6-2004

An Evaluation Of The Use Of Technical Conservation Measures Within the Inshore Mixed Fishery of Dingle Bay, Co. Kerry, Ireland.

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By

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June 2004

Submitted in fulfilment of the HETAC requirements for award of MSc.

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Acknowledgements.

Skippers: Alan Flannery, David Granville, Laurence Courtney, Tommy Russell, Jim Tome and Brendan Chilean and all the crews
Supervisors Fiona O'Flynn and Noel Mulligan,
Bord Iascaigh Mhara (BIM) Inshore Development Officer Lorcan O'Cinneide.
Other BIM staff: Jim Daley, Neil Cullen, Huan Tan, Lorcan and Eoghan Slattery.
Marine Institute (MI) staff David Stokes, Macdara O'Cuaig, and Cieran O'Donnell
Tony Sullivan and James O'Donnell for details on nets.
The Valentia Lifeboat crew.

Contents

1 Summary.

Discarding has been identified as a global problem in fisheries. ICES, the EU and national governments have prioritised studying discarding as an area of research. In conjunction with Bord Iascaigh Mhara (BIM), the Marine Institute, Institute of Technology, Tralee and the Dingle Bay Inshore Management Development committee a study of the impacts of incorporating technical conservation measures (TCM's) into trawls was undertaken. TCM's under investigation included 80mm and 90mm square mesh panels inserted in the top-sheet before the cod-end, 100mm cod-ends and a separator trawl. It was found that boats using 100mm cod-ends produced less discards than when towing standard nets with 80mm cod-ends, but that landings, particularly of black sole (*Solea solea*) were also reduced. Boats towing nets fitted with square mesh panels were also found to catch less undersized fish than when towing standard nets with less reduction in the landings of black sole than the 100mm cod-ends. Mean discard levels for the boats towing standard nets during the trial was found to be high for all species measured except black sole.

2 Introduction

Many of the world's fisheries are prone to wastage due to discarding of unmarketable fish, at a time when most fisheries are either fully or overexploited the reduction of this waste has been identified by fisheries management organisations and governments as a problem to be addressed. One of the methods of reducing discarding is to modify the fishing gear in a number of ways to allow unwanted fish to escape, these modifications, often referred to as Technical Conservation Measures (TCMs) are the subject of many research projects nationally and internationally, this study being one of them.

2.1.1 A Brief Overview of World Fisheries Issues.

Since the 1950's there has been a massive increase in the landings from marine and freshwater fisheries (FAO 2000). In this period technologies have improved: boats have got bigger and more powerful, gear has advanced: synthetic fibres such as nylon and dynemia have been introduced. These fibres are strong and so thinner fibres can be used, reducing drag and allowing the use of bigger nets. Equipment for handling this gear has also improved- Hydraulic net drums and power blocks can haul these stronger larger nets onboard, needing fewer crew. Advances in electronics have improved the ability of fishers to position themselves and to locate their prey. Scanning devices attached to the net can monitor the gear during fishing allowing it to be adjusted to optimise performance during fishing (Valdemarsen 2001). With these and many other improvements fishers have been more able to exploit the oceans.

As advances in technologies have been introduced and the number of vessels and fishers in the industry increased the global production from capture fisheries has also risen. In 1950 production was at 19 million tonnes per year. During the next 20 years the annual increase in production was around 6% per annum so that in 1969 production was at 56 million tonnes. The rate of increase declined to around 2% per annum in the 70's and 80's and during the 90's production almost levelled off (FAO 2000).

In 2000 world production was at its highest ever level at 94.8 million tonnes (Figure 2.1.1.1), with an estimated value of US$81 billion. Estimates for 2001 production indicate a drop to around 92 million tonnes (FAO 2002). Increases in production in 1999 and 2000 were mainly due to fisheries in, the India Ocean and the southeast and western central Pacific. Some areas of the Pacific, the southwest, northwest and the northeast, showed decreases in catch. The Northeast Atlantic showed an increase in production, due mainly to low value pelagic species such as capelin and blue whiting. Very few of the world's fisheries are under exploited (Figure 2.1.1.2) and the percentage of overexploited fisheries has almost tripled since 1975 (Figure 2.1.1.3).

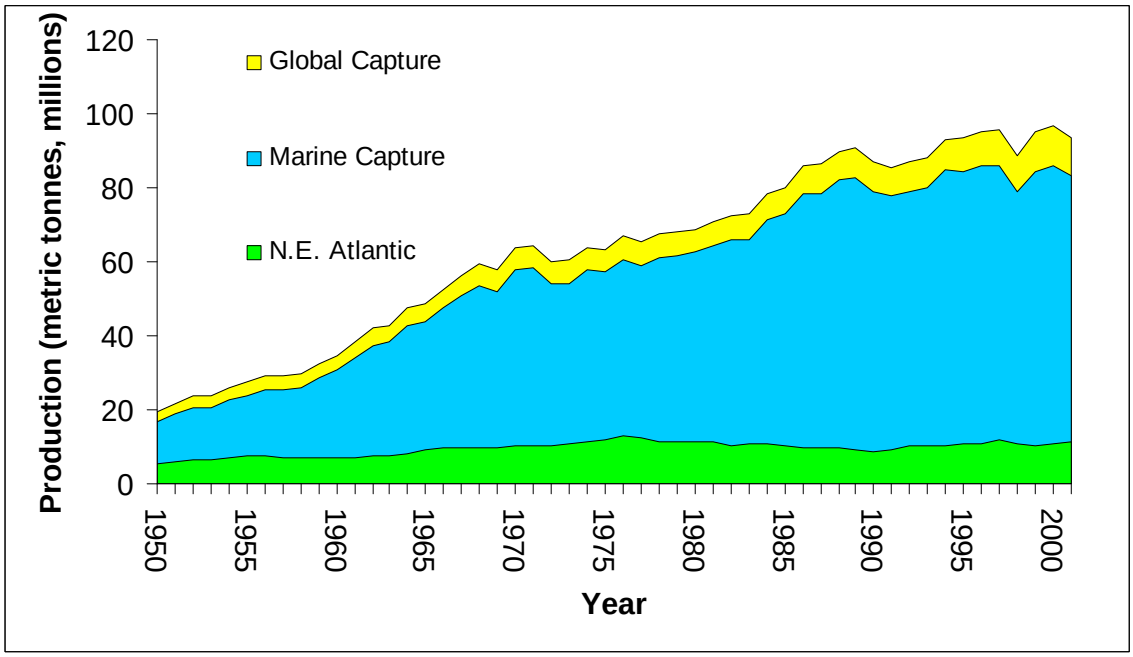


Figure 2.1.1.1Global Marine Production between 1950 and 2001 (excluding production figures for marine mammals, corals, sponges and aquatic plants). (FAO, fishstat 2001).

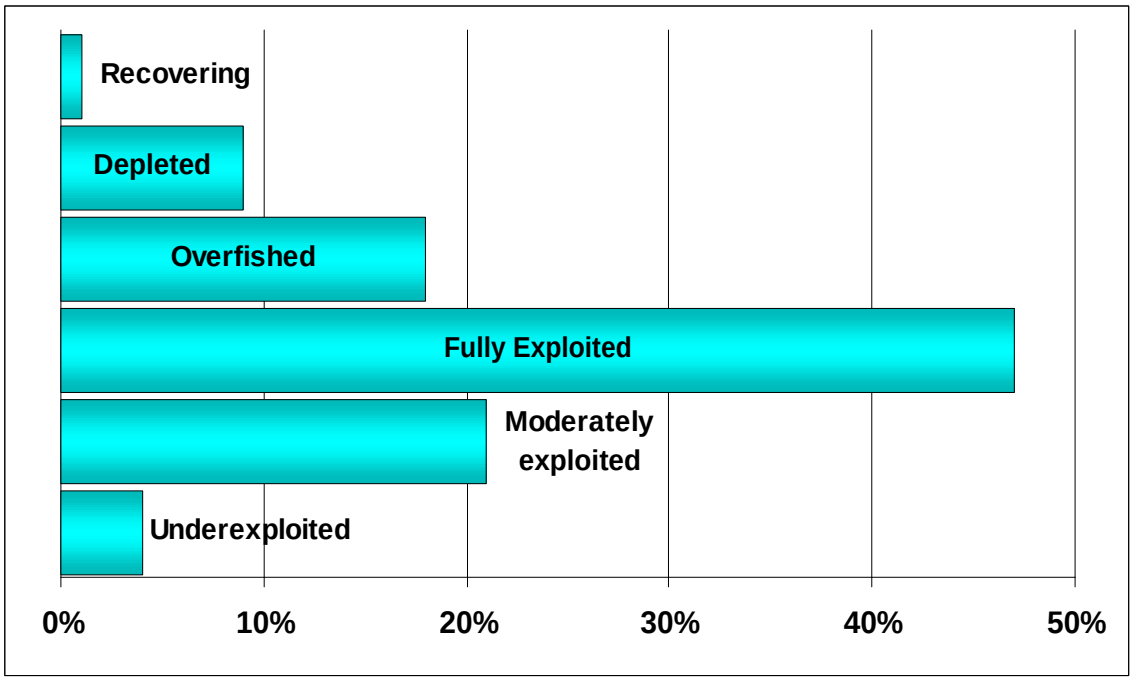


Figure 2.1.1.2 Levels of exploitation (FAO 2000) .

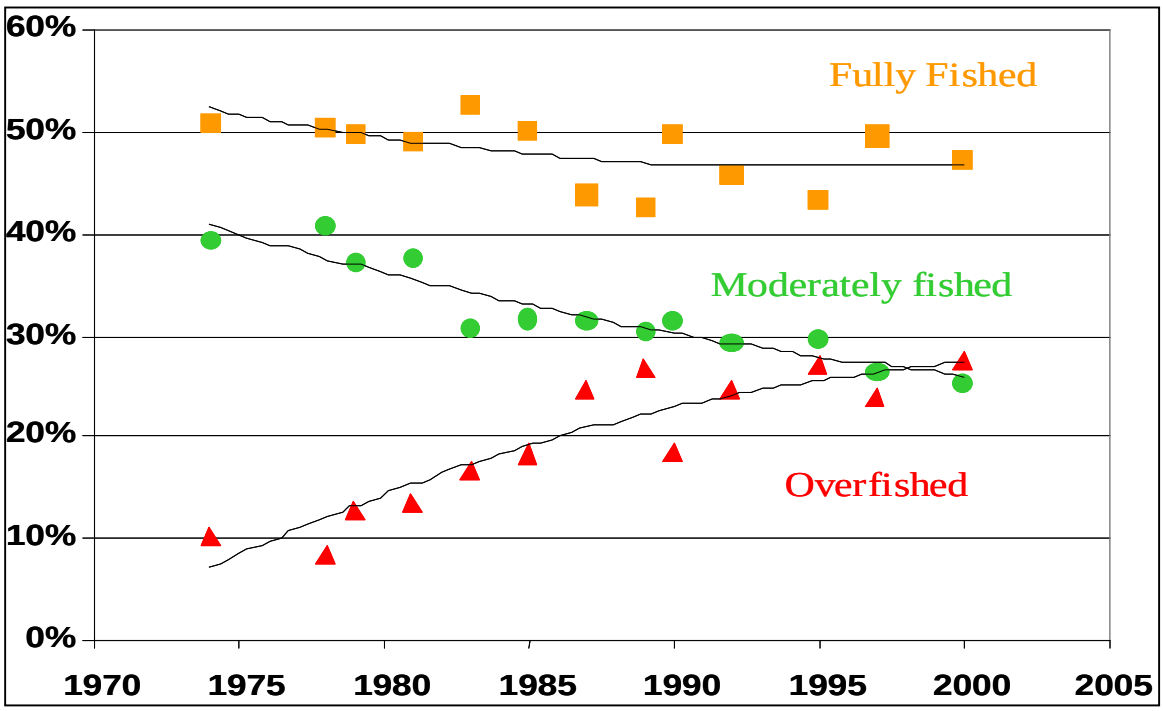


Figure 2.1.1.3 Global Trends in exploitation levels. (S.M. Garcia and I. De Leiva Moreno in Sinclair and Valdimarsson, 2003).

Fisheries that are under exploited include deepwater and oceanic species, and species low down the food chain. In the past twenty years or so some countries have begun to fish for deepwater species. These may however be short-lived fisheries if not carefully managed. The environment in the deep sea is generally regarded as being low in energy and productivity. Many of the deepwater species have long life spans (Clarinet, 2001); this may also mean that they have very variable recruitment (Longhurst 2002). One of the more studied species, orange roughy (*Hoplostethus atlanticus*), grows slowly and does not mature until in its twenties and can live for up to 125 years (Smith et al., 1995 in Callinet 2001). It is vulnerable to overexploitation and slow to recover (Clarke 2001). With this species the maximum average sustainable yield is estimated to be 2% of virgin biomass. Careful management of this fishing environment may be necessary to ensure that this and similar species are fished sustainably (Gordon 2001).

Moving down the trophic levels and fishing for species such as krill may achieve an increase in landings but unless there is adequate knowledge of ecosystem dynamics the ecological implications of such moves are uncertain (Cury 2003 in Sinclair and Valdimarsson 2003).

The FOA data upon which the above statements on levels of landings are made are not believed to be totally accurate; this was identified in the most recent assessment of state of the world fishing and aquaculture published in 2002. Data from China is thought to be particularly inaccurate. When the Chinese data is omitted from the world catch there are indications of a slow decrease in overall landings since the early 1990's (Watson and Pauly 2001 in Sinclair et. al. 2002). The European union has seen (between 1970 and 1999) a 1% increase in production (Anon 2001a). It is clear that many, or most of the worlds fisheries are now fully exploited, or overexploited. World capture levels are predicted to level off within the next thirty years (though production from aquaculture is predicted to continue increasing). At the beginning of the new century it is becoming apparent that changes have to be made in the way fishing is managed.

2.1.2 Recent Developments in Approaches to Fisheries Management.

During the past 30 years or so there has been an increase in public awareness of and concern for environmental considerations. There has been a realisation of the need to move to a process of sustainable development in many spheres of industry and life in general. Over the years there have been several seminal summits to discuss addressing the issues. From initially discussing general principles, the agendas under discussion have become more specific. In terms of fisheries the reduction of wastage by avoiding discards has long been a point of discussion. The first of these summits, the United Nations Conference on the Human Environment was held in Stockholm in 1972. At the end of the conference a declaration was issued, Principle 3 Stated:

> "The capacity of the earth to produce vital renewable resources must be maintained and, wherever practicable, restored or improved."

Twenty years later at the earth summit in Rio June 1992 world leaders adopted Agenda 21, a comprehensive plan of action for attaining sustainable development in the twenty first century. Chapter 17 of agenda 21(Anon, 1992) dealt specifically with the oceans. Article 17.72 states:

> "Fisheries in many areas…face mounting problems, including local overfishing, unauthorized incursions by foreign fleets, ecosystem degradation, overcapitalisation and excessive fleet sizes, underevaluation of catch, insufficiently selective gear, unreliable databases, and increasing competition between artisanal and large-scale fishing, and between fishing and other types of activities."

Around the same time as the Rio summit the FAO was drawing up a code of conduct for responsible fisheries. Serious concerns about clear signs of the overfishing of some important stocks, ecosystem damage, economic losses and other issues had been raised at various meetings of the FAO. These led to the organisation of a conference in Cancûn, in May 1992. The Declaration of Cancûn endorsed at that conference further developed the concept of responsible fisheries, stating that:

> "this concept encompasses the sustainable utilization of fisheries resources in harmony with the environment; the use of capture and aquaculture practices which are not harmful to ecosystems, resources or their quality; the incorporation of added value to such products through transformation processes meeting the required sanitary standards; the conduct of commercial practices so as to provide consumers access to good quality products".

