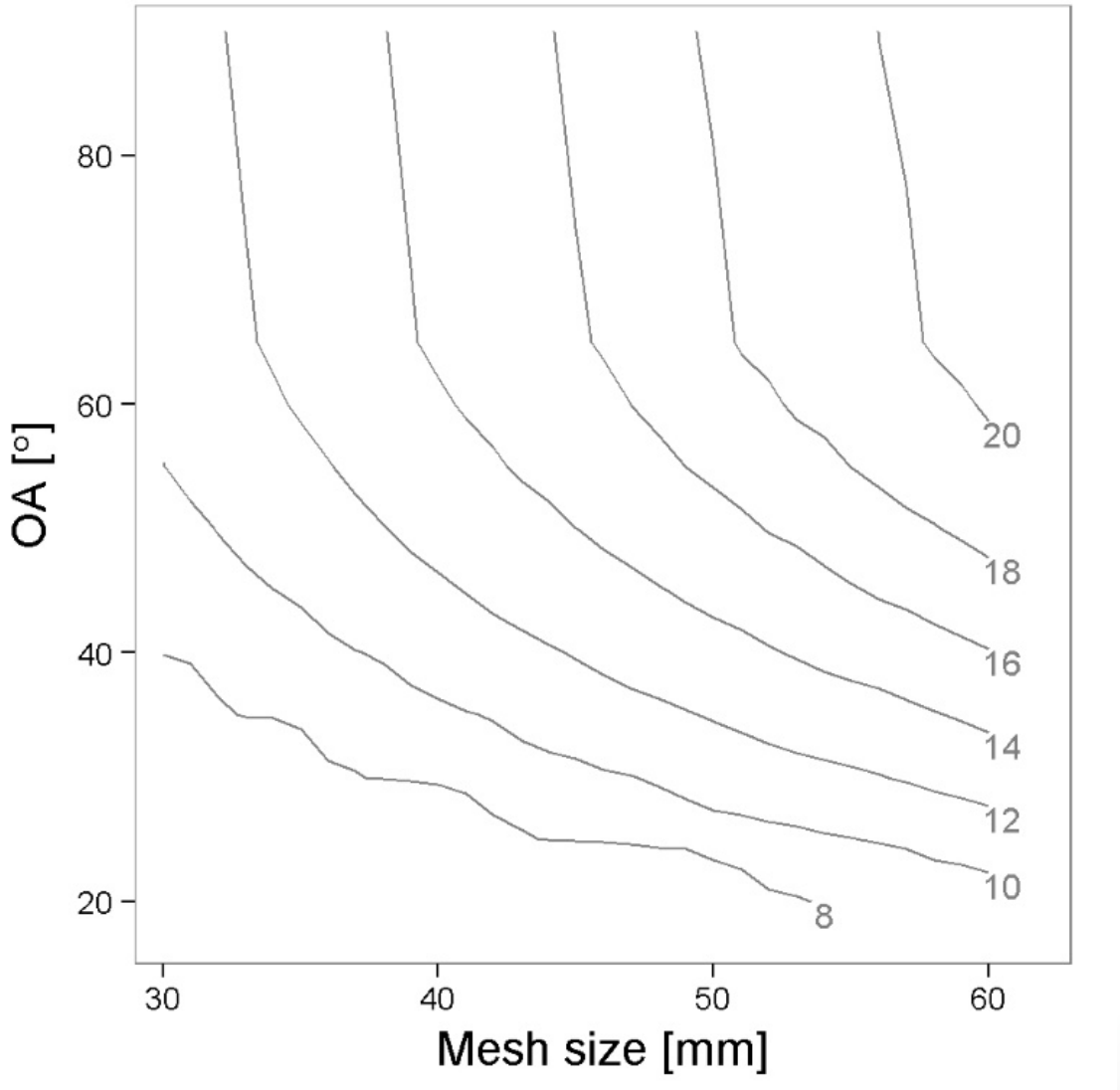
When can a square-mesh become hexagonal?



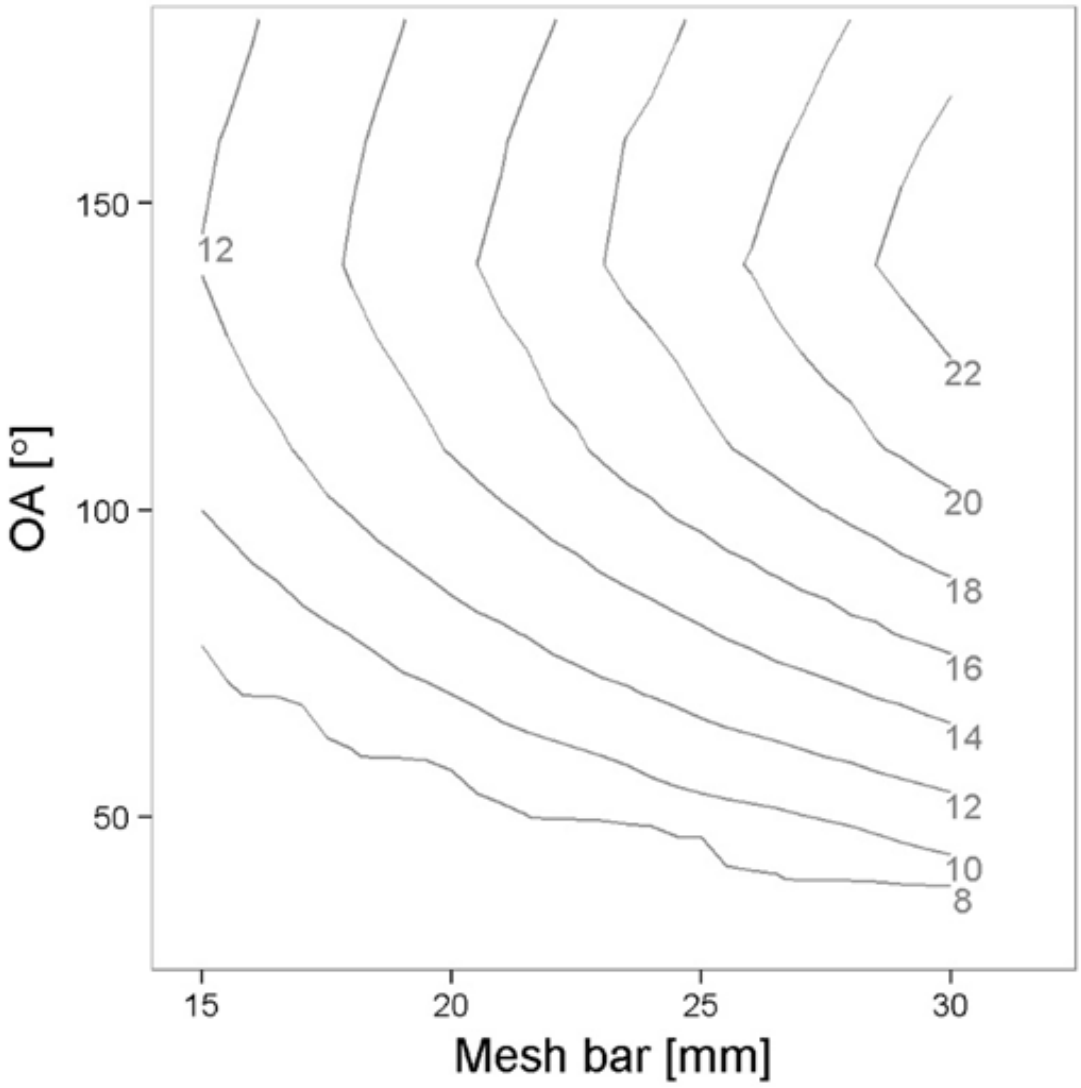


Krag et al. (2011). Fish. Res., 110: 225-235.

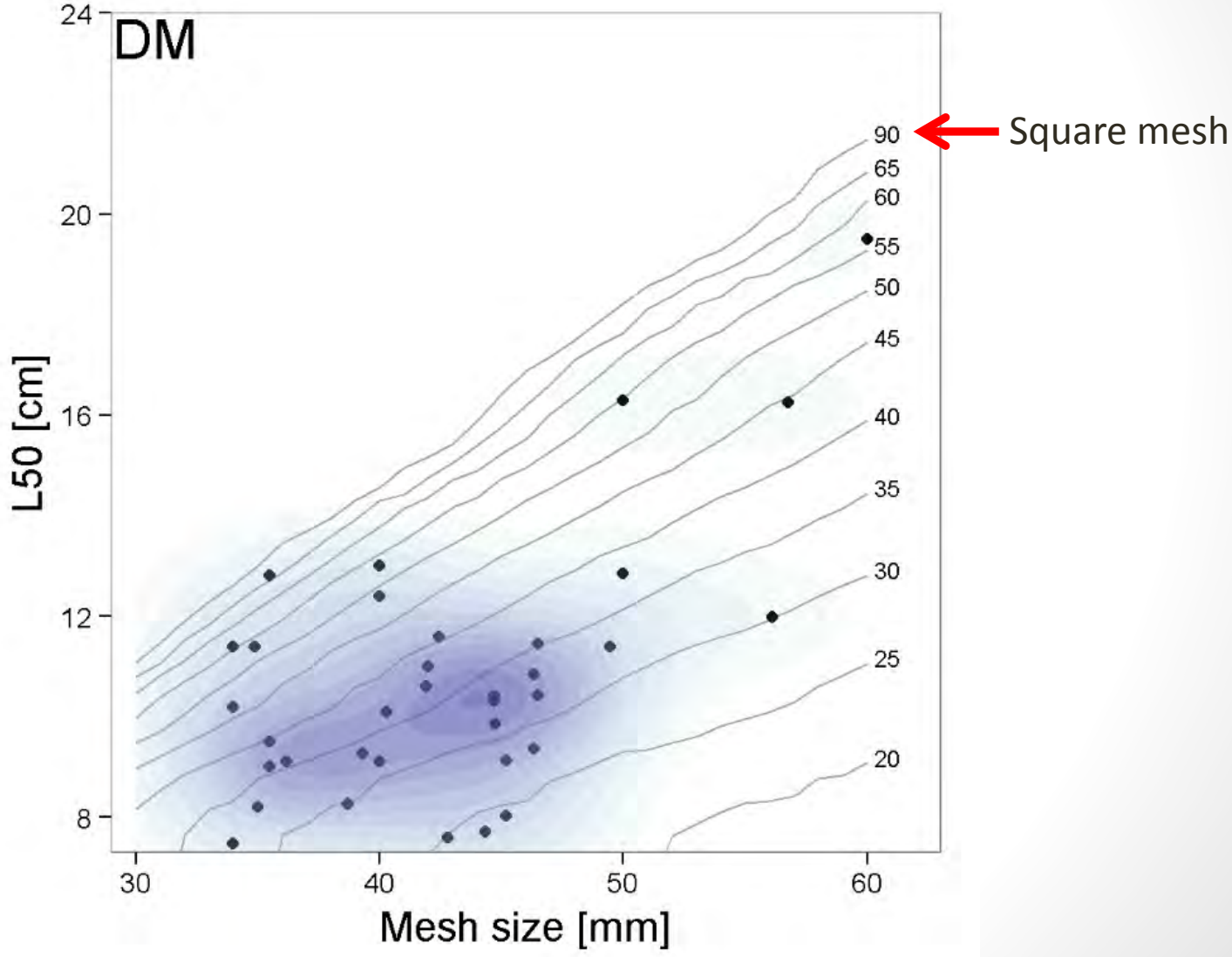
Design guides for DM: Hake (MLS = 20 cm)



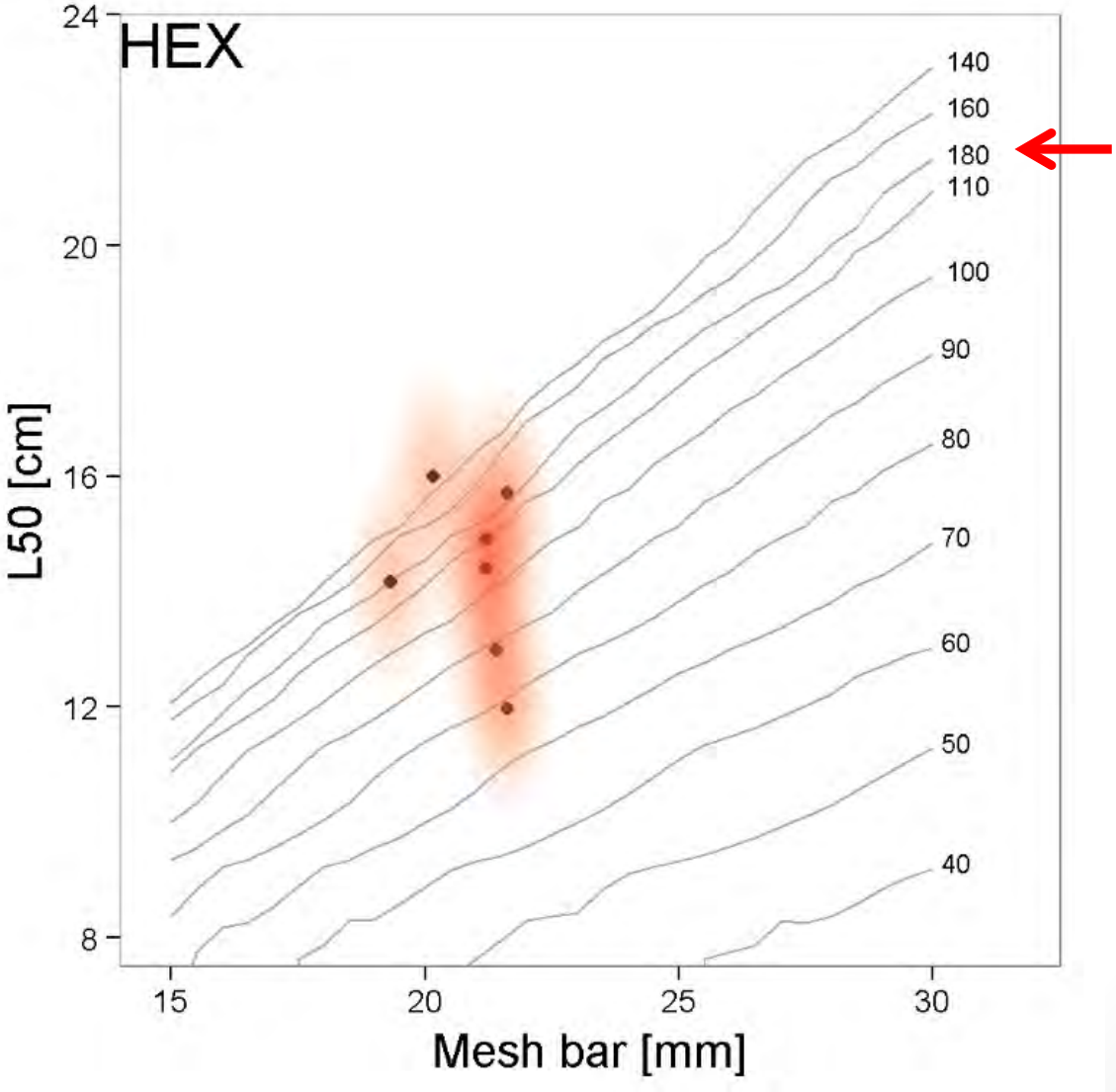
Design guides for HEX: Hake (MLS = 20 cm)



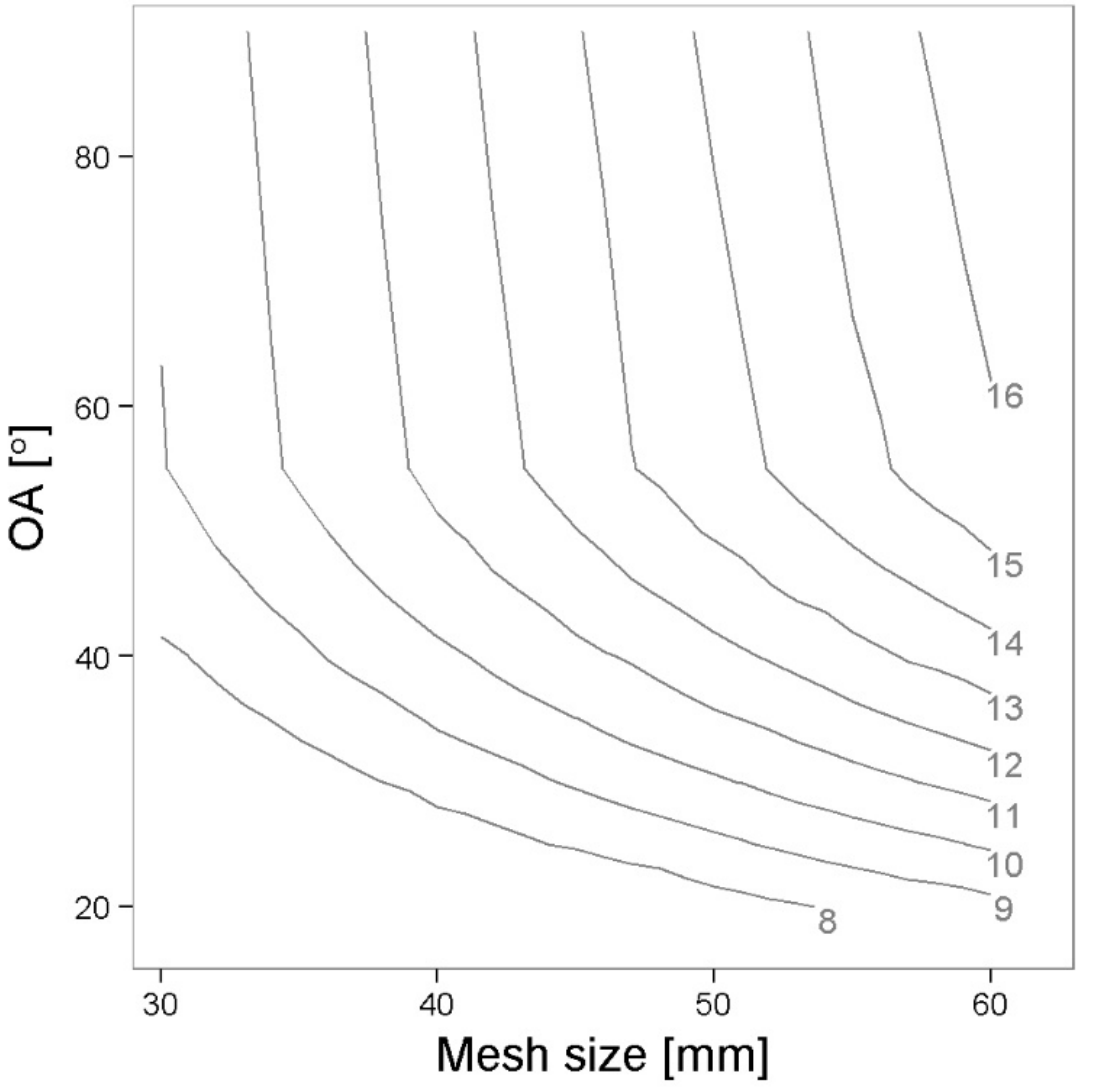
Hake (*Merluccius merluccius*)



Hake (*Merluccius merluccius*)



Design guides for DM: Red mullet (MLS = 11 cm)