This declaration was taken to the Rio summit and is reflected in article 17.75 of agenda 21 which commits states to:

> "(a) …the conservation and sustainable use of their living resources….
>
> (c) Maintain or restore populations of marine species at levels that can produce the maximum sustainable yield….taking into consideration relationships between species."

And in regard to fisheries by-catch:

> "(d) Promote the development and use of selective fishing gear and practices that minimise waste in the catch of target species and minimize by-catch of non-target species."

Armed with these commitments the FAO developed its code of conduct and after several more meetings the Code of Conduct for Responsible Fisheries was adopted by the 28th Session of the FAO Committee on Fisheries on 31 October 1995.

In 2001 in Reykjavik the FAO along with the governments of Iceland and Norway held a conference on responsible fisheries in the marine ecosystem. The conference reviewed relevant knowledge on marine ecosystems, tried to identify ways of incorporating ecosystem considerations into management and predict future challenges and solutions. Several problems that needed to be addressed in new fisheries management regimes were identified. These were: Overcapacity, overfishing, detrimental impacts of fishing on the marine ecosystem and the detrimental impacts of contaminants on fisheries ecosystems. At the end of this conference the Reykjavik Declaration was adopted calling for the adoption of ecosystem based fisheries management practices. This declaration was amongst the inputs to the world summit in sustainable development in Johannesburg in 2002.

2.1.3 Problem of Discards and By-catch in World Fisheries.

In the face of the concerns for responsible fisheries it seems inexcusably wasteful that according to the most recent estimate about a quarter of world catches are discarded. This amounts to about 20 million tonne per annum (Cook in Sinclair and Valdimarsson 2003). Discards consist not only of unwanted portions of the target species but in many cases include non-target species, or incidental catch. The term by-catch describes the discarded portion of the target catch and all of the incidental catch (Cook 2002), as is summarised in Figure 2.1.3.1

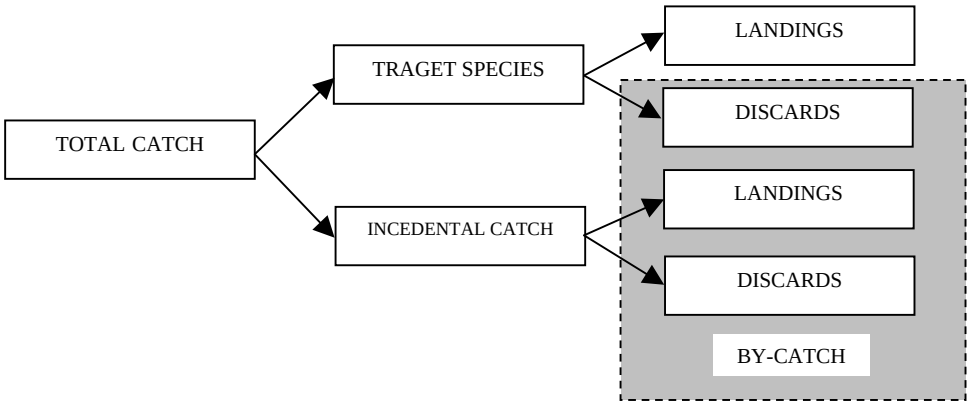


Figure 2.1.3.1 Summary of terms used to describe portions of catch.

In a comprehensive review of the global problems of discards and of by-catch Alverson *et al.*, (1994) summarised that at that time the northeast Atlantic region accounted for around 14% of the global discards (by mass). Different fishing techniques are more prone to the problem than others, Alverson *et al.*, 1994 places shrimp trawls at the top of the list in terms of mass discarded to mass landed (Figure 2.1.3.2) The second most significant fishery is non-pelagic fish trawling, such as that undertaken widely in Europe, Ireland and indeed in Dingle Bay.

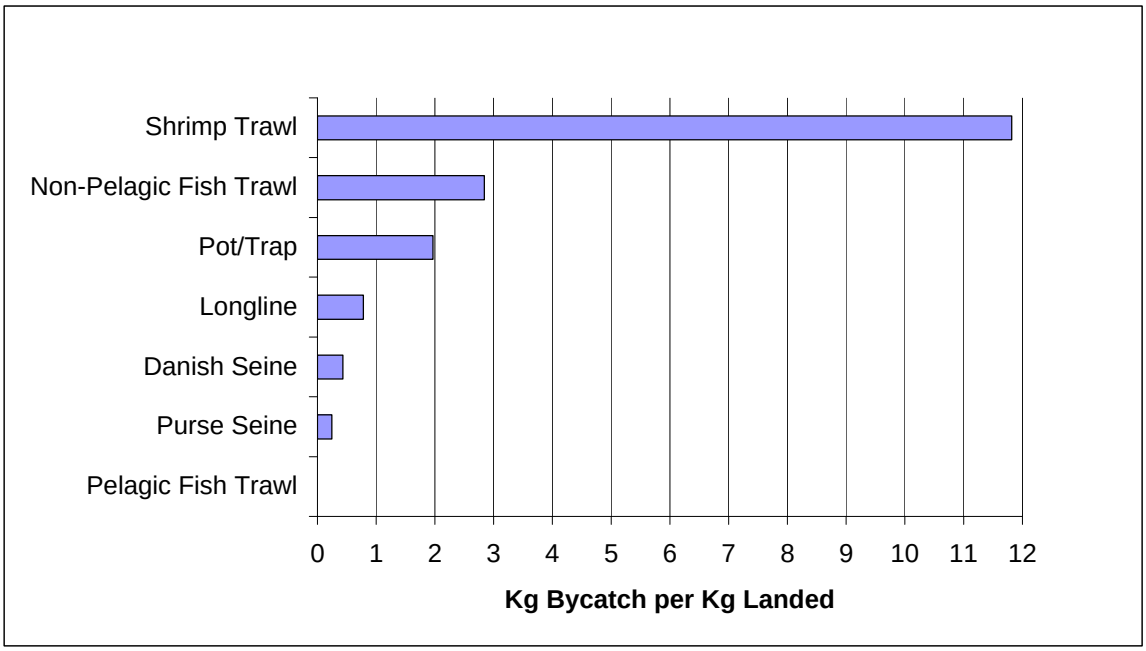


Figure 2.1.3.2 Levels of discards generated by seven types of fishing.

There are many reasons for discarding. These were summarised as follows (Clucas 1997, in Hall 2000):

- Fish caught are wrong species, size or sex, or fish are damaged.
- Fish are incomparable with the rest of the catch.
- Fish are poisonous.
- Fish spoil rapidly.
- Lack of space onboard.
- High Grading (Discarding low value species in favour of more valuable species).
- The catch was of prohibited species, in prohibited season or fishing ground, or with prohibited gear.

There are also occasions where damage to nets results in loss of the catch. Also it is inevitable that fish of marketable size are missed in the sorting process. The levels of fish lost this way will likely be a factor of the bulk of the catch, the size range of the catch and the attitude of the crew.

The approach to managing (or not as the case may be) the levels of by-catch and discards will depend upon the characteristics of the problem. Hall (2000) identified eight criteria of use in classifying by-catch:

1. The spatial pattern of by-catch rates: May be controlled by closed areas.
2. The temporal pattern: May be controlled by closed seasons.
3. The level of control: May be controlled by fishing behaviour/ training.
4. The frequency of occurrences: Infrequent events may be unpredictable and difficult to mitigate.
5. The degree of predictability: Species may follow for example diurnal, tidal or lunar cycles that may be of use in management.
6. The ecological origin: Harvesting of predator or prey may have subsequent consequences on the balance and functioning of an ecosystem.
7. The level and type of impact: By-catch of endangered or charismatic species will elicit a greater response that may incur greater economic costs and social impacts.
8. Legal or economic considerations. Changes in the value or legal status (such as minimum size, or quota) of a species can be used to modify levels of by-catch.

It is clear that there are many factors involved in generating by-catch and numerous tools that may be used in conjunction with one another to ameliorate the situation.
There are several ways to reduce the levels of by-catch in a fishery. The most obvious method is to reduce overall fishing effort in the fishery in question, such as occurred when the UN proposed banning pelagic drift netting on the high seas. This method is rarely a practical or acceptable control method to fishers. Alternatively a reduction in the rate of by-catch within a fishery is often more practical and acceptable. This can be achieved by implementing technical changes in the fishing gear, changing the way the gear is used, improving the training of fishers or by managing the fishery: closing areas when by-catch levels are unacceptable or by setting vessel by-catch limits. Gear can be modified to exploit the morphology or behaviour of the species in question. Grids can be placed inside the net to exclude certain species. Increasing the mesh size of mesh cod ends will allow larger fish out of the net. Square mesh panels can be placed in specific areas of the net to allow certain species of fish to actively escape. These methods ideally maximise the catch of target species of marketable size whilst reducing the level of discards of non-target species and undersize and juvenile fish.

2.2 European Fisheries.

2.2.1 The Common Fisheries Policy.

In Europe the common fisheries policy (CFP) was first established in 1983. Its purpose was to jointly manage and allow access to the fisheries resources of the member nations within the European Union. The policy has been much criticised due to the fact that during the period it has been in force many of the stocks it was designed to control access to have become depleted. The policy was reviewed in 1992 and again in 2002. The recently published 'roadmap' (European Communities 2002) acknowledges the failures of the CFP to maintain fish stocks within safe biological limits and states that "urgent" reform is required to address the "critical" situation of many stocks. Other problems are identified such as poor profitability, declining employment, a lack of a "level playing field" across the union and a lack of involvement by stakeholders. The current CFP came into force on 1st January 2003. Regarding the sustainable exploitation of fisheries resources Council Regulation (EC No 2371/2002) was adopted with the objectives of applying a precautionary approach to management and to aim for progressive implementation of an ecosystem based approach to management whilst providing a "fair standard of living for those who depend on fishing activities and taking into account the interests of consumers."
There are many problems to address, but the priority, above all others, and upon which the success of all reforms must be based is to achieve sustainable use of fisheries resources. To realize this goal the Commission has identified a number of aims. These are:

- An immediate and significant reduction of fishing effort;
- A refocus of management onto long term sustainability with high yields;
- Incorporation of environmental concerns and preservation of biodiversity;
- Move towards ecosystem-based approach to fisheries management;
- To support the provision of high quality scientific advice;
- To make the best use of harvested resources and avoid waste.

These aims may be achieved by a combination of management techniques and restructuring schemes. Perhaps the most apparently straightforward way of reducing

fishing pressure on a species is to reduce the level of fishing allowed, i.e.) reduce the total allowable catch (TAC) for that species. However species such as cod, whiting and haddock are often caught in a mixed fishery, and it is often difficult to avoid catching one species, such as cod say, whilst still maintaining a viable fishery for other species. So implementing such management plans is often fraught with difficulties. In addition a reduction of fishing effort upon one species, where species are not taken in a mixed fishery could in theory increase the fishing pressure upon other fisheries as effort was redirected. It is clear then that many factors other than just the biology of the particular stock have to be accounted for in the management process.

Other proposals designed to achieve reduction of fishing effort include reducing the number of vessels involved or the amount of time that fishers can fish. In respect of reduction of fleet there have been several multi-annual guidance programmes (MAGPs), the aim of which was to reduce fishing capacity, in terms of fleet tonnage and engine power and in some cases time at sea in line with the available resources. These measures are also difficult to implement, especially when it is perceived that measures are not being applied equally to each member states fleet.

An alternative approach to improving sustainability, increasing yields, and reducing impact on the ecosystem is to employ measures designed to reduce by-catch, these include:

- The introduction of more selective fishing gear such as nets with larger mesh sizes, square mesh panels, separator grids and changes in design and rigging.
- Restriction on fishing to protect juvenile fish, sensitive non-target species and habitats.
- Minimum landing sizes in line with selectivity of gear.
- Banning discards: trials encouraged by economic incentives.
- Targeting of incentives for the use of more selective fishing practices. (European Communities, 2002).

In order to make best use of the tools available to managers ongoing monitoring of the stock is required as is research into the selectivity and probable effects of changes in gear design. Because the population and size structure of fish communities varies greatly from place to place and the nature of the fishing industry reflects this diversity, the conservation measures required will vary and the selection of appropriate measures needs accurate local knowledge. With this in mind it seems that the future of the CFP could include more involvement of local fisheries management initiatives and a decrease in the amount of control exerted from commission headquarters.

2.3 Technical Conservation Methods.

As fish stocks in European waters have come under more pressure, studies on the effect of using various technical conservation measures have been carried out to try to identify measures appropriate for the particular fishery.

The simplest way of allowing more fish to escape through a net is to increase the mesh size. This will increase L_{50} (the length at which half of the fish escape through the mesh) for most species able to escape the net. Decreasing the twine dimensions will have a similar effect to increasing mesh size, (Lowry and Robertson, 1994, Briggs et al., 1999). The conventional diamond meshes used in most nets close up under towing pressure, this effectively reduces the mesh size. Square mesh has the advantage over diamond mesh that under tension it maintains its shape and does not close up. It is possible to make square mesh cod-ends, but these are weaker and more difficult to handle, the knots are also liable to slippage (Graham et al., 2003). Knotless square mesh is available but can be far more expensive than conventional netting material. A practical alternative to a complete square mesh cod end is to insert a panel of square mesh into the net.

The addition of a square mesh panel into the top sheet of a net has been found to reduce discard numbers of gadoids (Armstrong et al., 1997, Madsen et al., 1999a) with virtually no reduction in the catch of flatfish (van Marlen, 2003). Direct observation of the behaviour of fish suggests that they actively escape through the square mesh panels. It has been found that smaller fish, which are less able to see and swim to and through panels, do not escape as well as larger members of the same

species. The position of the panel can affect its effectiveness. Graham and Kynoch (2001) found the insertion of an 80mm square mesh panel immediately in front of the cod-end extension did not have any significant effect on selectivity, while a similar panel placed in the cod end improved selectivity. Subsequently trials indicated panels placed too far forward of the cod end had little effect on selectivity. (Graham et al., 2003).

Separator trawls exploit the behaviour of fish entering the net to separate them into compartments, fish staying near the ground, such as flatfish, crustaceans and cod will be directed into one cod-end, while fish with a tendency to swim higher in the water column such as whiting and haddock will be diverted upwards into a second cod-end by an inclined panel inserted into the tunnel of the net. The selectivity of the netting in these cod-ends can then be tailored appropriately for the fish expected within. They are of particular use in separating the whiting and haddock from the crustaceans and stones that would otherwise cause damage to the catch. Also due to the fact that these trawls can potentially separate cod (MLS 35cm) from haddock (MLS 30cm) and whiting (MLS 27cm) they may be suitable in mixed fisheries to protect undersized cod which would be retained in meshes suitable for catching legal sized haddock and whiting (Cotter, 1996).

2.4 Irish Inshore Fisheries.

The inshore sector in Ireland employs thousands of people and accounts for 83% of the entire fisheries fleet and 50% of the onboard employment in the fishing sector (Anon, 1999). BIM defines inshore fisheries as those fisheries that are conducted within 12 miles of shore, including demersal, pelagic, shellfish, salmon and sea angling fisheries. A report on Irish inshore fisheries sector was produced in May 1999. This report highlighted some of the problems in the sector and identified some possible solutions for the sector. Among the recommendations in the report was a proposal to set up local Inshore Fishery Development Committees (IFDCs) to promote local involvement in decision making and management of inshore sea-fisheries. One of the functions of these committees would be to manage the fisheries to ensure the sustainability of the resources. Committees are now in place around the

Irish coast, with facilitators based in Wexford, Kerry, North and South Connemara, North Mayo and North Donegal.