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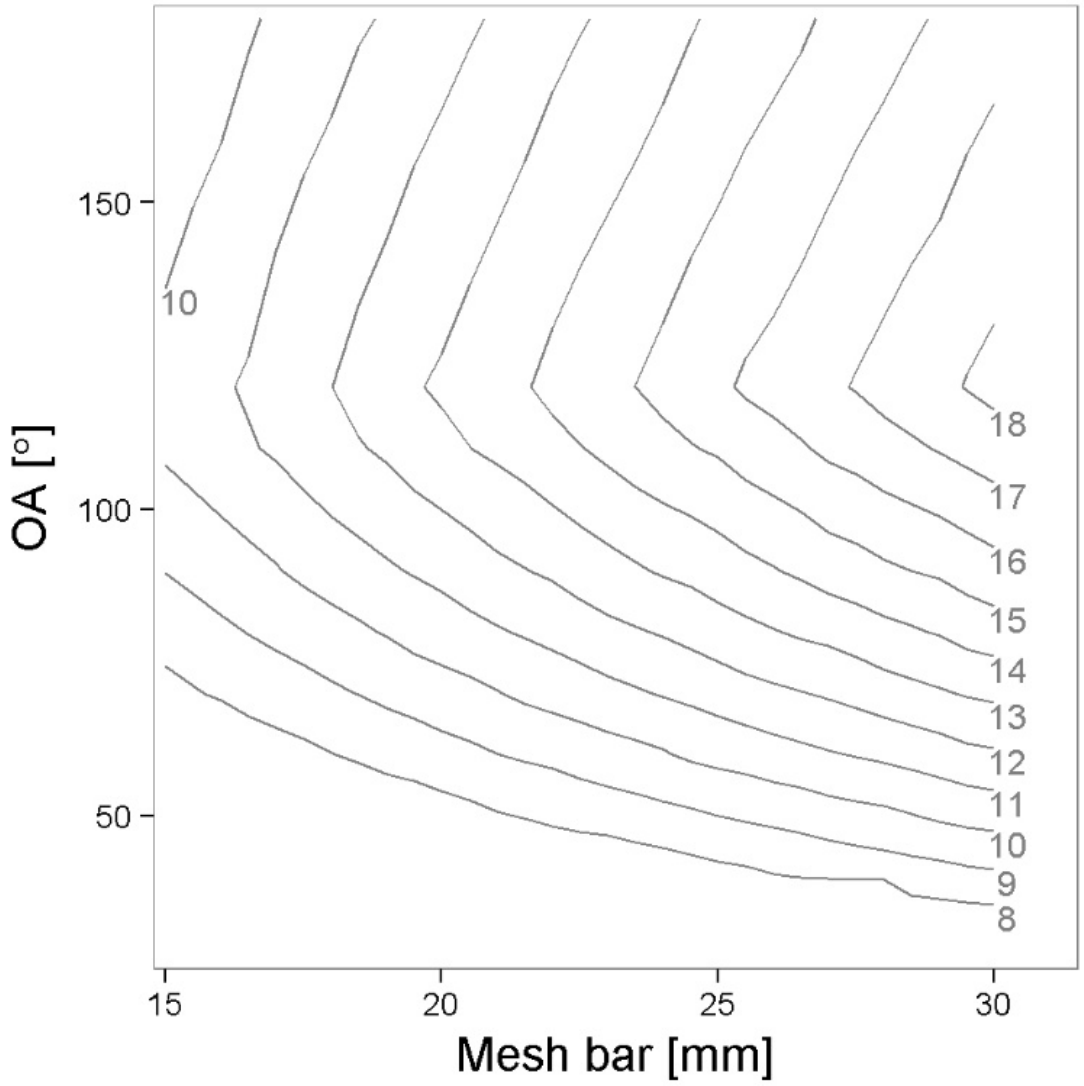
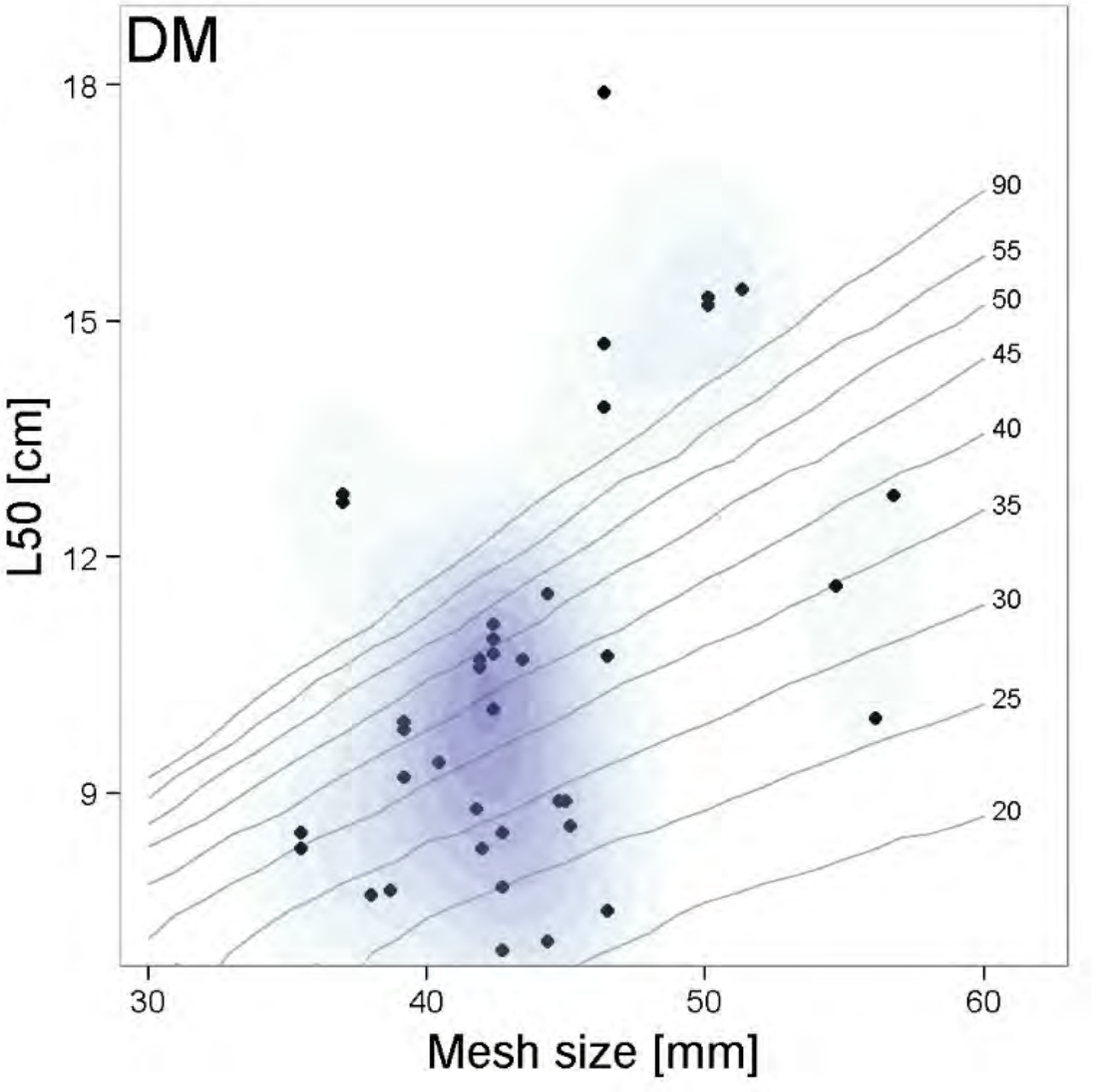
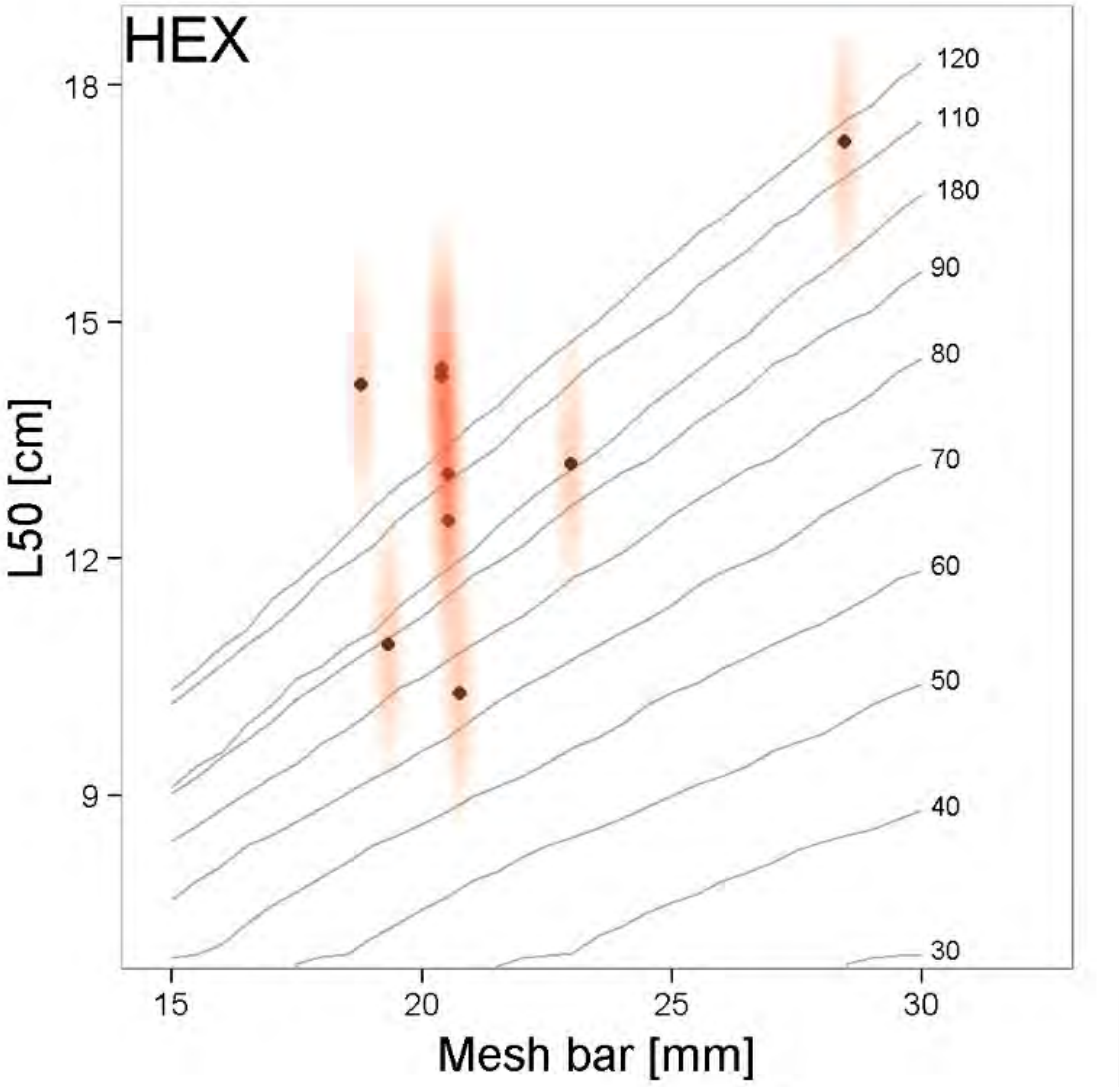


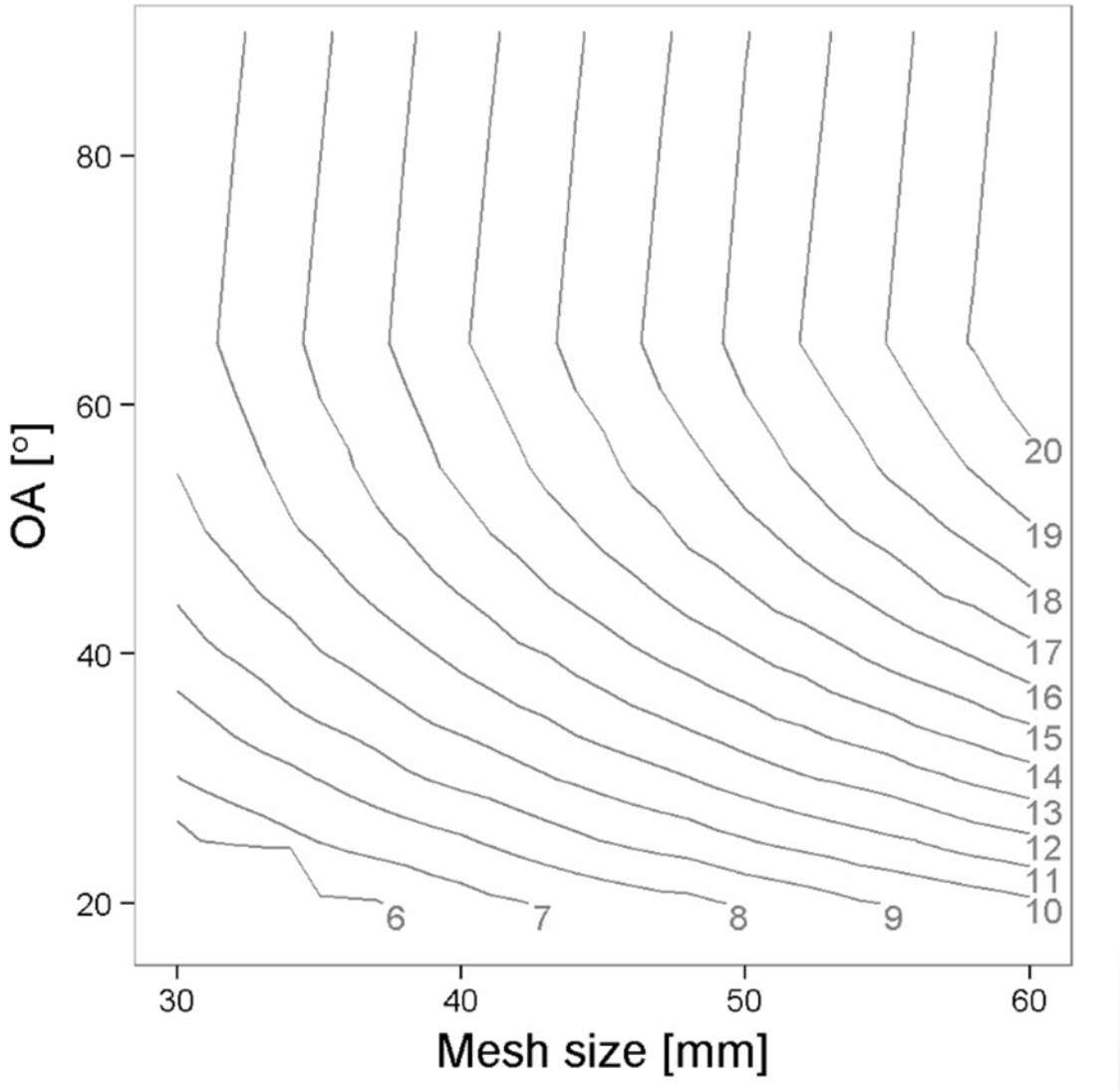
Red mullet (*Mullus barbatus*)



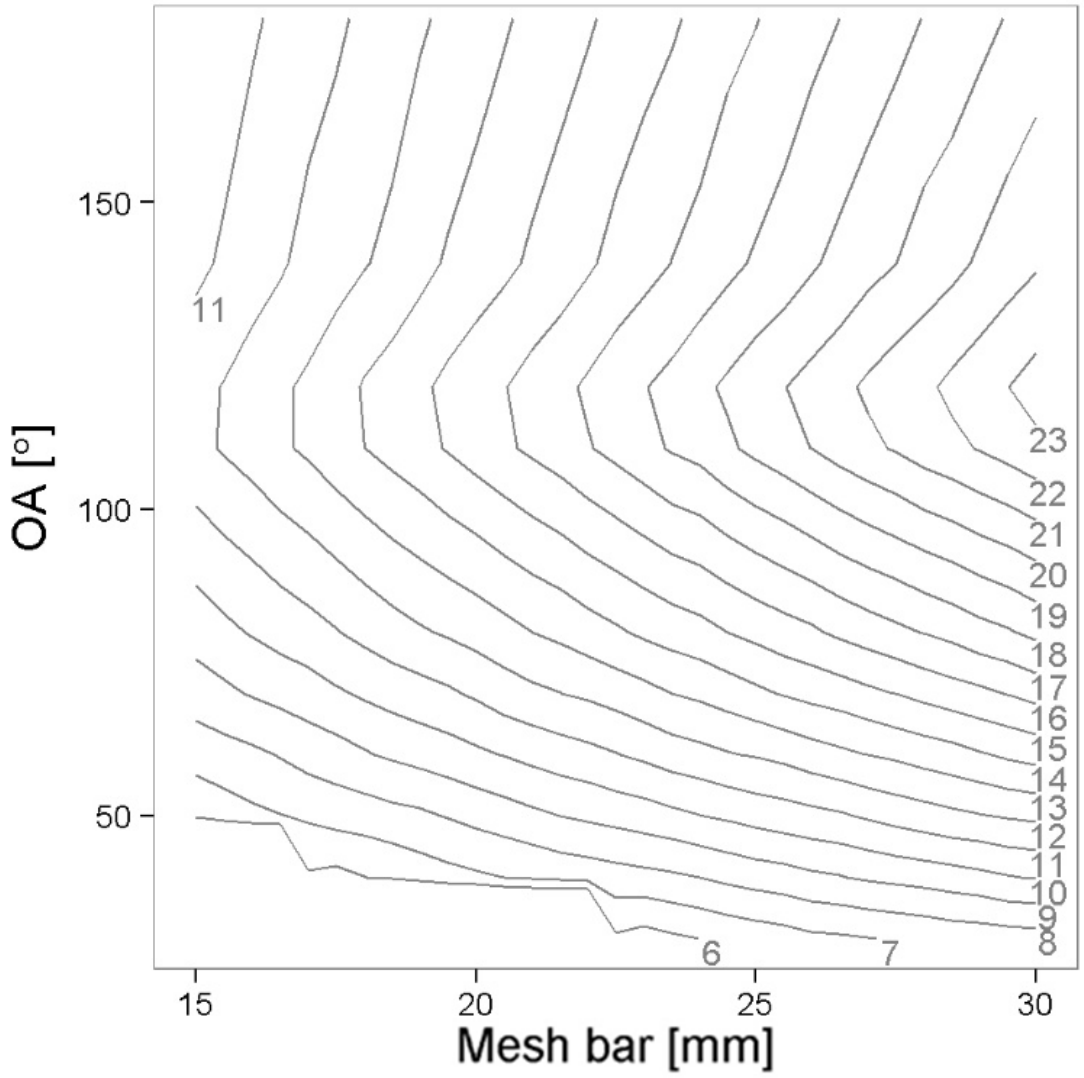
Red mullet (*Mullus barbatus*)



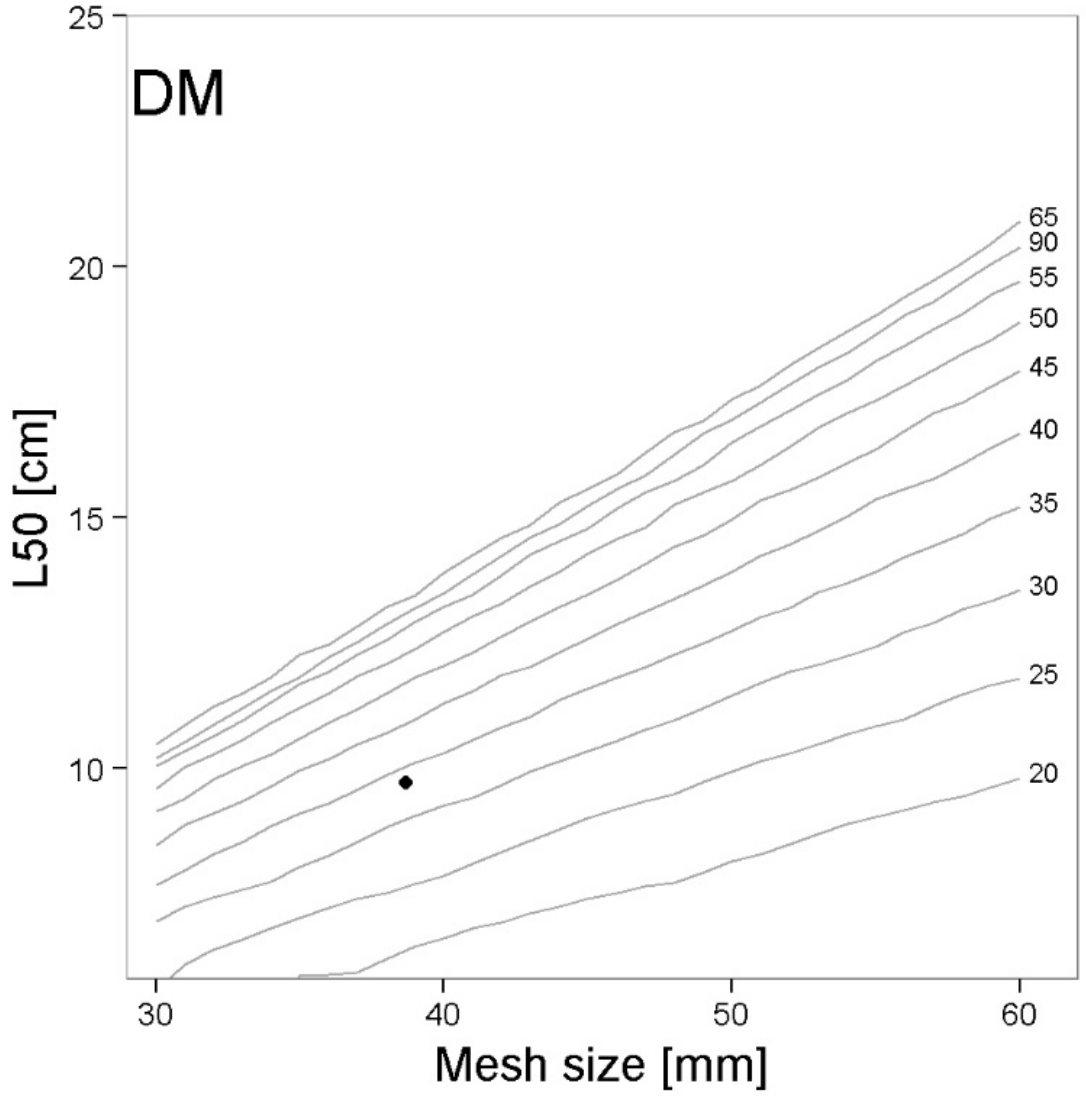
Design guides for DM: Horse mackerel (MLS = 15 cm)



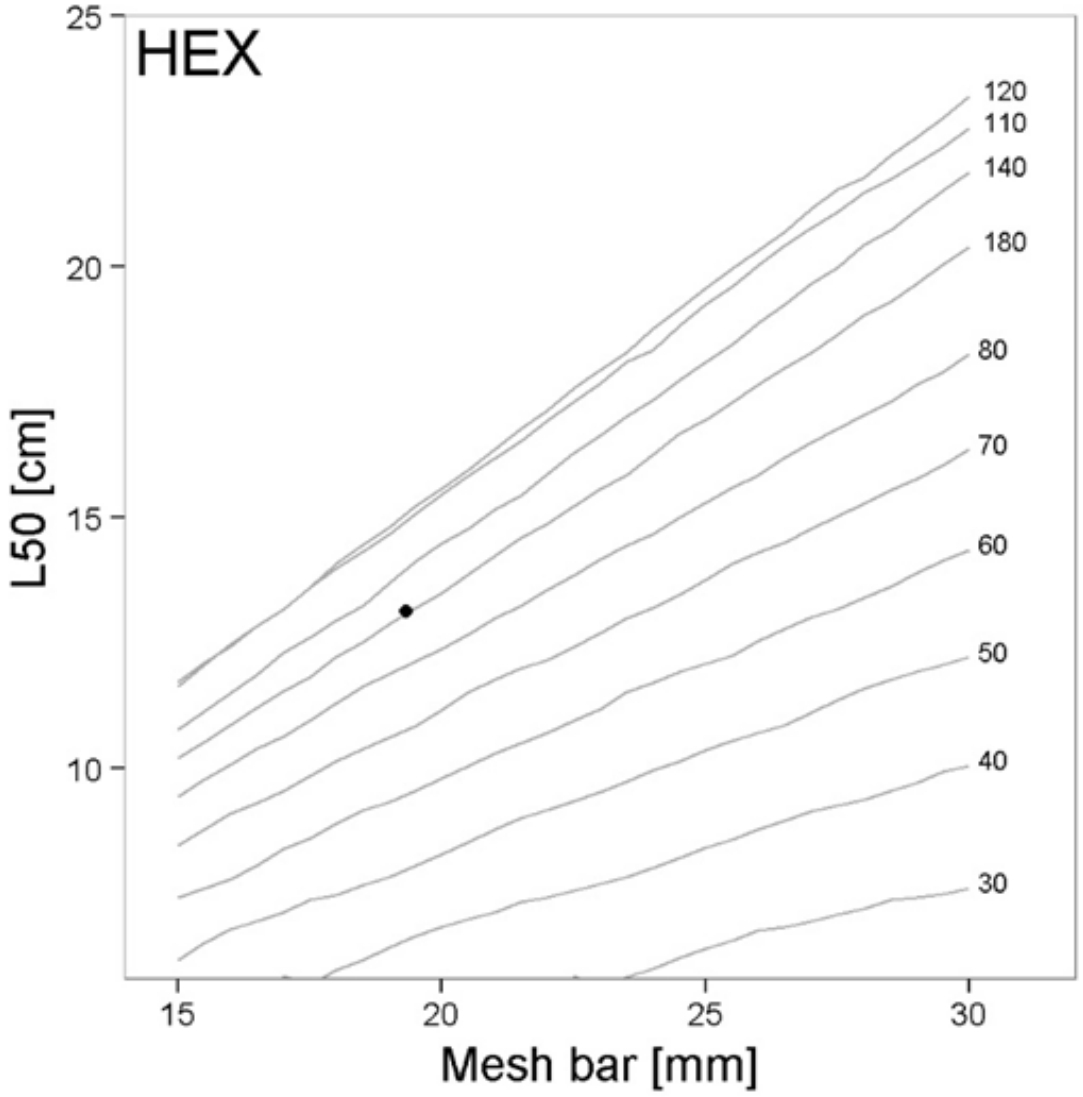
Design guides for HEX: Horse mackerel (MLS = 15 cm)