The Dingle Bay IDCF identified discarding as one of the important issues to be addressed within the bay. A proposal for a study of discarding and the use of technical conservation measures was drawn up jointly with the committee and The Institute of Technology, Tralee. Nationally BIM was undertaking research into the effects of TCMs and so were able to provide funding of £200,000 to cover the expense of hiring boats, some observers and manufacturing experimental nets. The Department of Education and Science funded the MSc researcher through a Technology Sector Research Strand I grant. The Marine Institute provided some additional funding and expertise. They were closely involved in the development of the study, which would also be able to provide data for their pre-existing discards programme. This project was developed to operate within the Commercial Fishing sector to generate scientific research for use by the local fishers. The research was to be undertaken with the fishermen working, as much as possible, under normal fishing conditions. The skippers and crews, who have most to gain or lose by the use of TCMs were very closely involved in the project. Their expertise in handling the nets and boats were essential to the successful completion of the project. Their involvement in the planning and execution of the sampling would provide them with hands on experience of using the nets under investigation. This would give them an insight into both the immediate haul-to-haul effects of the nets and the scientific methods of investigating those effects.

2.5 Dingle Bay

Dingle Bay is located at the southwest of Ireland (Figure 2.2.1.1). The area in which this study was carried out covers an area extending from around 10º 7 to 10º 45 west and 51º 55 to 52º 10 north. The depths fished varied from 22m to 118m (average 54m). Boats from Dingle, and on occasion those from Valentia fish the bay. The main fishing method employed is trawling, though some gillnetting occurs where trawling is impossible. There is also a pot fishery for lobsters and crab. The small inshore whitefish trawling fleet, at this time, consists of six vessels. The boats are typical of those found in many inshore fisheries around the coast of Ireland. They are between twenty and forty years old and between 50 and 65 feet in length (for further details see section 4.4). These boats are involved in a mixed demersal otter trawl fishery. They target a variety of fish, plus squid and nephrops. Most of the species encountered during these trials are recorded in Table 2.2.1.1. The majority of the species were not taken in large numbers on a daily basis. As well as species encountered in the fishing net, the bay supports other wildlife. Animals present at various times of the year include bottle nosed dolphins, harbour porpoises, grey seals and basking sharks. Numerous species of seabird visit the area and fifteen breed regularly in the area The species present include Cormorant, Shag, Common gull, Herring gull, Kittiwake, Lesser black-backed gull, Great black-backed gull, Manx shearwater (over 2,000 pairs), Fulmar, Puffin, Razorbill, Guillemot, Black guillemot, Arctic tern, Storm petrel (over 20,000 pairs) and Gannet, of which over 20,000 thousand pairs breed on nearby Little Skellig. This means that the area has one of the highest diversities of breeding seabirds in Ireland and Britain (Brazier and Merne, 1989). Several species are commonly seen in the vicinity of fishing boats, Gannet, Kittiwake, Herring Gull, Lesser and greater black backed gulls all frequently consume discards, both of fish and offal (Berrow, 1998). It is to be assumed that the discards generated in this fishery are of direct benefit to at least some of these birds. In the North Sea it has been estimated that the approximately 789,000 ton of waste generated in the whole fishery could support 5.9 million seabirds. When the population of scavenging birds in that area is estimated to be between 3 and 6 million birds, it would appear that fisheries waste could be of considerable importance to seabird populations.

The fish population in the bay consists of numerous species (Table 2.4.1). Being a relatively shallow inshore area the bay is considered an important nursery ground for commercial species such a plaice, brill, turbot, sole, whiting and cod.

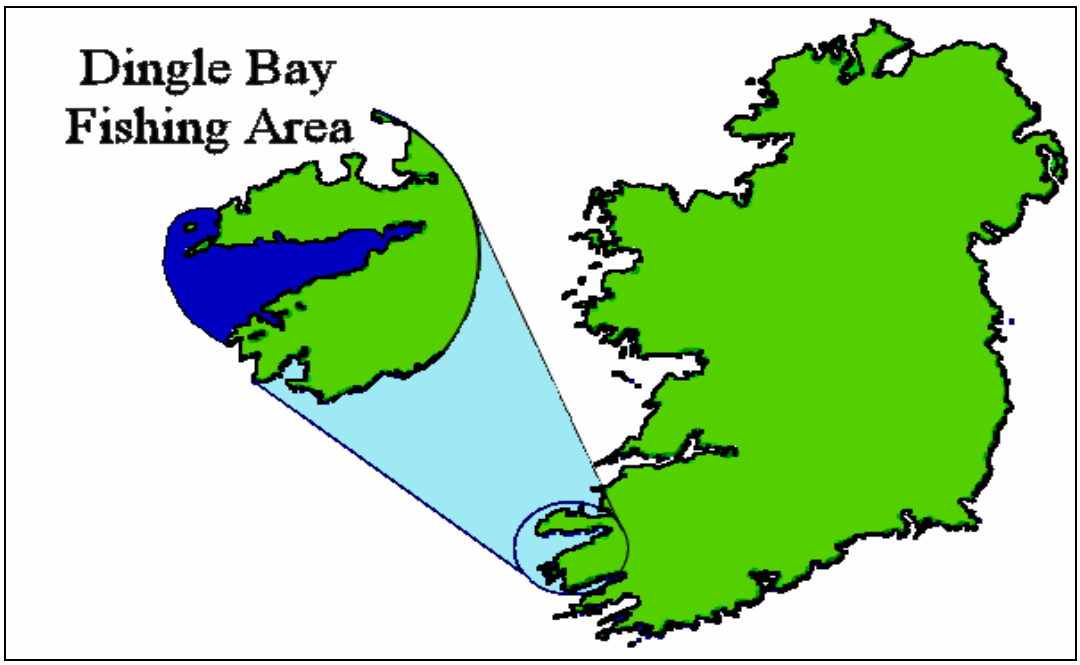


Figure 2.2.1.1 The extent of the grounds fished during the project.

Table 2.2.1.1 Species encountered during trials.

Species landed:	By-catch:
*Angler (Black and White).- *Lophius spp.*	Bass - *Dicentrarchus labrax*
*Black sole – *Solea solea*	Bib - *Trisopterus luscus*
Brill - *Scophthalmus rhombus*	Blue whiting- *Micromesistius poutassou*
Cod – *Gadus morhua*	*Brittlestar.
*Haddock - *Melanogrammus aeglefinus*	Common Skate – *Raja batis*
John Dory - *Zeus faber*	Conger eel – *Conger conger*
Lemon sole - *Microstomus kitt*	Crayfish - *Palinurus elephas*
Ling - *Molva molva*	*Dab- *Limanda limanda*
*Megrim - *Lepidorhombus whiffiagonis*	*Dragonet - *Callionymus lyra*
*Plaice - *Pleuronectes platessa*	*Edible crab- *Cancer pagarus*
Pollack - *Pollachius pollachius*	Lobster – *Hommarus gammarus*
*Ray – *Raja spp.*	Electric ray - *Torpedo nobiliana*
Turbot - *Scophthalmus maximus*	Flounder - *Platichthys flesus*
*Whiting - *Merlangius merlangus*	*Grey Gurnard - *Chelidonichthys gurnardus*
Witch - *Glyptocephalus cynoglossus*	Hake - *Merluccius merluccius*
Squid – *Loligo forbesi*	Hermit crab
	Herring - *Clupea harengus*
	King Scallop - *Pecten maximus*
	Lesser Weever - *Echiichthys vipera*
	*Lesser spotted Dogfish - *Scyliorhinus canicula*
	Mackerel - *Scomber scombrus*
	Norway Lobster – *Nephrops norvegicus*
	Norway pout - *Trisopterus esmarkii*
	Octopus
	Poor cod – *Tricopterus minutes*
	Purple Sea Urchin - *Paracentrotus lividus*
	Red gurnard - *Chelidonichthys cuculus*
	Sand sole - *Solea lascaris*
	Sandeel - *Ammodytes tobianus*
	Scad - *Trachurus trachurus*
	Scaldfish - *Arnoglossus laterna*
	Seamouse
	*Spidercrab - *Maja squinado*
	Spurdog - *Squalus acanthias*
	Sprat - *Sprattus sprattus*
	*Starfish
	Topknot - *Zeugopterus punctatus*
	*Velvet swimming crab- *Necora puber*

*Species encountered in large numbers on a regular basis. (Ref: Whitehead 1986)

3 Objectives.

Working with commercial fishing crews in the commercial fishing environment of the Dingle Bay fishery the primary objectives of the study were to:

1. Identify and apply sampling and analytical methods appropriate to the commercial setting.
2. To establish discard rates for the fishery.
3. Investigate the effects of a specific range of technical conservation methods on the landings and discards generated by the fishery.

4 Materials and Methods.

4.1 Introduction

In order to quantify the effects and importance of the TCMs a sampling procedure, experimental design and some method of collating and analysing the collected data had to be identified. The marine fisheries services division of the Marine Institute undertakes a discard sampling programme to monitor the levels of discards of undersized fish. A Microsoft access database was developed by the Marine Institute to collate this information. This study used that database to pull together the information collected during the sampling phases. The collection of data therefore was very much based on the well established and internationally recognised protocols set down by the Marine Institute. These protocols and the database would provide highly detailed information on size and species composition of the catch, which could be analysed in a number of different ways.

The six boats involved in the survey were engaged in the mixed fishery in Dingle Bay. In this fishery numerous species of fish are encountered in varying numbers throughout the year. It was necessary therefore to prioritise the fish species under investigation. Seven species were initially identified: Cod (*Gadus morhua)*, Dab (*Limanda limanda*), Haddock (*Melanogrammus aeglefinus)*, Whiting (*Merlangius merlangus*), Plaice (*Pleuronectes platessa)*, Sole (*Solea solea*) and Megrim (*Lepidorhombus wiffiagonis*). These, it was felt would occur in regularly, and in sufficient numbers to allow large representative sub-samples to be taken. In practice it was often possible to measure the entire landings of most of these species. It was also decided that neither crustaceans (Lobster, edible crab, nephrops etc.) nor less commercially important species such as Lesser-spotted dogfish (*Scyliorhinus canicula)* would be measured at all. This would allow the measuring of more of the commercially significant and representative discards.

During discussions between the BIM Inshore Development Officer and the six skippers it was decided that sampling would be undertaken over two periods, one in the autumn of 2001, the second in the spring of 2002. Each would consist of sixty

days of fishing involving two hauls per boat per day. This would constitute 120 days of fishing and a total of 240 hauls would be available for monitoring. In order to get through all these days fishing during the agreed time scale some additional observer support was required. BIM and the Marine Institute provided these from their own staff.

4.2 Constraints and considerations.

One of the objectives of the project was to compare, under normal fishing conditions, the catch of nets incorporating TCM features with the catch of the regular nets the fishermen used. It had been agreed that the sampling and research methods should be designed so as to interfere as little as possible with normal fishing operations. For this reason, hauls of several hours duration were preferred to shorter hauls. This had the advantage of allowing more time to analyse the catch; with limited manpower of one observer per vessel it would be impractical to undertake tows of short duration when the sampling itself could take 60 to 90 minutes or more. In a research vessel based sampling scheme shorter tows would be the norm.

There are several ways of measuring the selectivity of fishing gears; Wileman et al.,(1996) discuses the application of several of them. These methods include the twin trawl (two trawl nets towed beside one another behind one boat); the trouser trawl (a single net with two cod ends), the alternate haul and the parallel haul methods. Each of these methods can be used to measure the selectivity of the whole trawl. Twin trawls require special rigging and trouser trawls would be too big to tow so both of these methods were inappropriate for the vessels involved in the survey. Also if using these methods the boats would not be fishing under normal operational conditions and so twin and trouser trawls were ruled out. The only methods left available to use were parallel hauls and alternate hauls. There are some issues with both of these methods: alternate hauls are susceptible to variations caused by the fact that hauls take place at different times, whereas parallel tows are more susceptible to differences due to the fact that different vessels tow the nets. However under ideal conditions each of these

methods would yield a direct comparison between the standard and the experimental net, and any differences in catch would be in the main due to the TCM feature in the experimental net. Unfortunately in the real world there are many other objective factors that will affect the numbers of fish entering the net. Different locations (Ehrich et al., 1998), weather conditions (Polet and Redant, 1994 in Armstrong et al., 1998) and times of day and year will yield different numbers of fish. These factors are difficult to predict and the sampling strategy was designed to try and minimise the effect that these would have on the final results. During the first phase of fishing alternate tows were used. The two nets under investigation were alternated in a manner so as to try to fish both nets under a variety of differing conditions to balance out the objective factors. During the second sampling phase two pairs of boats were used to perform parallel tows, so that the objective factors effecting catch would be as similar as possible for both nets.

Each day the skipper made the decision whether to put out to sea. The locations and towing routes sampled were chosen based upon his knowledge of the bay and its weather. Prevailing wind has a considerable effect on sea conditions. Dingle bay, though a relatively enclosed body of water, is exposed to the Atlantic to the southwest. Due to the shape and shallow nature of the bay relatively mild winds from that direction can raise considerable swell. Winds from the north or south can cause problems in areas of the bay exposed to those winds and can be avoided by fishing in waters sheltered by the land. Easterly winds do not cause undue problems but the skippers consider that the fishing is generally poor during easterlies. Within each area of the bay traditional towing routes have been established to avoid rocky areas. Traditionally these routes have been found, passed down and guarded by individual skippers.

During parallel hauls the two skippers made the choice of grounds. Due to the fact that the nets in use cannot be towed over rocky ground and that many of the suitable grounds within the bay are narrow it was not always possible for the two boats to tow side by side, in areas where this was the case the two boats made tows so as to cover the same ground. Where ground was suitable for boats to tow side by side they did so. Every effort was made to shoot and haul at the same time.

The selectivity of specific parts of the trawl gear such as cod-end and square mesh panels can be measured separately by use of small mesh covers over the areas under investigation. However the covers available were not recommended due to the suspicion that they were significantly altering the effectiveness of the TCM feature they were supposed to be assessing. The use of covers was therefore ruled out.

Even though the experimental nets were made to order to be as similar as possible to the regular nets they were not exactly the same. Any differences between nets could not be ascribed as due solely to the TCM feature, but only to the difference in the overall selectivity of each net. Also to be considered is the fact than none of the boats were exactly the same in the way they operated, different trawl doors and other characteristics would possibly affect net selectivity. All such factors mean that differences in catch found during any trials undertaken by this project can only be confidently applied to the particular combination of boats and nets involved in that particular trial. It would be speculative to compare different trials to one another or predict changes to the wider fishery were it to adopt a particular net type. That said results could give a general insight into what particular net types might be advantageous in fisheries management elsewhere. These constraints were inevitable in the commercial setting of this research and were anticipated from the outset of the project. With this in mind the project was designed to accommodate these factors as much as possible.

4.3 Sampling Protocol

A data sheet was designed onto which details from each haul were to be recorded (see appendix A).
For each haul time, depth, latitude, longitude and local name for the fishing ground were recorded along with details of depth, sea state, swell, and towing speed. The route of each haul was plotted on a chart.

Whilst the crew were sorting the catch all Dogfish and Crustaceans were removed from the pound. The amount of each was recorded as a fraction of a 40kg box. These were then discarded. This process is summarised in figure 4.3.1.

When the catch had been sorted the total number of boxes of discards was counted. Initially this was done by physically filling boxes with discards before throwing them over the side, later the discards were all retained on the deck and an estimate of the number of boxes was made after the marketable catch had been removed. One box was then filled with discards by taking samples from different areas of the pound, this box was set aside and the rest of the discards were put out through the scuppers.

The total amount of landings of each species was recorded in terms of 40 Kg boxes. If boxes were mixed, i.e.) containing more than one species, they were recorded as a mixed box and described more fully later if possible.

The fish under investigation were then measured. In accordance with MI protocols the length measurement recorded was length to the nearest cm below total length.
If there was more than one box of any species landed then a sub-sample was measured: at least one box was measured, the total number of fish was then calculated by multiplying each length class by a raising factor where:

$$\text{Raising factor} = \frac{\text{Number of boxes landed}}{\text{Number of boxes measured}}$$

If the landings of a particular species were sorted into large and small fish then these were measured separately to get a raising factor for each.