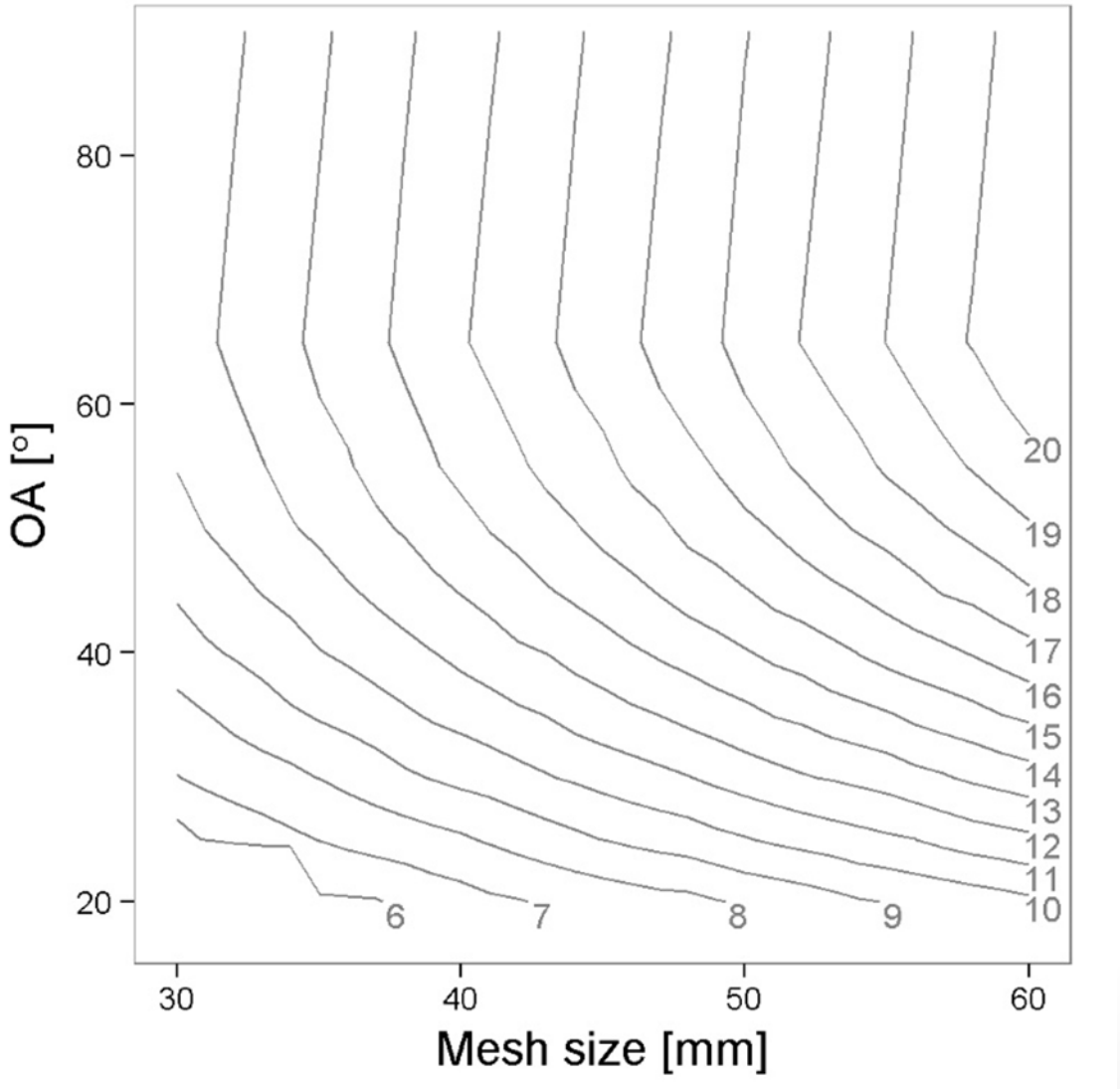
Mediterranean horse mackerel (*Trachurus mediterraneus*)



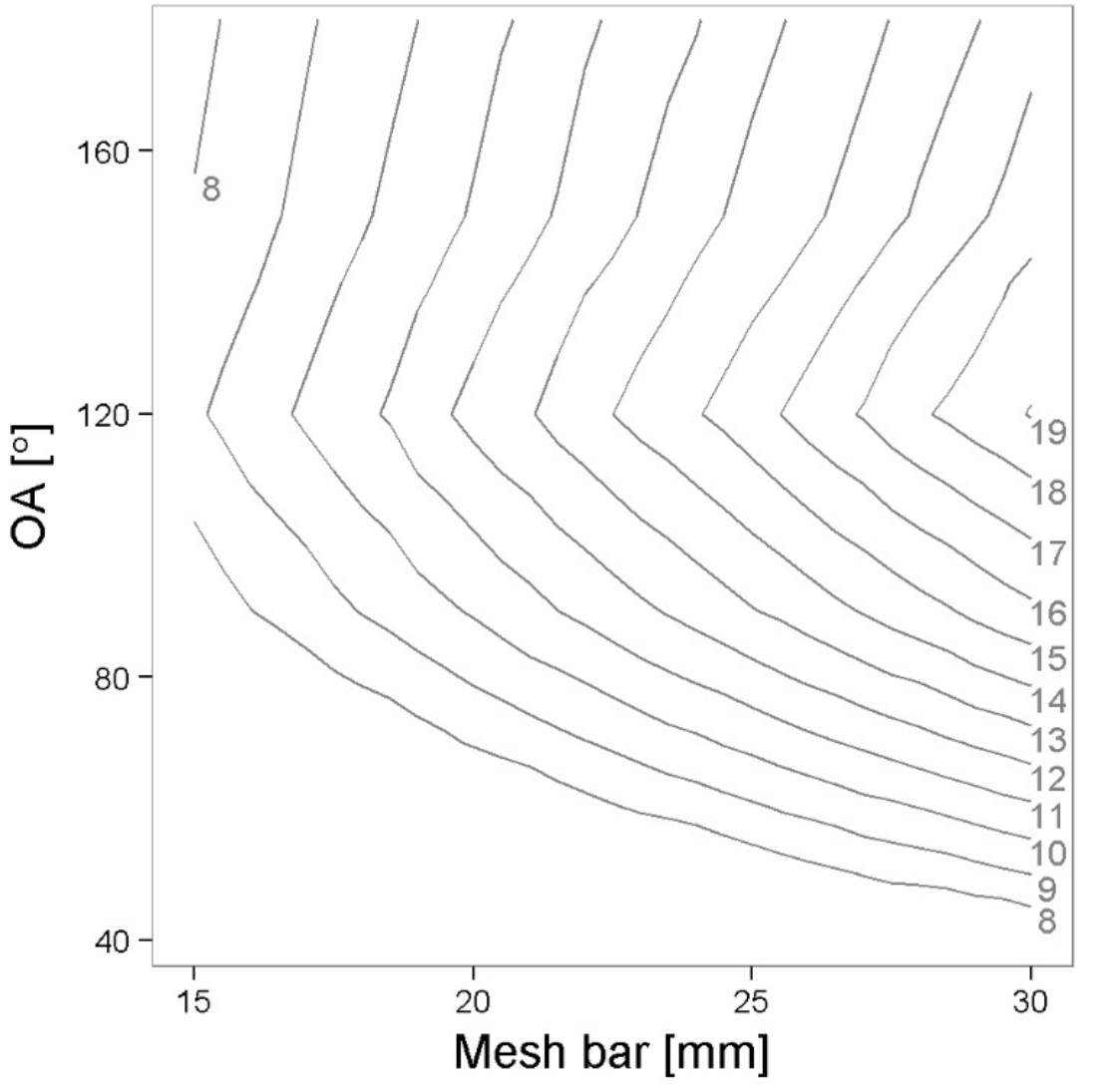
Mediterranean horse mackerel (*Trachurus mediterraneus*)



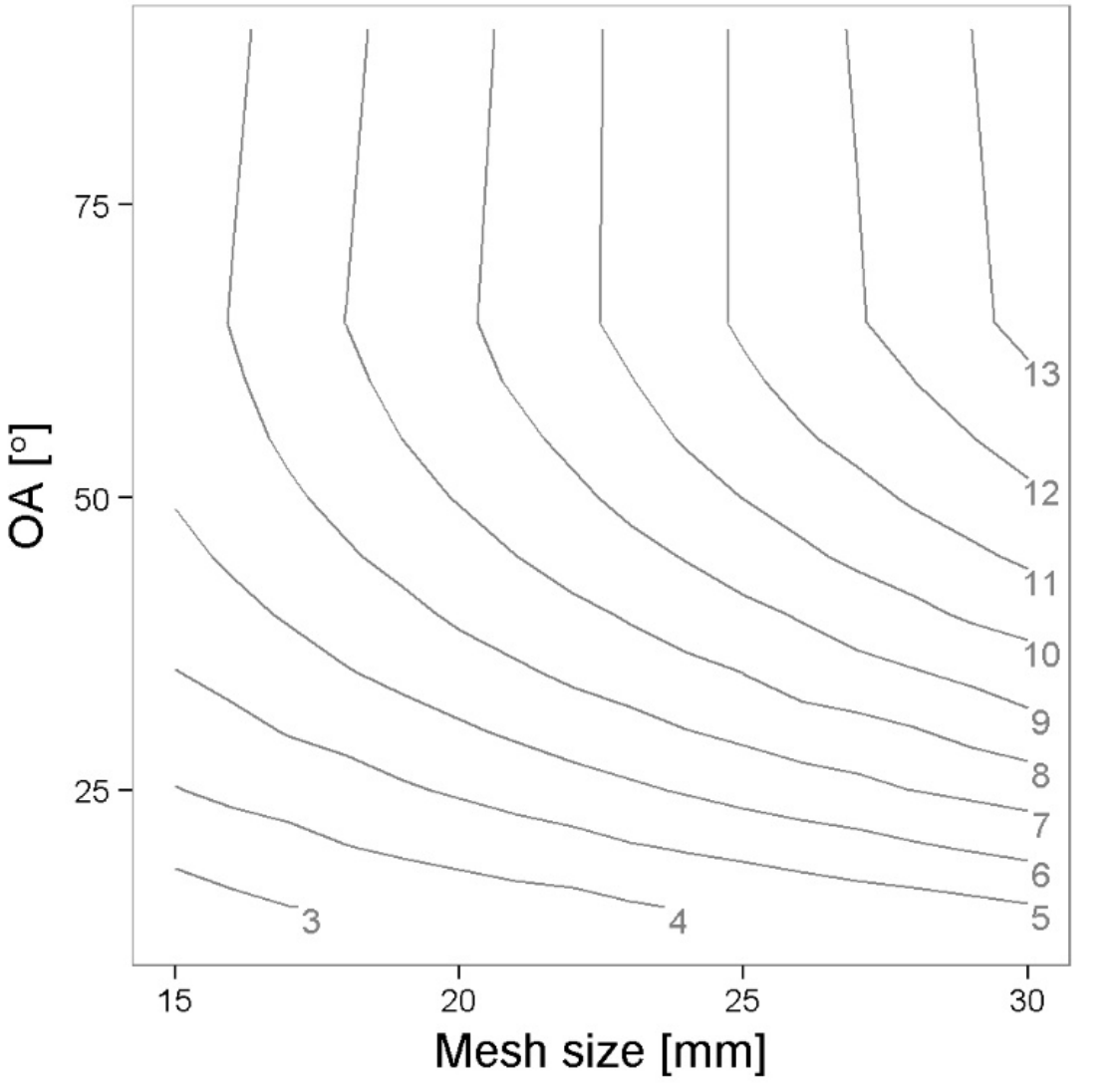
Design guides for DM: Striped red mullet (*Mullus surmuletus*)



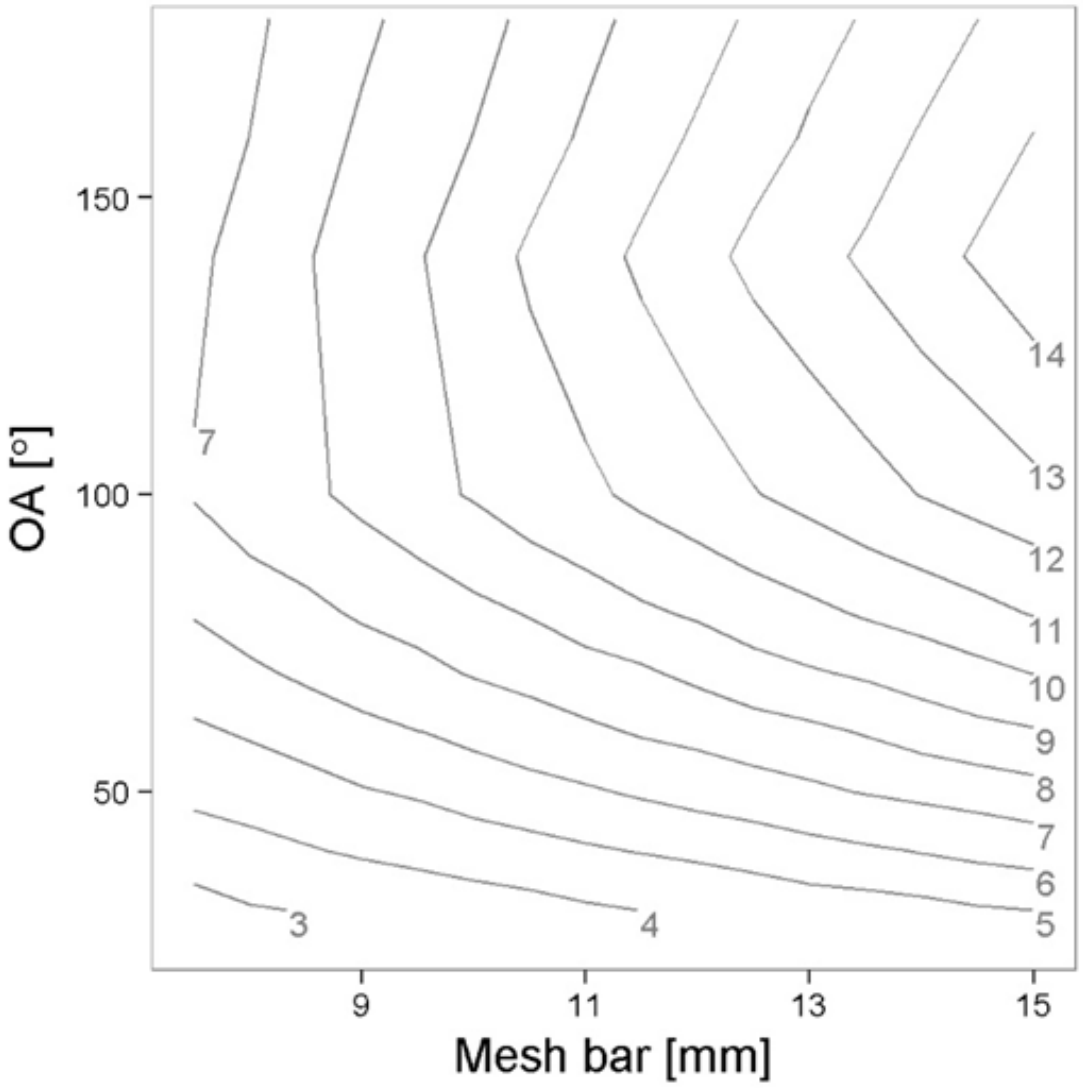
Design guides for HEX: Striped red mullet (*Mullus surmuletus*)



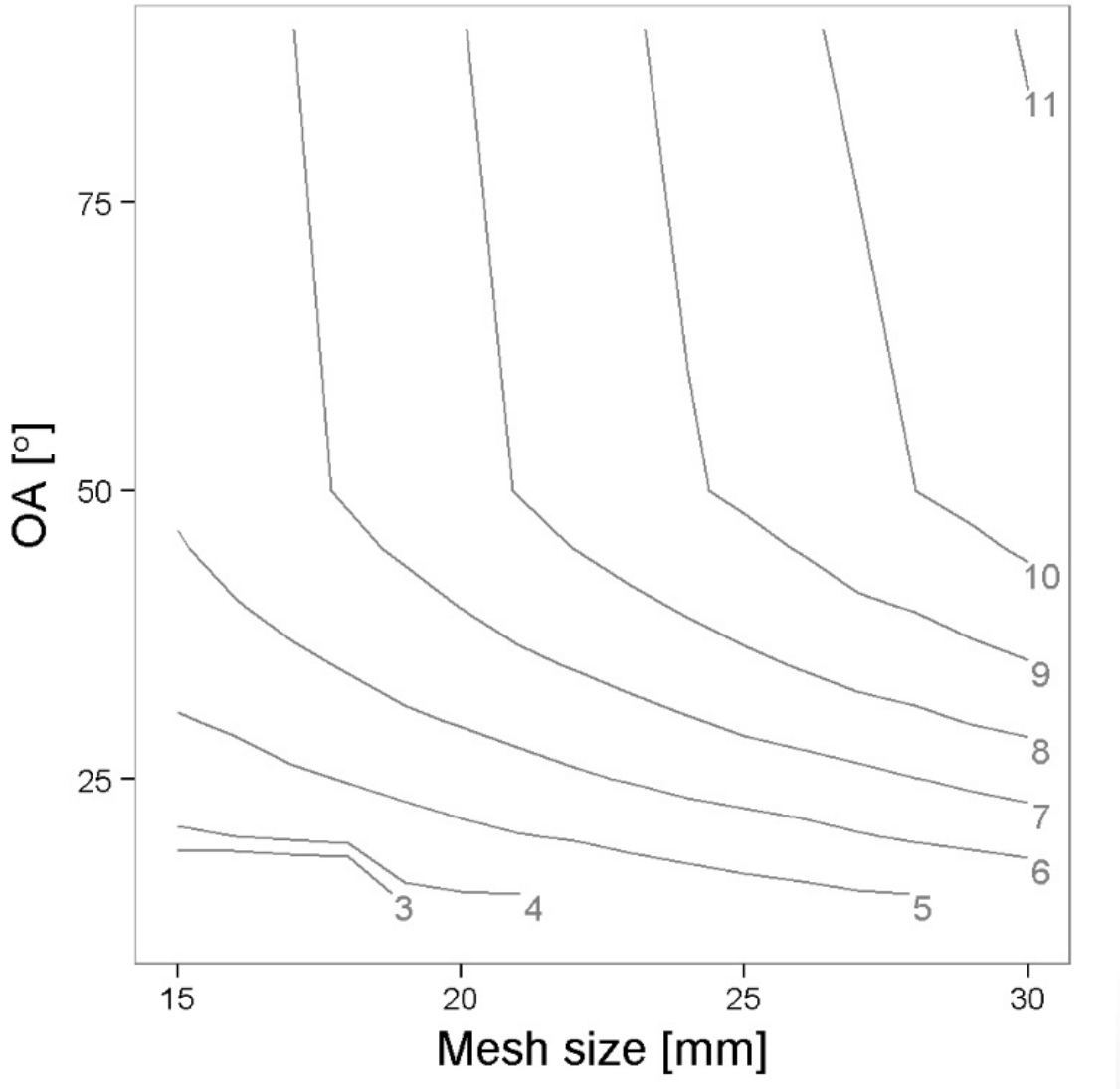
Design guides for DM: European anchovy (MLS = 9 cm)



Design guides for HEX: European anchovy (MLS = 9 cm)



Design guides for DM: European sardine (MLS = 11 cm)



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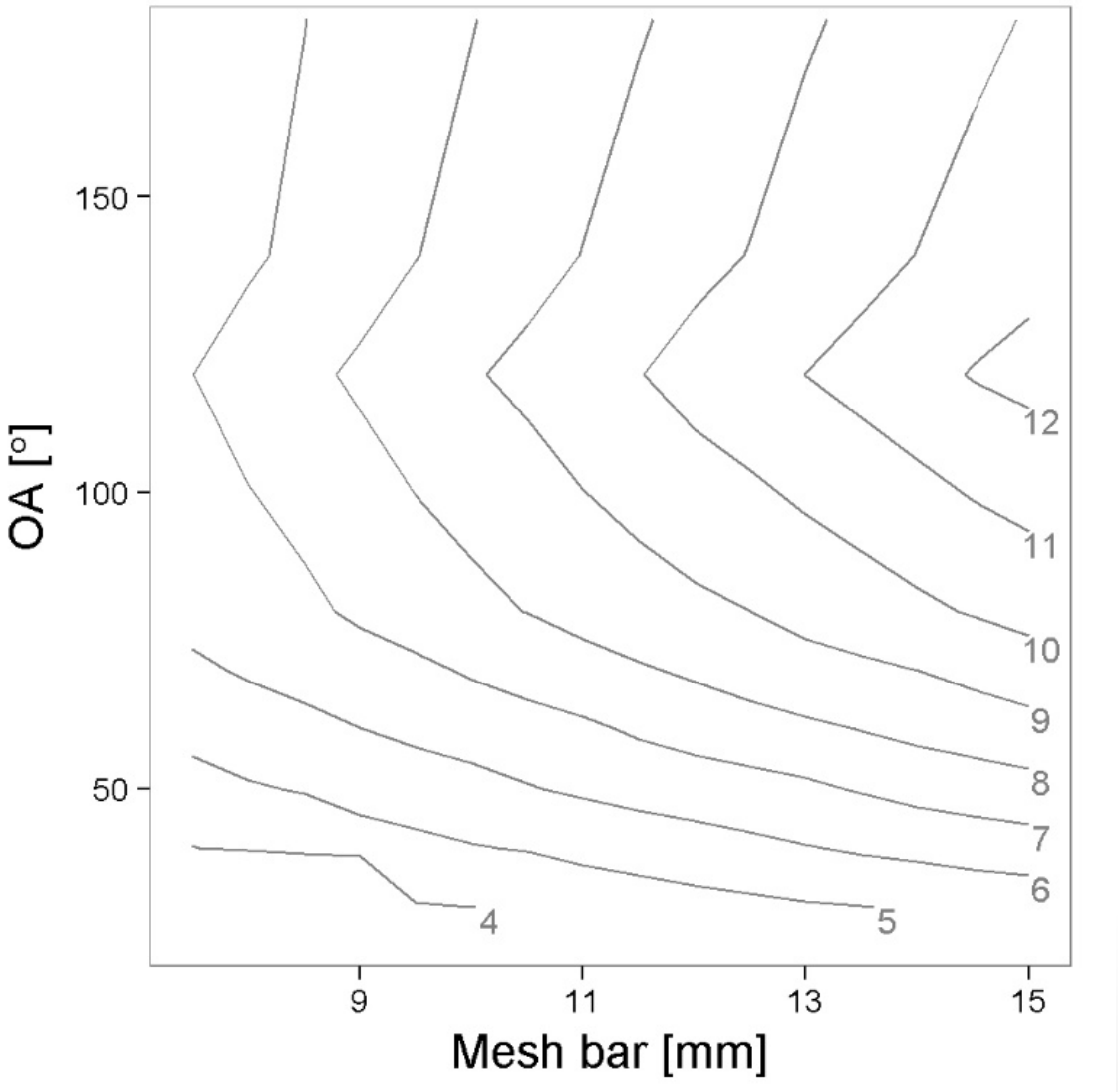

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Experimental and theoretical size selectivity