Once as much of the landings as was practical had been measured the box of discards was measured. To save on time only the commercial fish were measured. These were: Cod, haddock, plaice, megrim, sole, monk and dab, the other (non-commercial and not measured) fish i.e., Gurnard, Dragonet, Weeverfish, Wrasse, Scald fish, ray etc were placed into a separate box, the amount in this box was then recorded as non commercial fish discards, anything else such as stones, seaweed etc was described as non fish discards and recorded as a proportion of a box. All discards were returned to the sea before return to port.

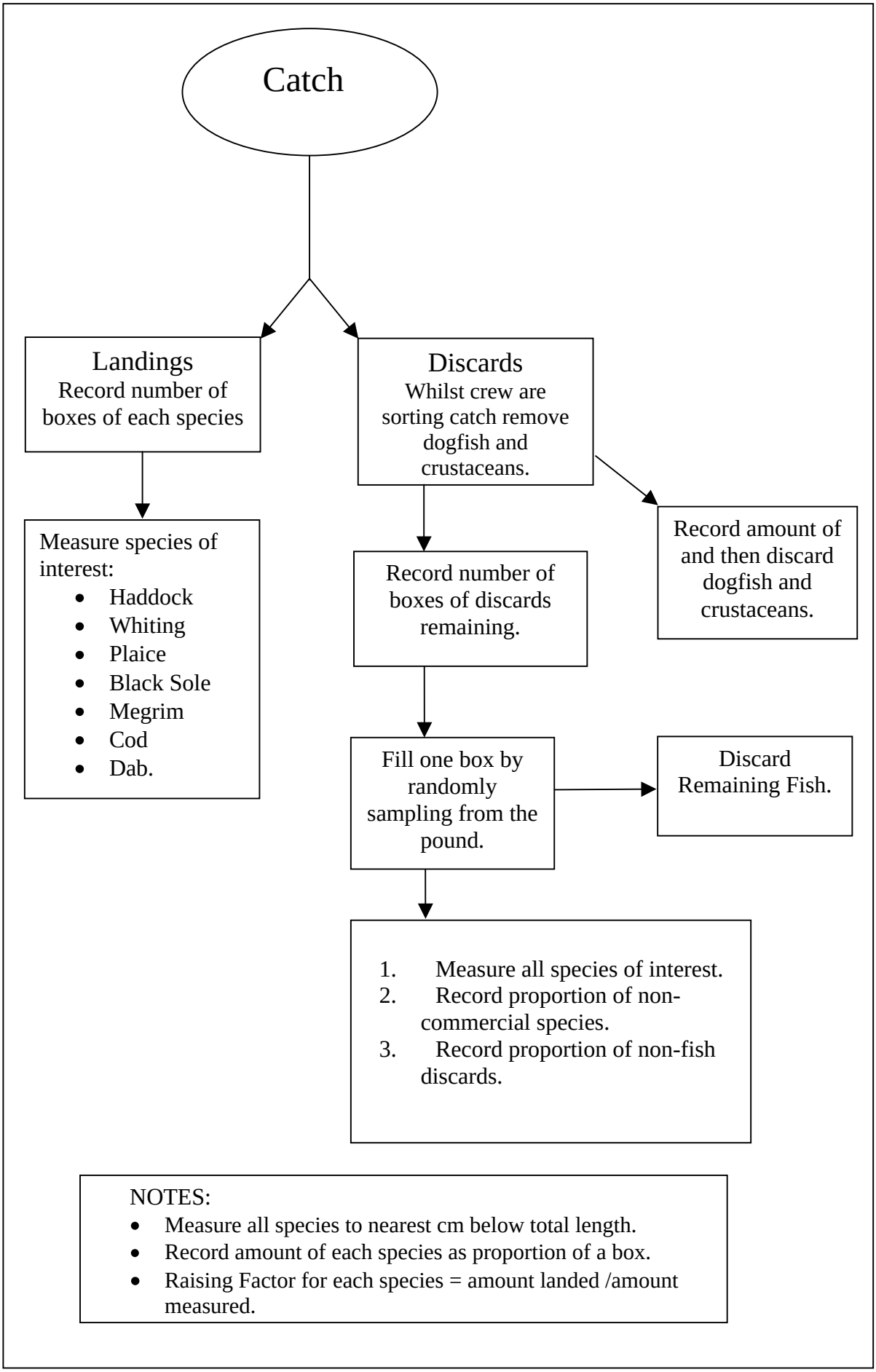


Figure 4.3.1 Summary of sampling procedure for all hauls.

4.4 Fishing Vessels Employed

The six boats involved in the trials are all wooden built trawlers between 1956 and 1972; Table 4.4 lists the vessels and net types employed. The nets had been ordered very early in the project, each was specifically designed to suit one of the six boats taking part in the sampling programme. Most were standard design dual-purpose nets but for the addition of one TCM feature. Swan Net-Gundry net makers, Castletownbere, Co, Cork, manufactured experimental nets. The cod-ends were all manufactured from 4mm diameter compact polyethylene twine, a braided single green twine. James McDonnell of Gear Tech, Howth, inserted square mesh panels. The square mesh panels were all Ultracross™ net. This is a knotless mesh made from a 4mm braided black twine, and renowned for holding shape; all panels were 3m by 3m and placed 49.5 meshes ahead of the first cod-end extension.

James McDonnell also designed the separator trawl. The nets used in the first year were modified for the second phase of sampling. Details of precise designs of experimental nets are given in appendix B.

Table 4.4.1 Some details of vessels and nets involved in gear trials

Boat Name	Built	Built	Length (m)	Beam	GRT	Main Engine	HP	Doors
Maid of Nazareth	1972	Baltimore	19.81	6.25	74.1	Kelvin	440	Tyborn 7'
Gerlisa	1972	Killybegs	19.81	6.16	65	Poyaud	350	Kilkeel 6'
Deux Orchidees	1972	France	15.58	5.04	30.02	Baudouin	399	Dunbar 6'
Elsie Marie	1970	Killybegs	19.81	6.07	67.45	Kelvin	450	Tyborn 7'
Naomh Deararca	1956	Arklow	16.76	5.2	36.98	Gardner	200	Bison 4' 4"
Floralie	1970	France	17.98	5.43	45.77	Baudoin	287	Kilkeel 6'3"

		Experimental net.	
Boat Name	Standard Net	Year 1	Year 2
Maid of Nazareth	45 fm dual purpose	80mm Square mesh panel	80mm Square mesh panel
Gerlisa	40 fm dual purpose	100mm Cod-end	100 mm cod-end
Deux Orchidees	25 fm dual purpose	100mm Codend	90mm cod-end
Elsie Marie	45 fm dual purpose	Seperator Trawl	80mm Square mesh panel
Naomh Deararca	24 fm dual purpose	160mm From coversheet back	100mm cod-end
Floralie	32 fm dual purpose	90mm Square mesh panel	100mm cod-end

4.5 Experimental Design

4.5.1 First Sampling Phase, Autumn 2001.

During this phase all boats were equipped with one TCM net and their own standard net. The two nets were to be alternated; the new net being used 60% of the time the old one 40% of the time. The idea was to pool the data gathered from each net to make an overall comparison of the selectivity and discard ratio of each. Each boat was funded for ten days of sampling. It was agreed that two tows, each of about four hours duration would be undertaken each day. The six boats were all studied separately and in the exact same manner. One observer was to be stationed on each boat for the duration of each trial.

At the end of the sampling period the progress was reviewed and some preliminary analysis of results undertaken. Noise factors in some of the data made clear interpretation difficult. To try to reduce these factors it was decided to employ parallel tows, to undertake more tows, and, in order to achieve more uniform data recording, use fewer observers.

4.5.2 Second Sampling Phase. Spring 2002.

For the second phase the changes designed to improve the quality of data coming from the sampling programme were implemented. More and shorter tows would provide more replicates. Very short tows however were impractical from point of view of the survey having minimal impact on normal fishing activity. Also due to financial cut backs the number of days per trawler were reduced from the ten in the first phase to eight in the second phase. After negotiations, three tows of three hours duration per day were agreed upon, giving a maximum of 24 tows per boat. Of the six boats two pairs were deemed to be of similar enough design to be used in parallel tows. The remaining two boats would be surveyed with the alternate hauls. There would be a 50:50 split between of nets, three hauls per day, the nets being changed

once daily after the second of the three tows to account for possible changes in catch due to changes in time and tide. As in the first sampling phase the results from alternate tows would be pooled.

4.6 Summary.

The methodology was refined and improved throughout the sampling period and the final design of the sampling phase of the project is summarised in table 4.6.1, the boats involved and the experimental method is indicated, as is the final number of tows conducted with each net. Due to the way the data was inputted the numbering is not logical, the trials in the first year are numbered from pairing 11 to pairing 16, those in the second year from 1 to 8. Details of all the valid tows used in the subsequent analyses are listed in appendix C.

Table 4.6.1: A summary of TCM features under investigation, the method used and number of tows completed for each trial.

Year 1	Boat	Nets Under Investigation.	Method	Number of tows
Pairing 11	Maid Of Nazareth	80mm square mesh panel 80mm codend	Alternate	12 7
Pairing 12	Floralie	90mm square mesh panel 80mm codend	Alternate	12 5
Pairing 13	Gerlisa	100mm codend 80mm codend	Alternate	5 8
Pairing 14	Elsie Maria	Separator Trawl 80mm codend	Alternate	8 4
Pairing 15	Naomh Deararca	160mm from Cover sheet back 80mm codend	Alternate	8 8
Pairing 16	Deux Orchidees	100mm codend. 80mm codend	Alternate	2 4
Year 2				
Pairing 1	Deux Orchidees Floralie	100 mm codend 100 mm codend	Parallel Parallel	6 6
Pairing 2	Deux Orchidees Floralie	80 mm codend 100 mm codend	Parallel Parallel	8 8
Pairing 3	Deux Orchidees Floralie	100 mm codend 90 mm codend	Parallel Parallel	9 9
Pairing 4	Maid Of Nazareth Elsie Maria	80mm square mesh panel / 80mm codend 80mm square mesh panel / 80mm codend	Parallel Parallel	5 5
Pairing 5	Maid Of Nazareth Elsie Maria	80mm codend 80mm square mesh panel / 80mm codend	Parallel Parallel	8 8
Pairing 6	Maid Of Nazareth Elsie Maria	80mm square mesh panel / 80mm codend 80mm codend	Parallel Parallel	8 8
Pairing 7	Naomh Deararca	80 mm codend 100 mm codend	Alternate	8 11
Pairing 8	Gerlisa	80 mm Single purpose 90 mm Dual purpose	Alternate	10 10

5 Statistical Analysis.

5.1 Aims Of Statistical Analysis

In each trial two nets, one experimental and one standard were compared. The aim of the analyses was to identify any significant differences in the numbers or lengths of fish of a particular species caught. Several methods were employed in an attempt to highlight the selectivity of nets. Line graphs of length frequency distribution gave an overall impression of the catch composition. Boxplots, Mann-Whitney and Chi^2 tests looked at individual species abundance. Biplots were used to try and identify relationships between the relative abundance of species caught in the trials. Where appropriate selectivity ogives were estimated.

The data was inputted into the Marine Institute's discards database (a Microsoft access database). Landings and discards were combined to give a complete account of the catch. The catch for each species could then be divided into categories based on legal sizes and value (see section 5.2.2). In this way bias caused by the selectivity of the crew could be removed. Search queries were designed to convert numbers of fish caught for each species in each length category to raised numbers per tow and raised numbers per hour per tow. This process is summarised in figure 5.1.1. The results from each tow were then combined to calculate the average catch per hour for a particular net. The data was manipulated and reorganised in Excel pivot tables. SPSS version 11.0 and SPLUS 6.0 were used for analysis.

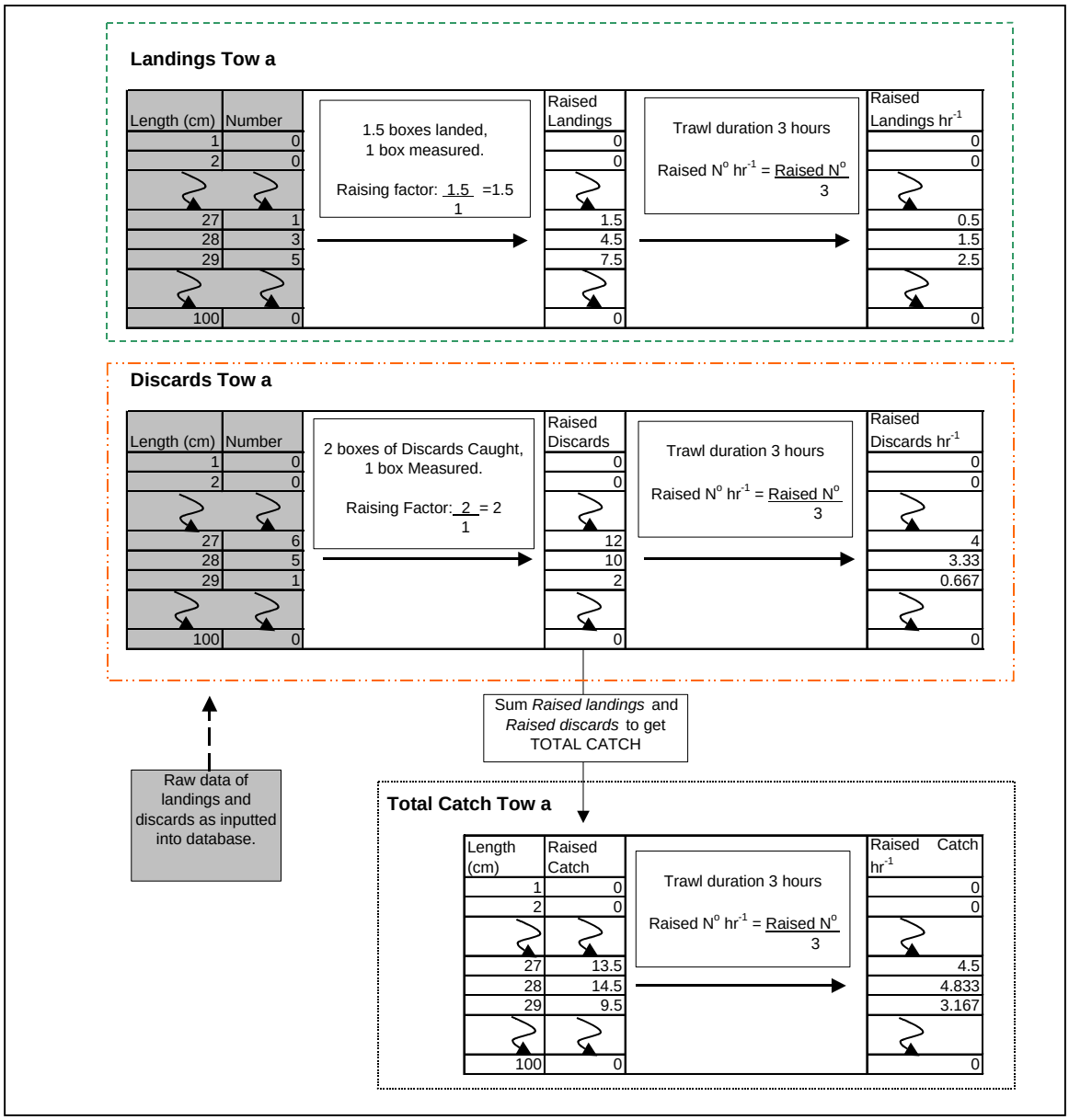


Figure 5.1.1: Showing processes involved in calculating total catch per hour for each tow.

5.2 Graphs

5.2.1 Boxplots

These were generated using S-PLUS 6.0 (Licensed to the Marine Institute).
The plots (appendix D) represent the distribution of total raised numbers per hour for each tow in a particular trial, to normalise the data to some extent and allow better interpretation the data all values were log transformed (Ln(n+1)). The black circle in each box is the median. The extremes, the extent of the box marks the quartiles, and the whiskers delineate the range of the data and the shaded areas show the 95% confidence intervals. Outliers are represented by separate circular marks beyond the whiskers. For each of the species measured the catch from each net used in a particular trial are presented alongside one another. When comparing the same species from the different nets it can be inferred that when the 95% confidence intervals of the two boxes do not overlap then there is likely to be a significant difference between the numbers caught by the nets in question (Anon 2001b).

5.2.2 Length Profile Graphs

Data was presented as line graphs of average catch per hour at length (Appendix E). The line might more accurately be a frequency histogram but in similar studies this type of data is presented in this manner (e.g. Madsen 1999,Lowry 1995). The lines represent a linearised catch curve of the average raised number of fish per hour in each length category.

They can be used to compare the selectivity of each of the nets under investigation in each trial. On each graph vertical lines indicate the minimum landing size and value categories for each species. These value categories are given in table 5.2.2.1.

Table 5.2.2.1: Showing Value categories. Prices and size ranges based on legal minimum sizes and value categories. (pers. comm. Iasc Ui Mhathuna 11/03/03)

		Discards	Category 1	Category 2	Category 3	Notes
Dab	Length	<30				Dab very rarely landed,
	Weight					No Value given
	Value	€ 0.00				
Black Sole	Length	<24cm	24=28 cm	28=33 cm	>33 cm	
	Weight		200g	200-400g	>400g	
	Value	€ 0.00	€ 5.50	€ 7.00	€ 10.00	
Haddock	Length	<30	30=48 cm	>48cm		Separated into round and gutted,
	Weight		Round	Gutted		Fish over about 500g are gutted
	Value	€ 0.00	€ 1.40	€ 1.60		
Megrim	Length	<20 cm	20=25 cm	25=30 cm	>30 cm	No value categories given,
	Weight					CSO* gives average value in 2001
	Value					as €2.37/kg
Plaice	Length	<24cm	24=48 cm	>48 cm		Large plaice given as "about1kg"
	Weight		Small	Large		
	Value	€ 0.00	€ 2.00	€ 3.00		
Whiting	Length	<27 cm	27=39 cm	>39cm		Separated into round and gutted,
	Weight		Round	Gutted		Lengths estimated from personal
	Value	€ 0.00	€ 0.60	€ 1.25		experience

*Price for megrim from Fishery statistics 2001, (Anon, 2002).

5.2.3 Relative Catch.

For the parallel tows plots were made showing the proportion of fish retained in the experimental net for each cm length category. Where:

$$\text{Proportion of fish in experimental cod-end} = \frac{\text{Number of fish in exp net}}{\text{Total number of fish in both nets.}}$$

If the two nets had the same selectivity one would expect the same number of fish of each length to be retained in each net. In this case the proportion would all be around 0.5. If however the experimental net was letting out smaller fish than the standard net then there would be a change from 0 retention of smaller fish to 0.5 retention of larger fish. To allow easier interpretation of trends in selectivity with changing length, the length classes were filtered with a weighted 5cm moving average that was plotted onto the graph. This was calculated using the following formula:

$$\text{Weighted moving average for length L} = ((n_{L-2}+2n_{L-1}+3n_L+2n_{L+1}+n_{L+2})/9)$$

Where n_L is the number of fish at length L: and
$n_{(L+1)}$ is the number of fish at length L+1.

This method does not give a true estimate of selectivity due to the fact that the control cod-ends are too large. It is however useful in giving a comparison of how the catch retained in the nets within each separate trial varies with length.

5.2.4 Estimation of Selection Ogive from Catch Curves.

An estimation of the selection ogive for a net may be made by extrapolation from the catch curve (Sparre and Venema, 1992). If an assumption is made that the total mortality rate, Z is the same for fish of all lengths then a comparison can be made between what is caught in the net and the expected population.

Sparre describes this method, but it is emphasised that results obtained should be treated with reservation. It is briefly included here because it is a tool that has been used to estimate L_{50} (the length at which a fish has a 50% chance of escaping through the mesh of a net) in trials such as this one where no use was made of small mesh covers or cod ends.

The first stage in this process is to use the Von Bertalanffy equation (below)

$$L(t)= L_8 (1-e^{-K(t-t_\circ)})$$

Where: L_8 is the theoretical maximum length of the fish,
t_0 is the age at which the fish would have a length of zero,
K is a growth parameter.

Taking age length data (provided by the Marine Institute) and assuming a t_0 of zero the Excel "solver" function can be used to find the values of L_8 and K for the population.

The values of L_8 and K are then used in converting the length based catch curve to an age based catch curve. The portion of this curve representing fully recruited fish will be a reflection of the total population and should be a straight line; this can be used to calculate the mortality rate for the population. This is then used to calculate the expected population of fish for all lengths.

The lower portion of the age based catch curve represents fish not yet fully recruited, this actual catch can be transformed and then by a linear regression compared with the expected population for these age classes which has been calculated using the mortality rate. The difference between the expected population and the catch will represent the selectivity of the net and can be used to generate a selection ogive and selection parameters such as L_{50} for the net. Ogives and L_{50}s from nets used in a particular trial can then be compared. The length profile graphs (section 5.2.2) were used in this process. The data to calculate L_8 and K for the population was provided by the Marine Institute. It must be noted however that because this method relies on the unproven assumption that Z is the same for fish of all length classes the results should be treated with a certain degree of reservation. These results are presented in 6.2.3.

5.3 Statistical Tests:

5.3.1 Tests on Numbers:

5.3.1.1 Mann-Whitney tests

Tests were undertaken to compare the mean number of fish in values categories between the standard and experimental nets. Due to the lack of normality for many of the datasets the Mann-Whitney test, the non-parametric equivalent of the two-sample t-test was used. These tests were all performed using SPSS V11.0.

Mann-Whitney tests were used to determine whether there were significant differences in the number of fish in various categories between the experimental and standard net for each of the following:

1. Caught
2. Landed
3. Discarded
4. In length categories based on value.

Results of the analysis were presented in a table; the values in the table express the catch in the TCM net as a percentage of the catch in the standard net. Cases where Mann-Whitney tests have shown this difference to be significant have been highlighted. The level of significance denoted by asterisks, (* for a =0.05; ** for a =0.01; *** for a =0.001).

5.3.1.2 Chi^2 tests.

Chi^2 tests were used to examine the numbers of fish in each category. In excel the observed average raised numbers of fish in each category for the two nets were compared with the expected values. To do this a contingency table of expected values was constructed, the expected value in each cell being the total for the row multiplied by the total for the column divided by the grand total for the table. The expected and observed values were then compared and the probability (a) of the chi^2 value was then calculated, an a value below 0.05 was considered significant. The null hypothesis is that there is no association between the numbers of fish in each category and net type. The process is summarised in Table 5.3.1.1.

Table 5.3.1.1 Showing process of construction of contingency table for chi^2 test. (OTB=Standard otterboard trawl net. TCM= Net With Technical Conservation Measure incorporated)

Observed

Numbers	OTB	TCM
	Deux Orchidees	Floralie
Discards	a	b
Category 1	c	d

Expected

Numbers	OTB	TCM
	Deux Orchidees	Floralie
Discards (<24cm)	(a+b) x (a+c)/ (a+b+c+d)	(a+b) x (b+d)/ (a+b+c+d)
Cat 1 (25-27 cm)	(c+d) x (a+c)/ (a+b+c+d)	(c+d) x (b+d)/ (a+b+c+d)

So For Black Sole :

Observed

Numbers	OTB	TCM
Black sole	Deux Orchidees	Floralie
Discards (<24cm)	0.835	0.063
Cat 1 (25-27 cm)	9.219	0.521
Cat 2 (28-33cm)	9.270	2.875
Cat 3 (>33 cm)	1.219	1.458

Expected

Numbers	OTB	TCM
Black sole	Deux Orchidees	Floralie
Discards (<24cm)	0.725	0.173
Cat 1 (25-27 cm)	7.859	1.881
Cat 2 (28-33cm)	9.799	2.345
Cat 3 (>33 cm)	2.160	0.517

Probability of CHI^2 Value	0.311

5.3.2 Tests on proportions

Mann-Whitney tests were carried out comparing the proportions of fish present in various categories between the standard and experimental nets for:

1. Discards
2. Fish in length categories based on value.

In the case of discards this is a test of the difference in discard rate between net types.

Results of the analysis were presented in a table; the values in the table express the proportion of the catch in each category in the experimental net as a percentage of the proportion of the catch in same category in the standard net. (For instance if the discard rate in the experimental net was half that in the standard net the figure in the table would be 50%). Mann-Whitney tests were used to determine whether there were significant differences in the proportion of the catch in various categories between the experimental and standard net. Cases where Mann-Whitney tests have shown this difference to be significant have been highlighted. The level of significance is denoted by asterisks, (* for a =0.05; ** for a =0.01; *** for a =0.001).

5.3.3 Principal Component Analysis

To try to interpret interactions between catches of species measured principal component analysis (PCA) biplots were generated in S-Plus 6.0. Principal component analysis is useful for investigating variance within large datasets by considering a smaller number of linear combinations of the original data (Anon 2001a). The variance is explained by a set of linear components, the principal components. By looking at those components which explain most of the variance within the original data it is possible to see relationships within the observed dataset, this is done using the PCA biplot. The original variables and transformed observations are plotted on axes where the x-axis represents the scores for the most important (in terms of explaining variance) principal component and the y-axis the scores for the second most important principal component. The original data are represented as vectors, the length of which indicates the amount of variance explained by the two principal components and the direction showing whether there is a positive or negative relationship between the data and the components. The angle between variables indicates the nature of the relationship between them, acute angles indicating a positive relationship, obtuse ones a negative relationship. The numbers plotted on the biplot correspond to the original hauls the variables are taken from. Relationships between hauls may be seen as clusters or patterns of these numbers.

PCA analysis was carried out for parallel tows on total catches for the species measured to try and identify relationships between the catches on each boat.

5.3.4 Bootstrapping

Bootstrapping (Efron and Tibshirani (1993) in Millar and Fryer (1998)) was used to generate a bootstrap mean with 95% confidence intervals around data points. As mentioned earlier much of the data is not normal, and the numbers of replicates for each trial are very low. The advantage of the bootstrapping process is that it can produce confidence intervals that would be obtained if the data were normalized.

For each length class random sampling from the original data points generated two thousand bootstrap samples. The bootstrapped mean is the mean of the 2000 samples, the samples were then sorted low to high, the 50^{th} and 1950^{th} values were the 95% confidence limits of the bootstrapped mean. These mean and percentile confidence limits were then plotted graphically for each length class. These graphs give an informal indication of the reliability of the data in question. Where the 95% confidence limits from two nets under investigation do not overlap it can be inferred that there is a significant difference between the mean numbers retained for that length class.

Bootstrapping was applied to both the length distribution data and the relative catch data. The process is time consuming and involved. It was applied to selected data sets where significance was seen.

5.4 Immediate Economic Impact of Technical Conservation Measures.

To give an indication of the scale of the immediate economic impact of using the various experimental nets it was necessary to convert the data from numbers of fish caught at length to the value of the fish in the catch. The weight in grams for each length was calculated from the length in cm by using the formula:

$$\text{Weight} = \exp(a) + \text{length}^{b}$$

Where a and b are constants found by linear regression of log transformed length and weight data. For this study the values for a and b were taken from the Marine Institute's discard database and are summarized in Figure 5.4.1.

Figure 5.4.1 summarizing the values of a and b used for converting length to weight.

Constant	Black sole	Haddock	Megrim	Plaice	Whiting
a	-6.0232	-5.4387	-5.4655	-4.43282	-5.8097
b	3.4163	3.2329	3.1287	2.9294	3.2852

The mass of fish at each length was found by multiplying numbers at length by weight at length. The value of the catch in each value category were found by summing the masses at length within the category by then multiplying by the value per kg (Table 5.2.2.1).

The values calculated in this way are a guideline only, showing the value of the catch in terms of the named species over the period of the particular trial.

5.5 Discard rates

These were calculated in terms of both numbers and mass using the following formula:

$$\text{Discard rate} = (\text{Discards}/\text{Catch}) \times 100$$

In this case the discards were what were actually discarded, rather than just the fish below minimum size. The rate was calculated for the standard nets, for those with 100mm codends, and those with 80mm square mesh panels over the entire sampling period.

6 Results

During the project a total of 57 fishing days were completed, 153 tows were analysed and over 100,000 fish were measured.

The results are discussed in terms of the catch in the experimental net compared with the standard net.

The results from the statistical analyses and the financial implications of using the experimental nets are presented separately in the format described below, the list of tables and figures is set out in Table 6.1. Only figures where statistically significant results occurred are presented in the results section. Figures where no significant results were found appear in appendices D to F. As mentioned in section 4.6 the trials are numbered: in the first year from pairing 11 to pairing 16, and in the second from 1 to 8.

Table 6.1 Summary of Tables and Figures presented in results section.

Year	Pairing	Boat / Boats	Experimental net	Statistical Analysis	
				Tables	Figures
1	11	Maid Of Nazareth	80mm Square Mesh	6.1.1.1 6.1.1.2	6.1.1.1 6.1.1.2
1	12	Floralie	90mm Square mesh	6.1.2.1 6.1.2.2	6.1.2.1 to 6.1.2.3
1	13	Gerlisa	100mm Cod-end	6.1.3.1 6.1.3.2	6.1.3.1 to 6.1.3.4
1	14	Elsie Marie	Separator Trawl	6.1.4.1 6.1.4.2	6.1.4.1 to 6.1.4.4
1	15	Naomh Deararca	Large Mesh coversheet	6.1.5.1 6.1.5.2	6.1.5.1
1	16	Deux Orchidees	100mm Cod-end	6.1.6.1 6.1.6.2	
2	1	Floralie / D.Orchidees	100mm Cod-end	6.2.1.1 6.2.1.2	
2	2	Floralie / D.Orchidees	100mm Cod-end	6.2.1.3 6.2.1.4	6.2.1.1 to 6.2.1.5
2	3	Floralie / D.Orchidees	100mm Cod-end	6.2.1.5 6.2.1.6	6.2.1.6 to 6.2.1.9
2	4	Maid.of.Naz./ Elsie Marie	80mm Square Mesh	6.2.2.1 6.2.2.2	6.2.2.1 to 6.2.2.2
2	5	Maid.of.Naz./ Elsie Marie	80mm Square Mesh	6.2.2.3 6.2.2.4	6.2.2.3 to 6.2.2.6
2	6	Maid.of.Naz./ Elsie Marie	80mm Square Mesh	6.2.2.5 6.2.2.6	6.2.2.7 to 6.2.2.10
2	7	Naomh Deararca	100mm Cod-end	6.2.3.1 6.2.3.2	6.2.3.1 to 6.2.3.3
2	8	Gerlisa	90mm Cod-end	6.2.4.1 6.2.4.2	6.2.4.1 to 6.2.4.3

For each trial tables of results of Mann Whitney tests on numbers and proportions of fish in various length categories are presented. Where percentages do not appear in cells it is because there is no category for that species (as indicated in table 6.2); that the calculated percentage is an imaginary number (eg. 0/10); or that no fish in those categories were caught in that particular trial. The percentage figures that appear in the tables represent the catch in that length category expressed as a percentage of the same category in the standard net. So if the figure appearing a cell in the table was 20% it would indicate that for every 100 fish caught in the standard net 20 were caught in the experimental net.

Table 6.2 Shaded boxes indicate where there is no size category for a particular species; these boxes will always be empty.