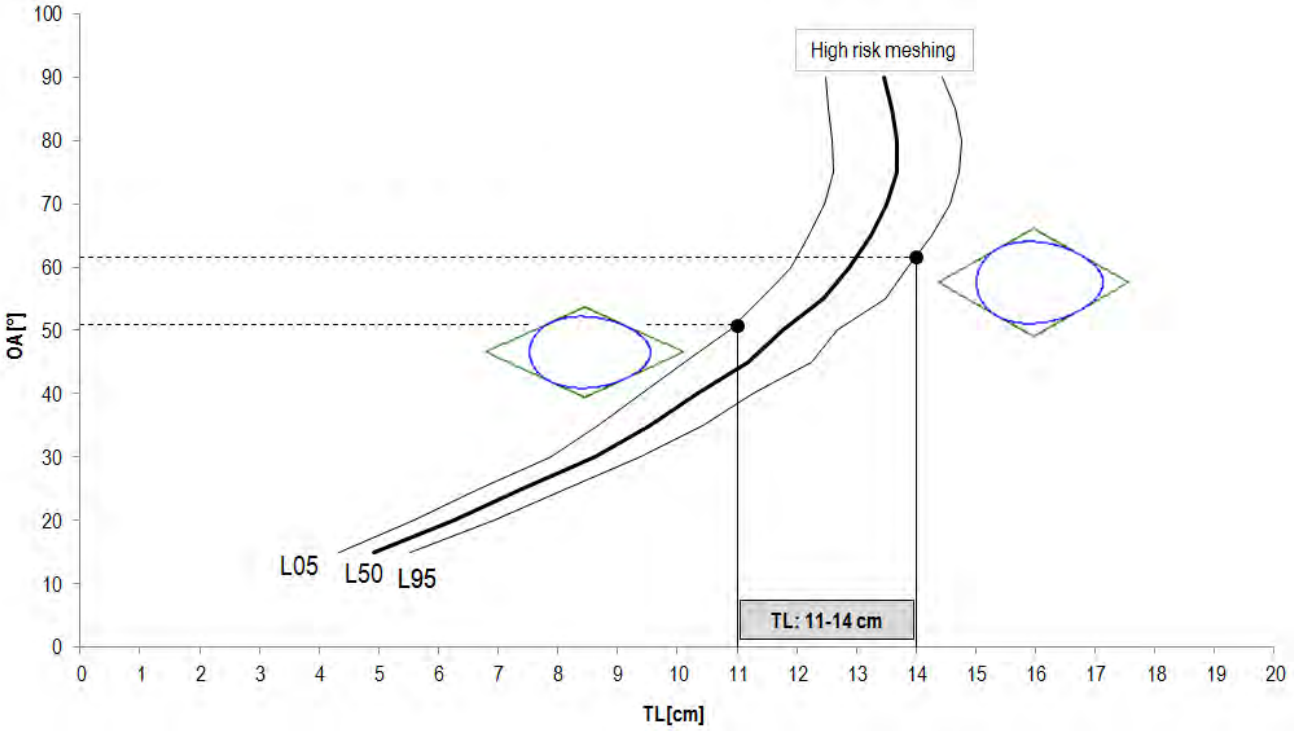
Selectivity simulation of the pelagic fish species

Simulation of catch anchovies in pelagic trawls

Prediction of size selectivity in different mesh

Virtual population: 2000 anchovies

Mesh shapes: 15-30 mm / opening angle 15-90°



Anchovy cross-sections

Mesh-shapes

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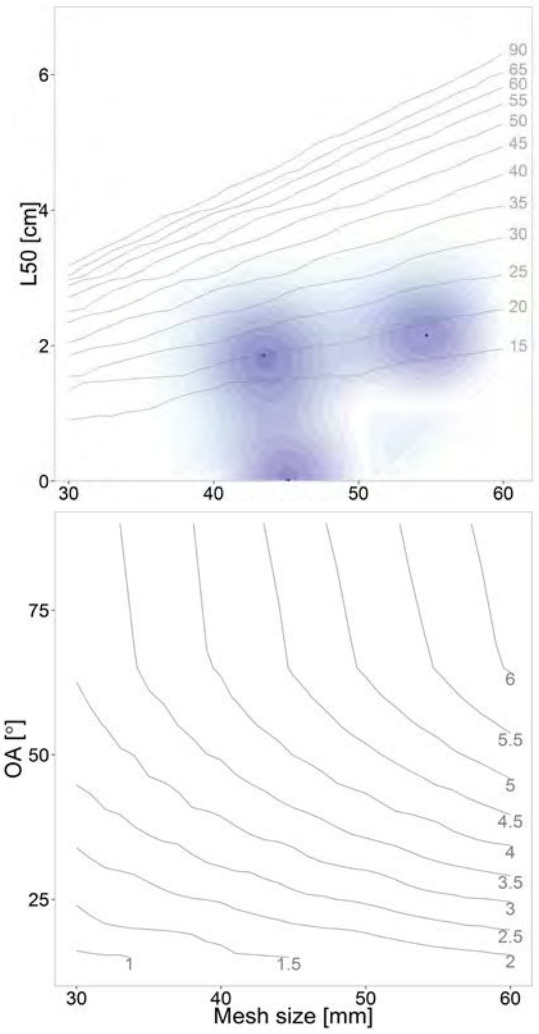
Experimental and theoretical size selectivity

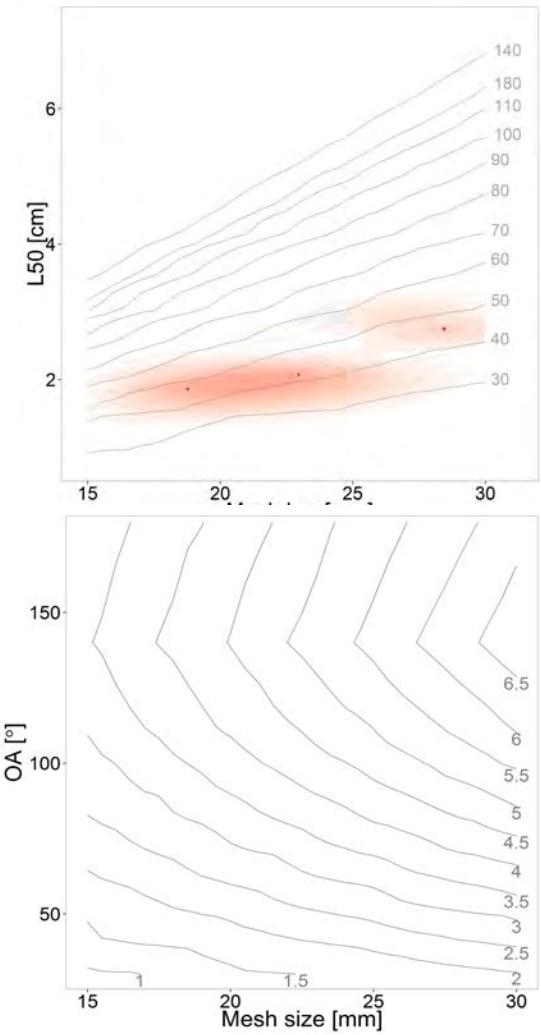
Selectivity simulation of the Crustacean species

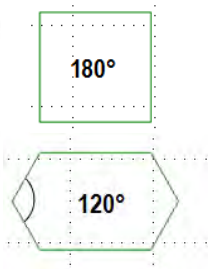
Giant red shrimp *(Aristaeomorpha foliacea)*

Diamond



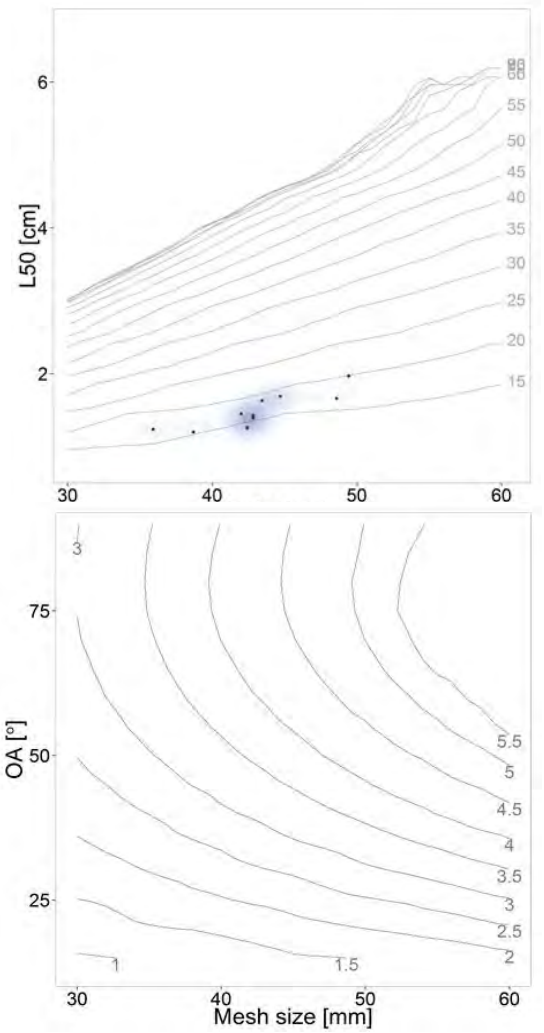
Hexagonal / Square



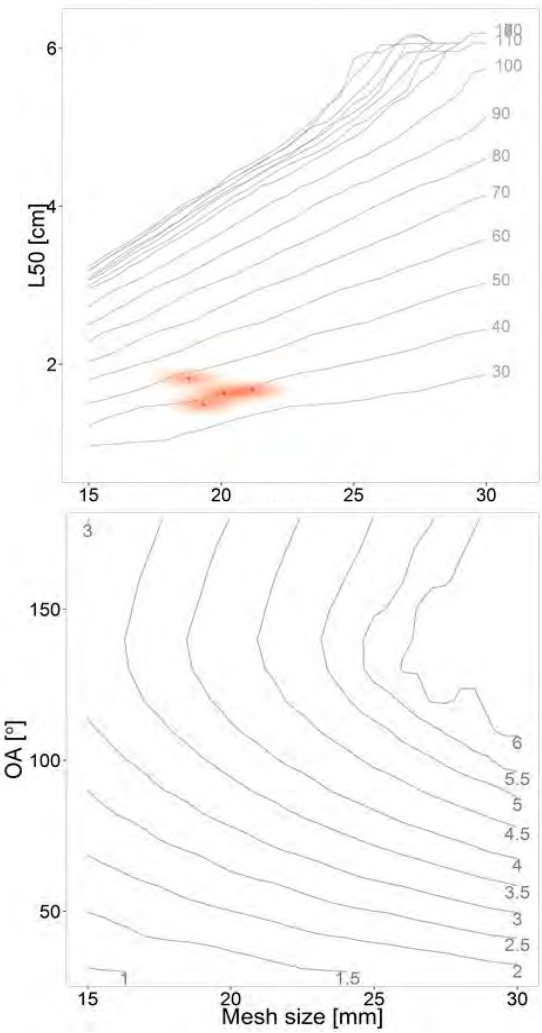


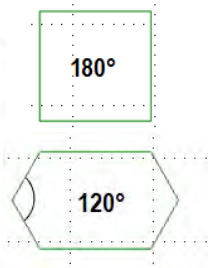
Deep-water rose shrimp *(Parapenaeus longirostris)*