Species	Proportions			
	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole				
Dab				
Haddock				
Megrim				
Plaice				
Whiting				

Where statistical significance was found using Mann Whitney tests, length profile graphs are presented. On these the bootstrapped mean numbers of fish for each 1cm length category are presented along with the 95% confidence intervals (95%CI). Where the 95% CI of the two nets do not overlap a significant difference can be inferred such as occurs below (Figure 6.1) in the lengths between 15cm and 19 cm

Where significance was observed over several size categories graphs of catch comparison are shown (Figure 6.2). These indicate graphically the nature of the differences in selectivity between the two nets in question. Where there is a difference in L_{50} between nets one would expect a sigmoid curve rising from 0 in the smaller lengths, where none of the catch is being retained in the TCM (i.e. where the two nets are selecting differently) net to 0.5 where the catch in the two nets was the same. The moving average shows this trend. Also shown is a moving average of the 95% CI.

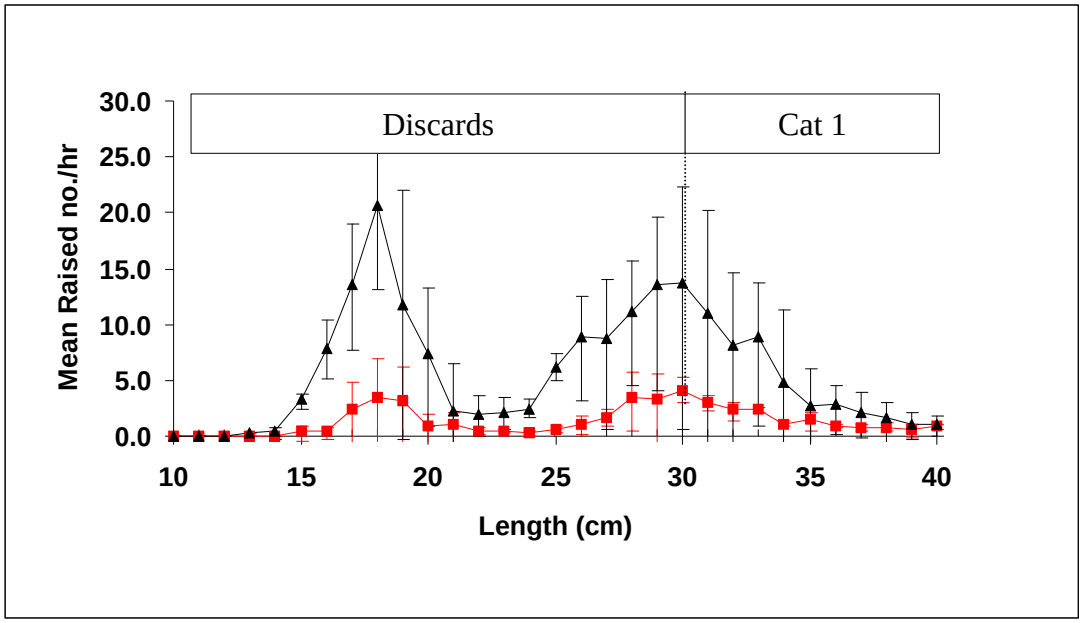


Figure 6.1 Length profile graph for catch in two different nets indicated by different coloured lines. Bars indicate 95%CI.

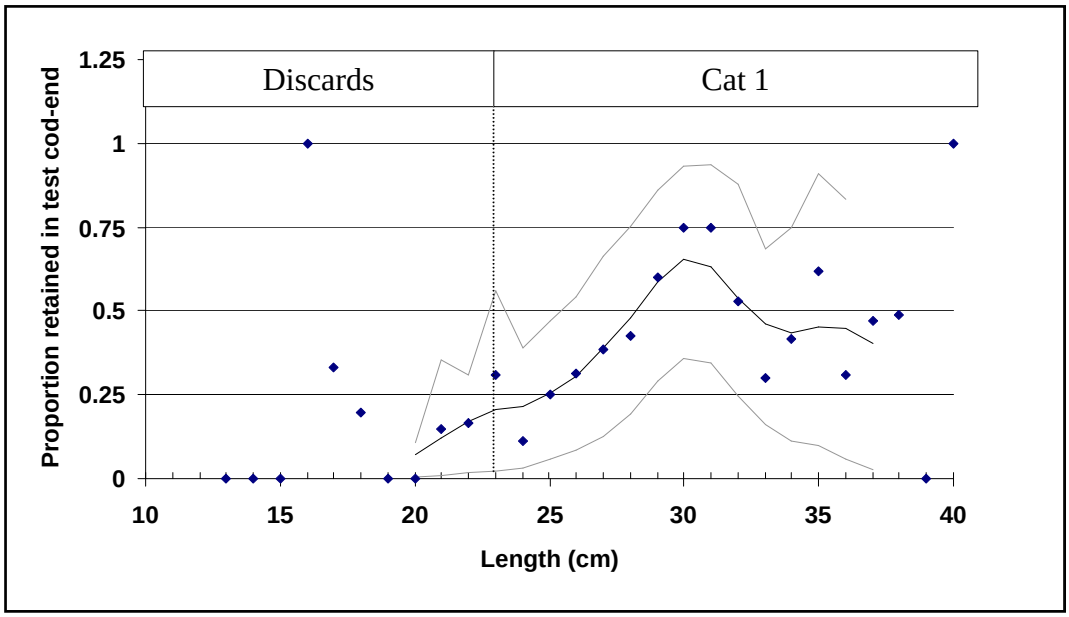


Figure 6.2 Catch comparison for catch retained in two nets, Points indicate bootstrapped mean of proportion retained in test cod-end, dark line indicates the moving average of these points, light lines indicate moving average of 95% CI.

6.1 Year 1.

6.1.1 Pairing 11: Effect of using 80mm square mesh panel.

Alternate Hauls: Maid Of Nazareth, standard net
Maid Of Nazareth 80mm square mesh panel. - Experimental net

Nineteen tows were conducted in this trial, seven with the standard net and 12 with the experimental net. Box-plots show that catches for all species were very similar, Mann-Whitney tests show a reduction in the discard numbers (Table 6.1.1.1) and discard rate (Table 6.1.1.2) of black sole, however Figure 6.1.1.1 shows the number of discards were very low.

Chi^2 tests indicate a change in the length distribution for plaice, it can be seen (Figure 6.1.1.2) that this is probably due to a reduction in numbers of plaice between 17 and 20cm, this is not picked up by the Mann-Whitney tests. It would have been expected that plaice would stay low in the water column (Cotter, 1997) and therefore been unaffected by the panel.

It can also be seen that the confidence intervals for much of the lengths are very wide. The general impression from the line profile graphs is that there is also reduction in the catch of black sole, megrim, whiting and dab. The overall landings were similar for both nets, with a small decrease of 6% in value.

Table 6.1.1.1 Summary of Mann-Whitney tests performed on catch data from pairing 11, the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	84%	101%	*9%	37%	159%	840%
Dab	56%	62%				
Haddock	85%	101%	80%	100%	183%	
Megrim	45%	45%	55%	14%	57%	87%
Plaice	85%	137%	57%	137%		
Whiting	32%	28%	53%	28%	48%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.1.1.2 Summary of Mann-Whitney tests performed on catch data from pairing 11; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

Species	Proportions			
	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole	*4%	63%	261%	*2102%
Dab				
Haddock	88%	136%	300%	
Megrim	716%	103%	123%	68%
Plaice	87%	112%		
Whiting	118%	92%	202%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

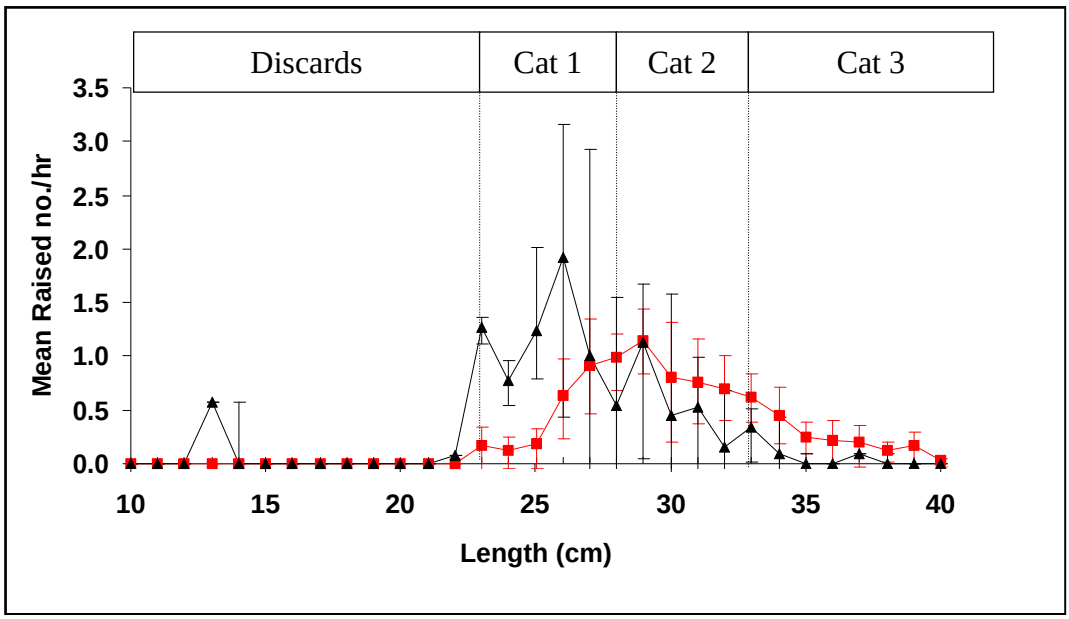


Figure 6.1.1.1 Comparison of length distribution for **Black Sole** for pairing 11; catch from experimental net in red (3 hauls); catch standard net in black (7 hauls). Also shown are 95-percentile ranges.

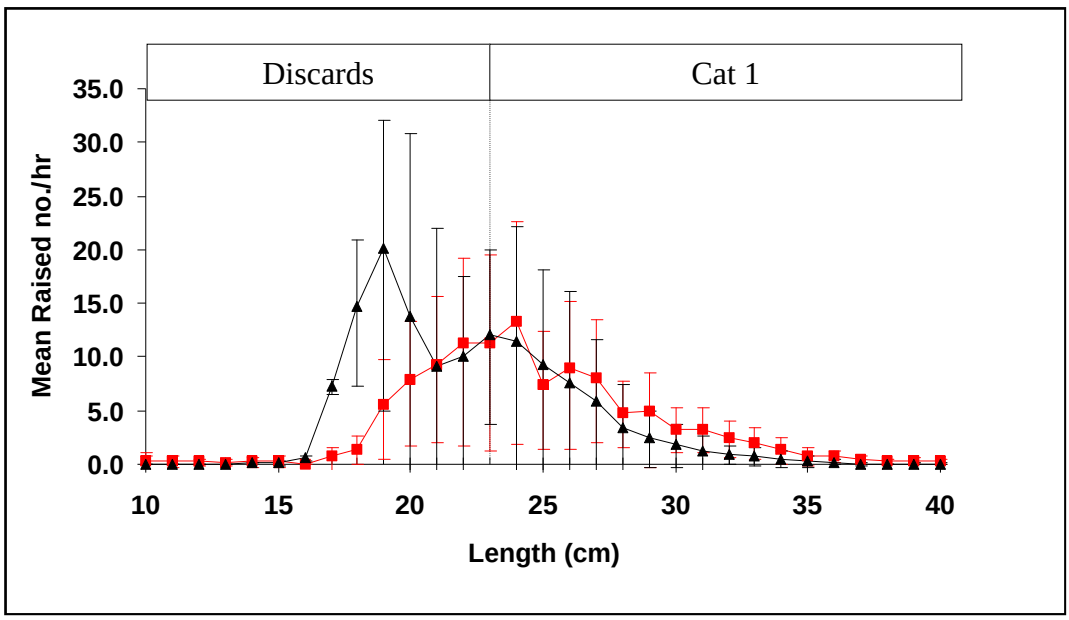


Figure 6.1.1.2. Comparison of length distribution for **Plaice** for pairing 11; catch from experimental net in red (12 hauls); catch standard net in black (6 hauls). Also shown are 95-percentile ranges.

6.1.2 Pairing 12: Effect of using 90mm square mesh panel.

Alternate Hauls: Floralie, standard net

Floralie, 90mm square mesh panel. Experimental net

Twenty valid tows were undertaken in this trial, 12 with the experimental net and 8 with the standard net. Box-plots of total number of fish caught show similar numbers of fish were caught with the two nets. Mann-Whitney tests however indicate an increase in catch and landings of whiting in the experimental net (Table 6.1.2.1). This can also be seen on the length distribution graph (Figure 6.1.2.1). Whiting would be expected to be one of the species most likely to escape through square mesh panels (Madsen et. al., 1999a). There seems to be little evidence in this case that the increase in numbers was related to length. The catch of whiting in the standard net was low when compared to trials on other boats so the observed effect may be due to towing at different times and therefore through different populations of fish.

Mann-Whitney tests on proportion of fish in length categories (Table 6.1.2.2) indicate a change in the length distribution of megrim. From the length distribution graph (Figure 6.1.2.2) it can be seen that this is probably due to a

slight increase in numbers of fish between 25 and 28 cm in the experimental net coupled with a slight decrease in numbers of fish between 27 and 33cm, but the confidence intervals on the graph are very wide for much of the two distributions. Length profile graphs indicate slight decrease in discards of dab and a slight reduction in the numbers of plaice of all lengths. Overall there seems to be little change in the catches between the two nets. In terms of income there was an increase of €7.30 in the value of whiting caught per hour in the experimental net as compared with the standard net (figure 6.1.2.3).

Table 6.1.2.1 Summary of Mann-Whitney tests performed on catch data from pairing 12; the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole				100%		
Dab	48%	162%				
Haddock	77%	63%	91%	63%	0%	
Megrim	107%	107%	112%	126%	147%	63%
Plaice	59%	62%	54%	62%		
Whiting	*289%	*277%	394%	*278%	181%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.1.2.2 Summary of Mann-Whitney tests performed on catch data from pairing 12; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole		100%		
Dab				
Haddock	129%	77%	0%	
Megrim	250%	219%	*200%	*31%
Plaice	57%	129%		
Whiting	80%	107%	54%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

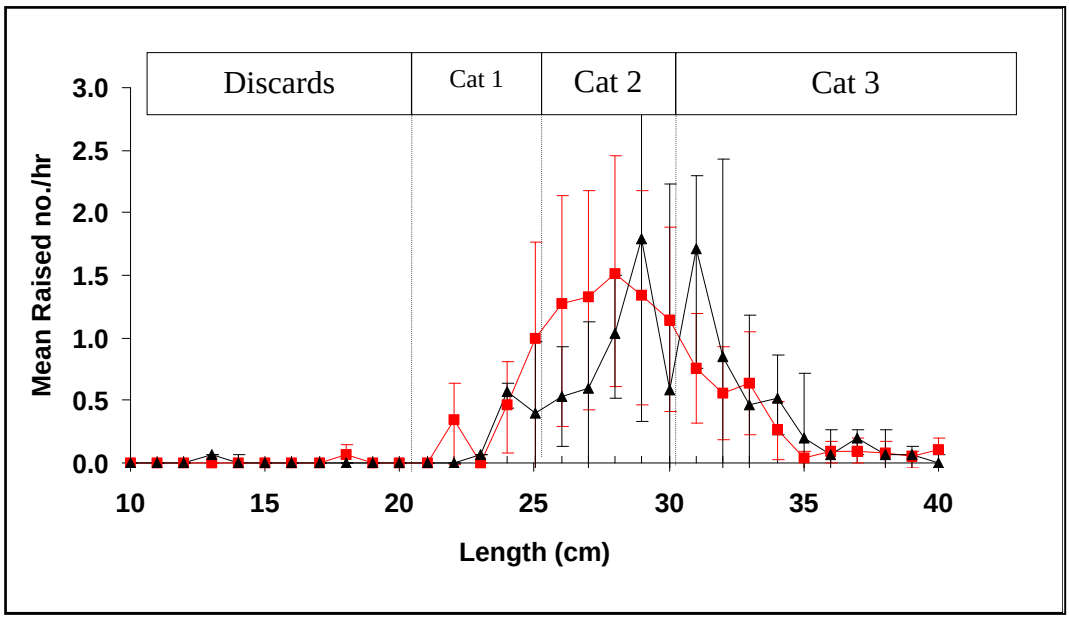


Figure 6.1.2.1 Comparison of length distribution for **Whiting** for pairing 12; catch from experimental net in red (11 hauls); catch standard net in black (8 hauls). Also shown are 95-percentile ranges.

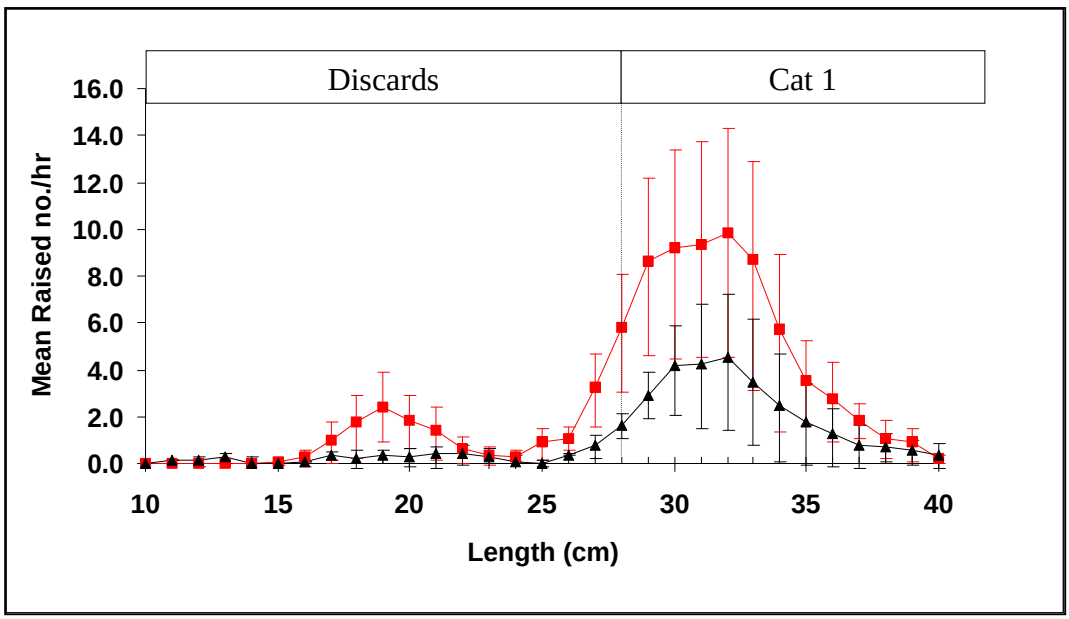


Figure 6.1.2.2 Comparison of length distribution for **Megrim** for pairing 12; catch from experimental net in red (6 hauls); catch standard net in black (4 hauls). Also shown are 95-percentile ranges.

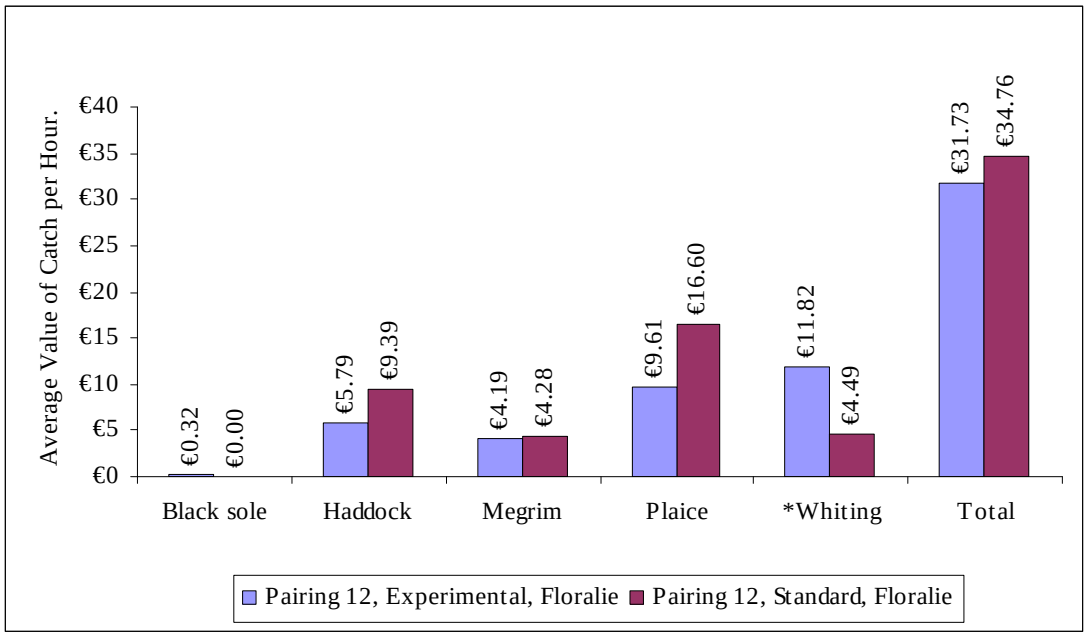


Figure 6.1.2.3; Mean value of measured landings using two net types for pairing 12. Asterisks indicate cases where a significant difference in numbers of landings was found: * for a =0.05; ** for a =0.01; *** for a =0.001.

6.1.3 Pairing 13: Effect of using 100mm cod-end.

Alternate Hauls:	Gerlisa, 80mm cod-end, Standard net
	Gerlisa, 100mm cod-end. Experimental net

Thirteen tows were undertaken in this trial, 5 with the experimental net and 8 with the standard net. Box-plots show that there were decreases in the numbers of dab, haddock and megrim caught by the experimental net. Mann-Whitney tests show that the difference was significant for haddock and megrim. A significant reduction of haddock discards can be seen; the length profile graph (Figure 6.1.3.1) shows this clearly. It can also be seen that the mean catch of larger haddock is reduced, but due to wide confidence intervals no significance can be attached to this. Figure 6.1.3.2 shows an almost complete absence of megrim in the experimental net; this is reflected in the Mann-Whitney tests on numbers (Table 6.1.3.1). Figure 6.1.3.3. shows the length profile for whiting shows that there is a reduction in discards and small legal sized fish but that the catches of larger fish of over around 35cm are very similar. Data for black sole was not recorded for this pairing due to factors beyond the control of the author.

The decrease in the numbers of megrim being landed equated to a loss of around €18 per hour (Figure 6.1.3.4).

In summary it appears that the experimental net on this boat led to a reduction in the numbers of discards of megrim, haddock and whiting, but that this was accompanied by a large reduction in the overall catch. The results are consistent with those expected due to an increase in mesh size. The 40% reduction in value of landings was very high.

Table 6.1.3.1 Summary of Mann-Whitney tests performed on catch data from pairing 13; the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole						
Dab	43%	0%				
Haddock	*26%	36%	*21%	36%	0%	
Megrim	**6%	**6%	43%	**3%	**2%	*23%
Plaice	79%	83%	61%	83%		
Whiting	48%	60%	**11%	61%	39%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.1.3.2 Summary of Mann-Whitney tests performed on catch data from pairing 13; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole				
Dab				
Haddock	*58%	*194%	0%	
Megrim	463%	36%	**37%	418%
Plaice	153%	92%		
Whiting	44%	116%	184%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

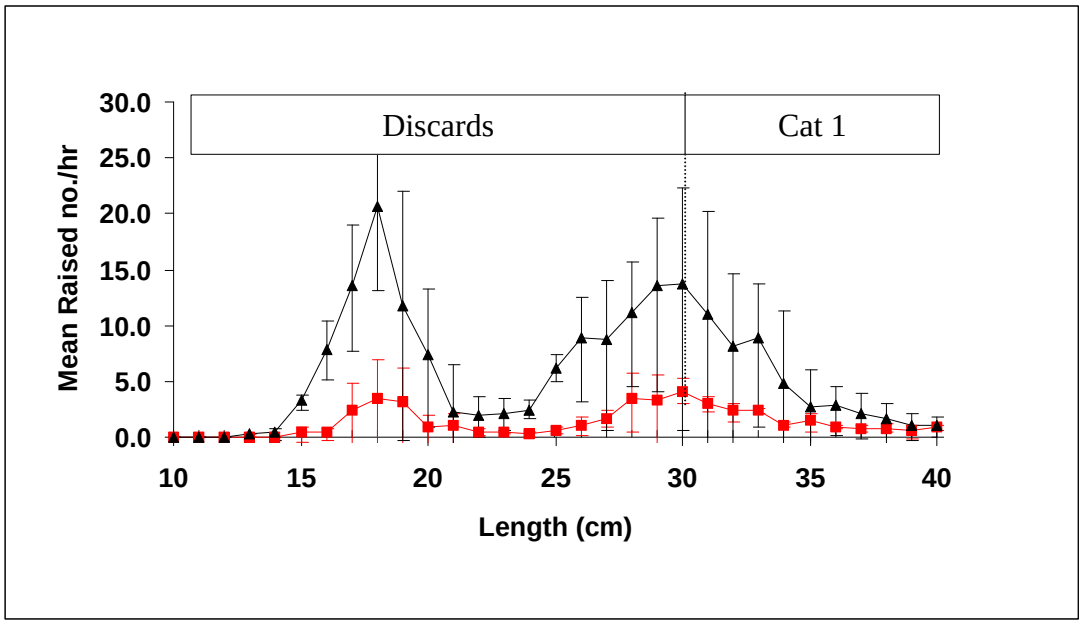


Figure 6.1.3.1 Comparison of length distribution for **Haddock** for pairing 13; catch from experimental net in red (5 hauls); catch standard net in black (8 hauls). Also shown are 95-percentile ranges.

Figure 6.1.3.2 Comparison of length distribution for **Megrim** for pairing 13; catch from experimental net in red (5 hauls); catch standard net in black (8 hauls). Also shown are 95-percentile ranges.

Figure 6.1.3.3 Comparison of length distribution for **Whiting** for pairing 13; catch from experimental net in red (5 hauls); catch standard net in black (8 hauls). Also shown are 95-percentile ranges.

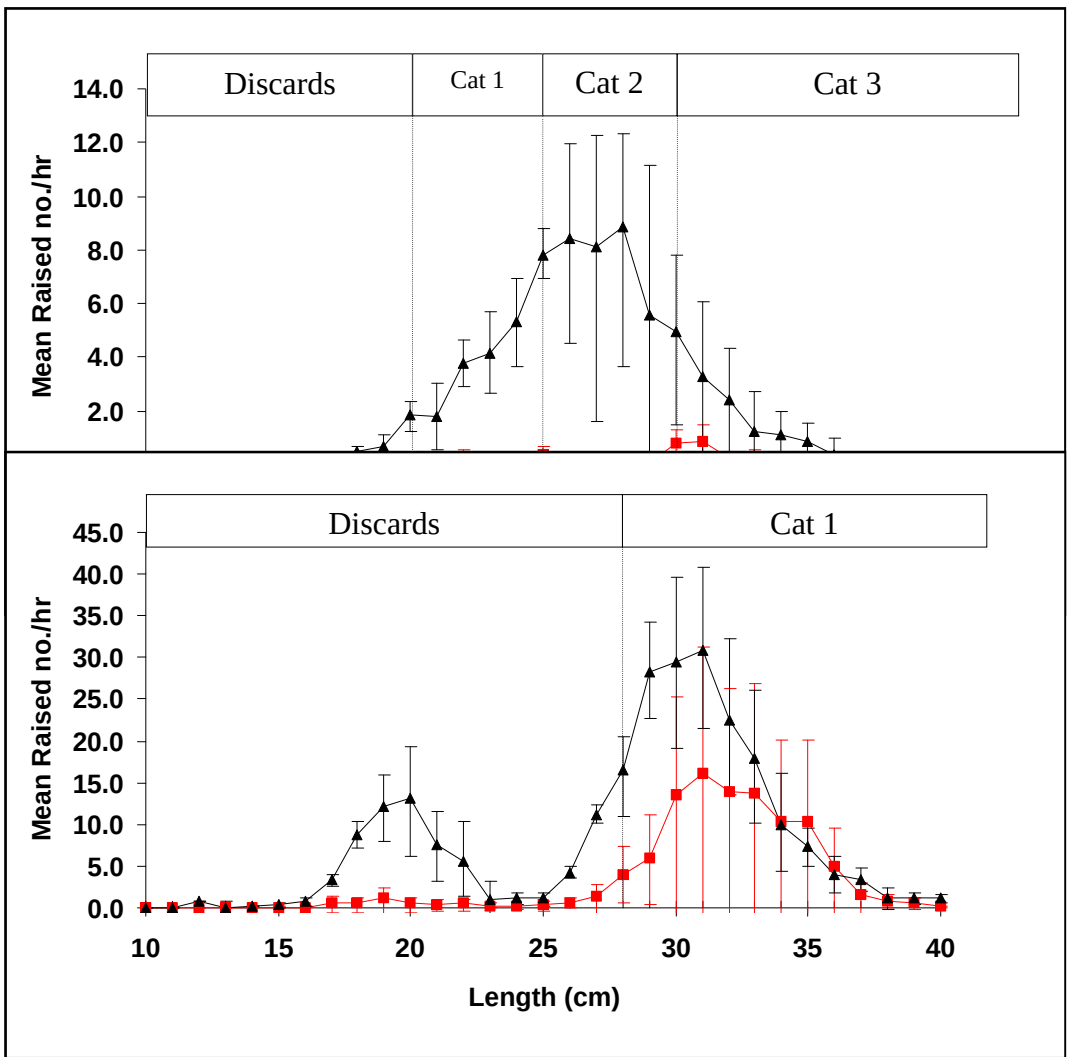
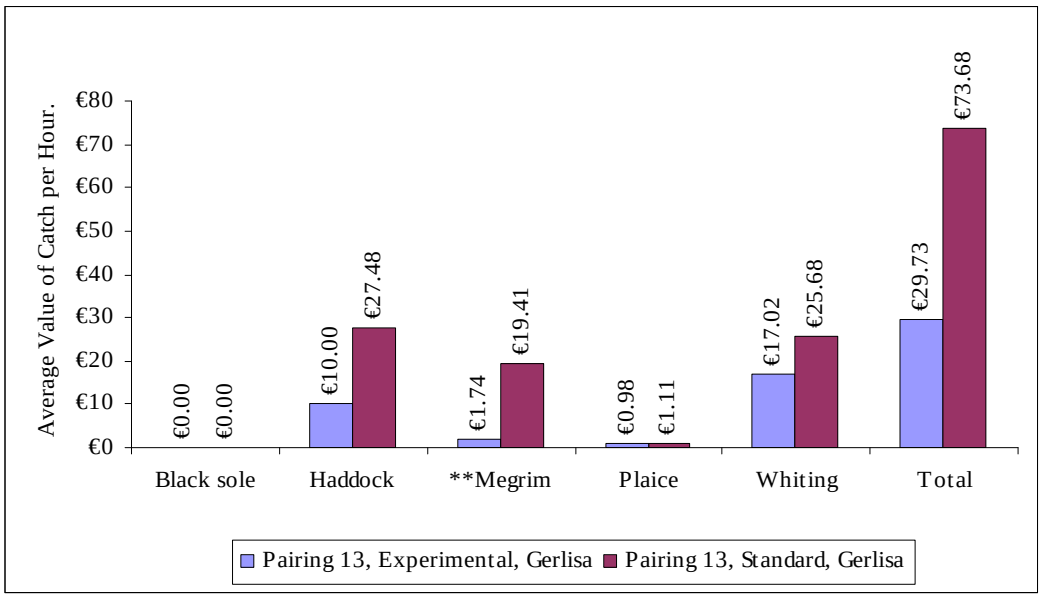


Figure 6.1.3.4; Mean value of measured landings using two net types for pairing 13. Asterisks indicate cases where a significant difference in numbers of landings was found: * for a =0.05; ** for a =0.01; *** for a =0.001.