Diamond



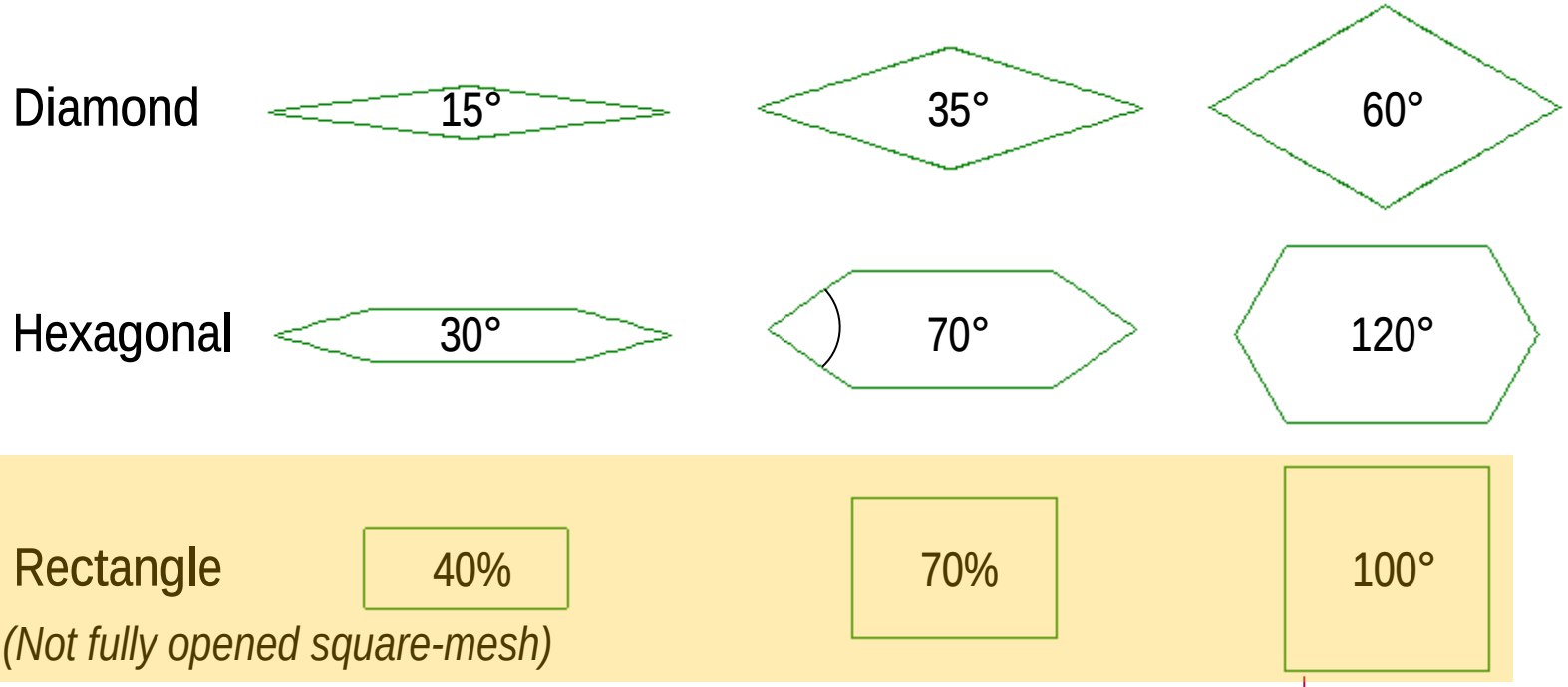
Hexagonal / Square





Assessment of codend mesh shape: crustaceans

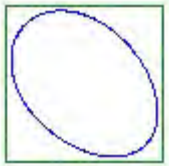
Mesh type	Openness	Stretched mesh size [mm]
		Crustaceans
Diamond	15-60°	30-60
Hexagonal	30-120°	15-30
Rectangle	40-70%	30-60



Potential effect of rotation of the cross-section in a fully opened square-mesh

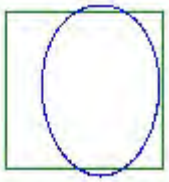
Giant red shrimp *(Aristaeomorpha foliacea)*
Example of a shrimp of a carapace length: 39.5 mm

Optimal orientation *(attack angle)*
Scale factor: 107.23%

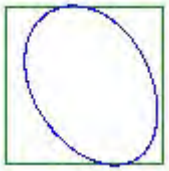


Random orientation

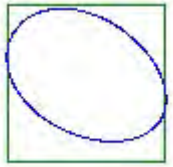
0 degree



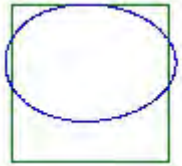
30 degree



60 degree



90 degree



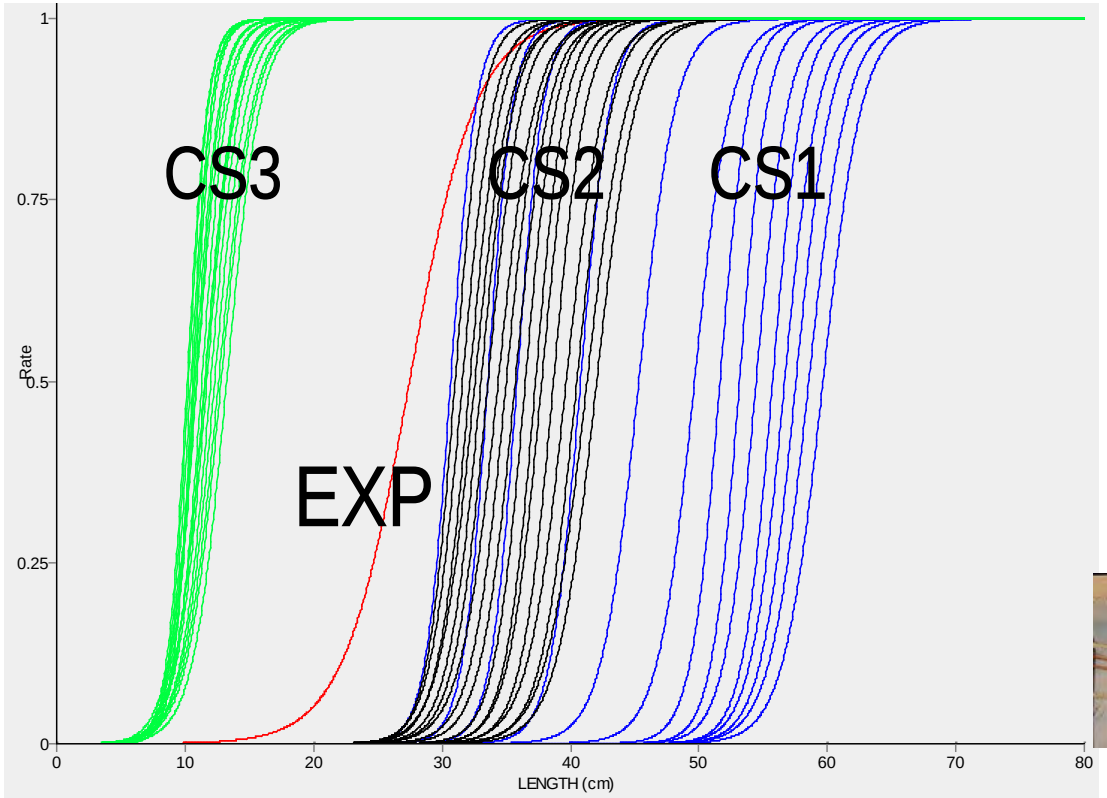
Crustaceans simulated selectivity: comparison with an experimental square-mesh case

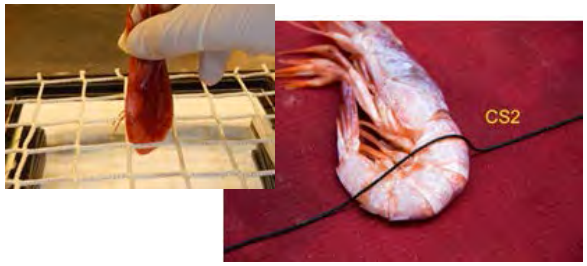
Initial hypothesis

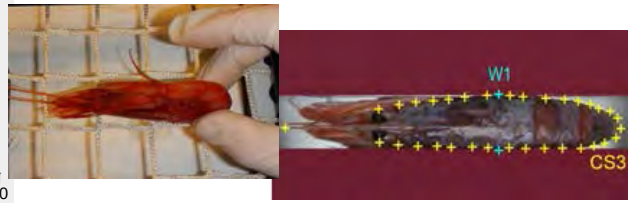
- Three potential penetrations
- Optimal angle of attack
- Fully opened square-meshes

Final assumptions

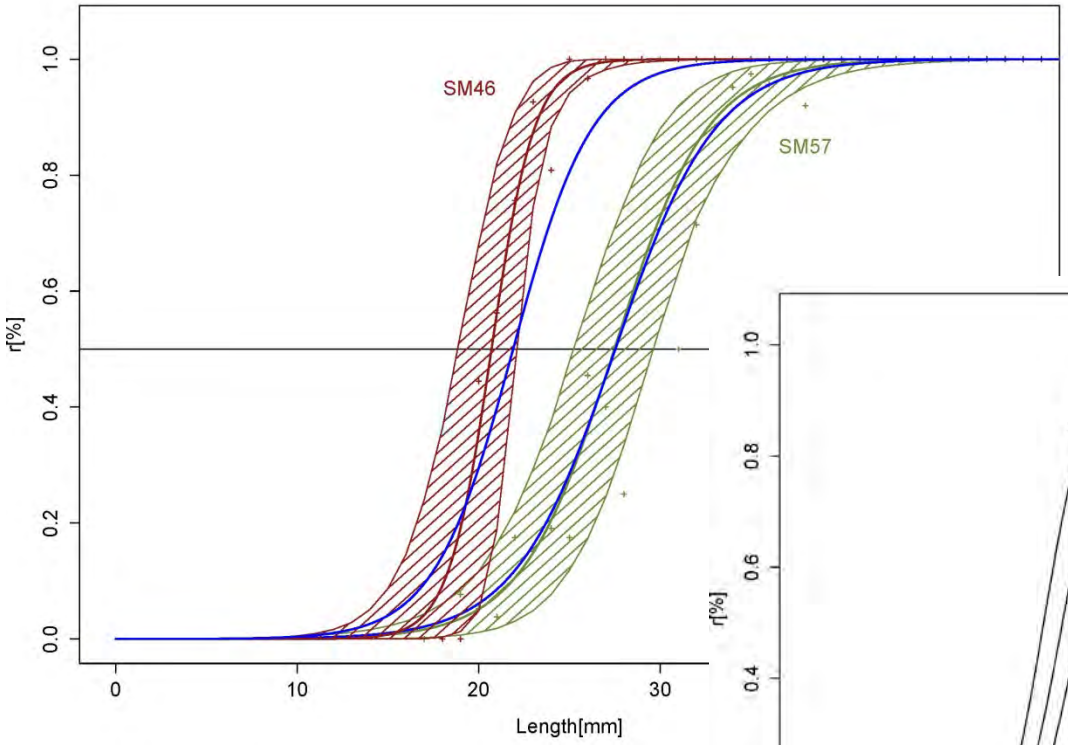
- CS2 best candidate
- Random angle of attack
- Not fully-opened meshes *(rectangle)*

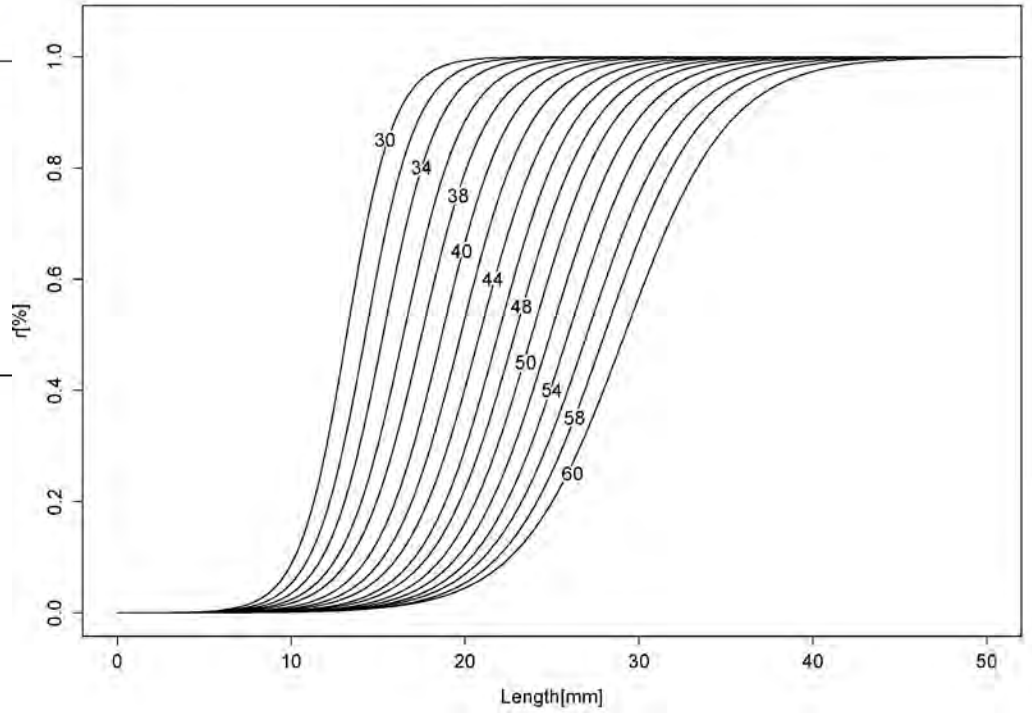






Rectangle / Square





Rectangle / Square