6.1.4 Pairing 14: Effect of using Separator trawl.

Alternate Hauls: Elsie Marie, 80mm cod-end standard net
Elsie Marie, Separator Trawl. Experimental net.

Twelve valid tows were completed for this trial, 7 with the experimental net and 4 with the standard net. Box-plots and Mann-Whitney (Table 6.1.4.1) tests show that the numbers of dab, plaice and sole caught in the experimental net were lower than those caught in the standard net. This can also be seen in figures 6.1.4.1 and 6.1.4.2, box-plots also show an increase in megrim caught using the experimental net but Mann-Whitney tests do not attach any significance to this. There was a significant change in the length distribution for black sole as can be seen in Table 6.1.4.2. The catch in the experimental net was very low for all lengths, this corresponded to a decrease in value of the catch of black sole of around €35 per hour (Figure 6.1.4.4). The length profile graph for whiting shows a large increase in the number and size range of whiting caught in the experimental net (Figure 6.1.4.3).

In summary it can be seen that the experimental net caught fewer black sole, dab and plaice than the standard net, but at the same time caught more megrim and more undersized whiting. The effect on different species varied but the pattern seems to be that catches for flat fish (except megrim) were reduced while catches for round-fish were on the whole similar. This may indicate that the ground rope of the separator trawl was not making adequate ground contact.

Table 6.1.4.1 Summary of Mann-Whitney tests performed on catch data from pairing 14; the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	*14%	*16%	*0%	*8%	25%	58%
Dab	8%		**8%			
Haddock	111%	59%				
Megrim	275%	288%	68%	177%	345%	313%
Plaice	*20%	23%	16%	45%		
Whiting	176%	151%	*277%	148%	2256%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.1.4.2 Summary of Mann-Whitney tests performed on catch data from pairing 14; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole	*0%	*54%	*212%	285%
Dab				
Haddock	103%	88%		
Megrim	74%	216%	166%	34%
Plaice	60%	132%		
Whiting	215%	71%	1209%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

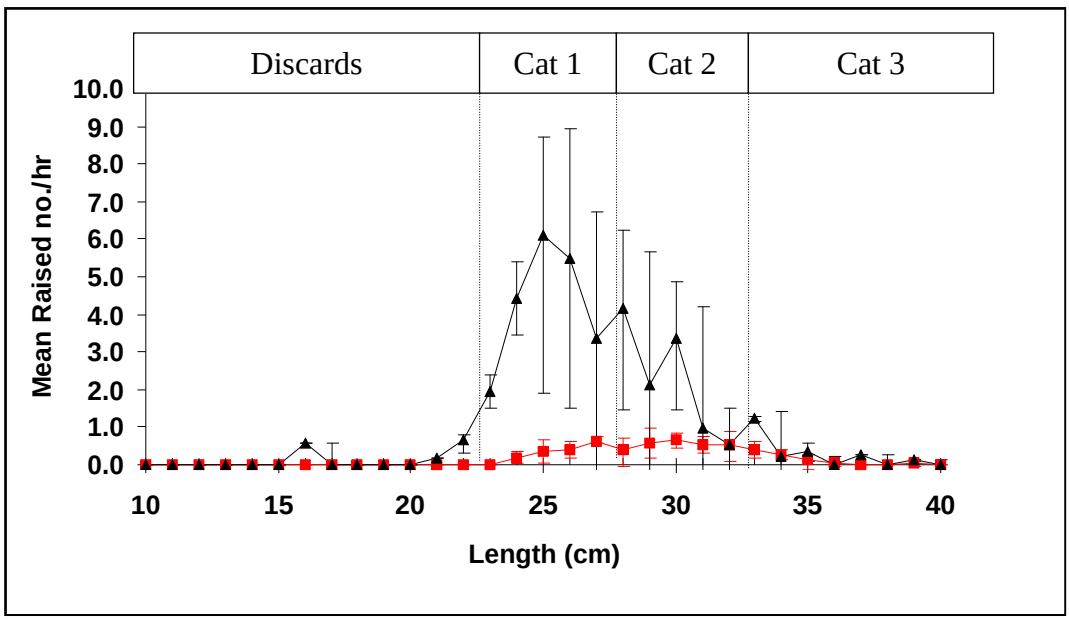


Figure 6.1.4.1 Comparison of length distribution for **Black Sole** for pairing 14; catch from experimental net in red (5 hauls); catch standard net in black (4 hauls). Also shown are 95-percentile ranges.

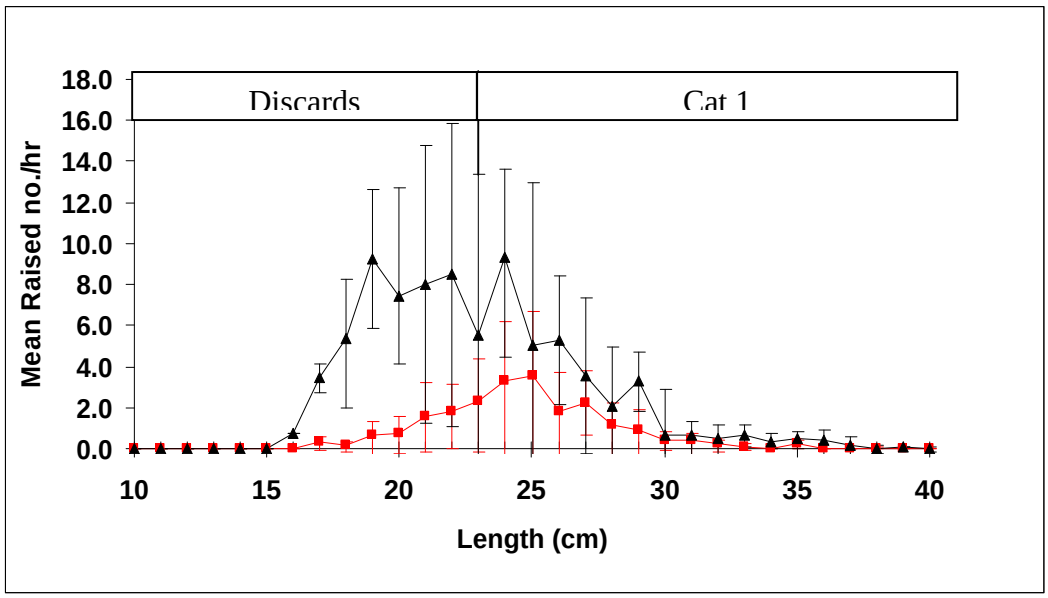


Figure 6.1.4.2 Comparison of length distribution for **Plaice** for pairing 14; catch from experimental net in red (6 hauls); catch standard net in black (4 hauls). Also shown are 95-percentile ranges.

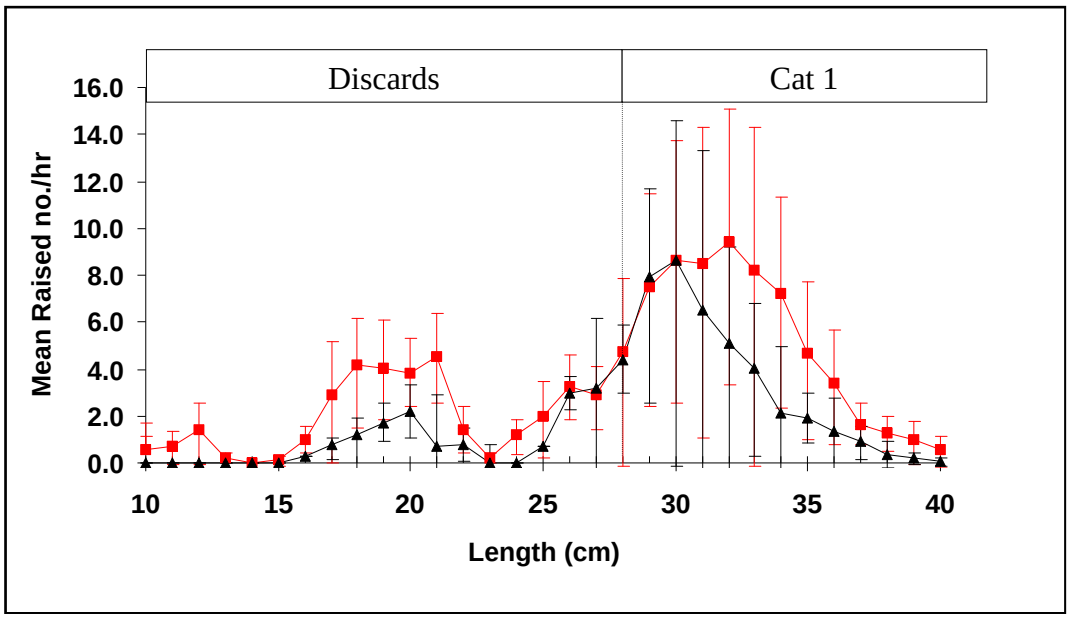


Figure 6.1.4.3 Comparison of length distribution for **Whiting** for pairing 14; catch from experimental net in red (7 hauls); catch standard net in black (4 hauls). Also shown are 95-percentile ranges.

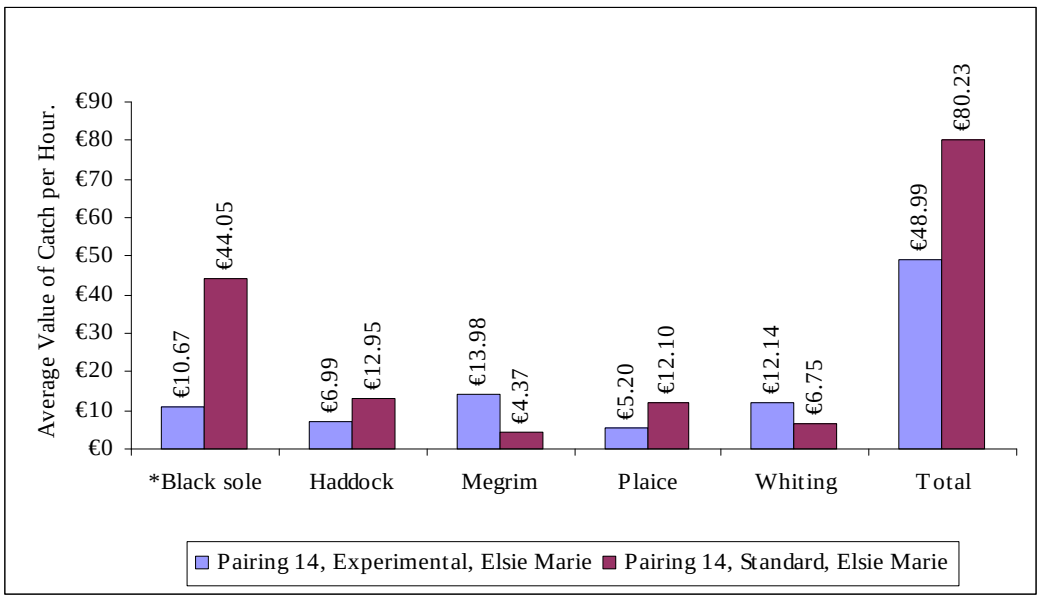


Figure 6.1.4.4; Mean value of measured landings using two net types for pairing 14. Asterisks indicate cases where a significant difference in numbers of landings was found: * for a =0.05; ** for a =0.01; *** for a =0.001.

6.1.5 Pairing 15: Effect of using Larger mesh from cover sheet back.

Alternate Hauls: Naomh Deararca, 80mm cod-end,
Naomh Deararca, 160mm from cover sheet back.

Sixteen tows were undertaken during this trial, eight with each net. Box-plots and Mann-Whitney tests on numbers (Table 6.1.5.1) show little difference in the catch between the two nets. There is however a significant reduction in the number of Black sole discarded from the experimental net. This is seen in Mann-Whitney tests on proportions of fish (Table 6.1.5.1) and in the length profile graph (Figure 6.1.5.1), however since the number of sole in the discards fraction of the catch were very low this effect is of little practical importance.
Looking at the graphs of proportion retained there seems to be some evidence of a decrease in the discards of both plaice and dab though this is not proven to be statistically significant. Overall there was little significant difference in the value of landings between the two nets. In this case there was little evidence that cover mesh size had any effect on the selectivity of the net.

Table 6.1.5.1 Summary of Mann-Whitney tests performed on catch data from pairing 15; the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	60%	71%	**5%	37%	215%	110%
Dab	35%	250%				
Haddock	121%	112%				
Megrim	54%	54%		9%	60%	74%
Plaice	115%	154%	68%	153%		
Whiting	128%	125%	136%	123%	198%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.1.5.2 Summary of Mann-Whitney tests performed on catch data from pairing 15; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

Species	Proportions			
	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole	**3%	60%	**361%	178%
Dab				
Haddock	120%	88%	44%	
Megrim		13%	87%	122%
Plaice	78%	113%		
Whiting	147%	91%	31%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

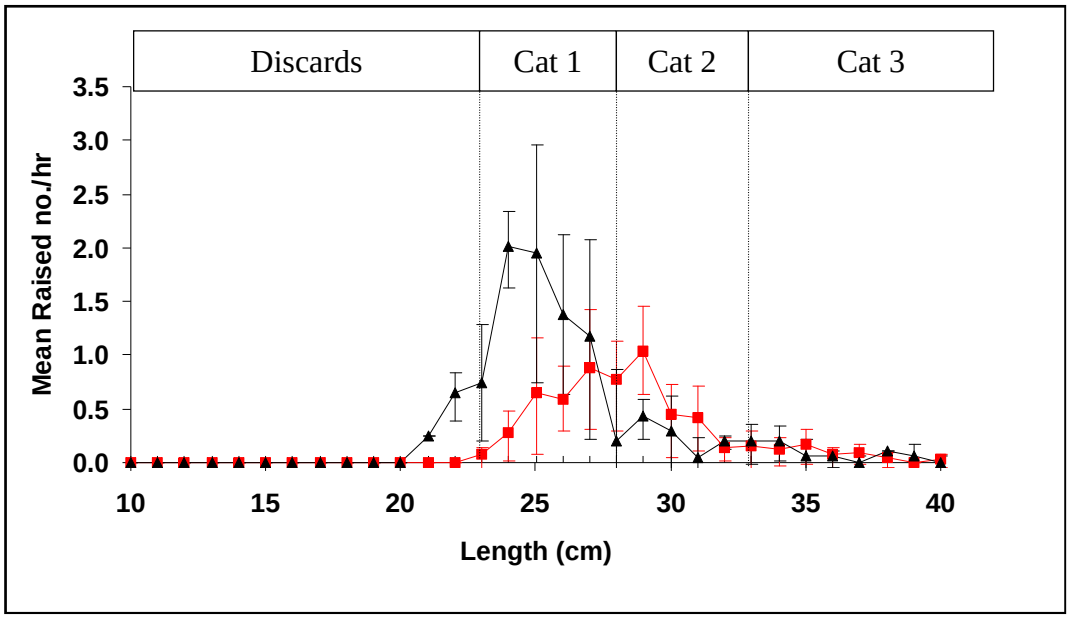


Figure 6.1.5.1 Comparison of length distribution for **Black Sole** for pairing 14; catch from experimental net in red (5 hauls); catch standard net in black (4 hauls). Also shown are 95-percentile ranges.

6.1.6 Pairing 16: Effect of using 100mm cod-end.

Alternate Hauls: Deux Orchidees, 80mm cod-end, Standard net
Deux Orchidees, 100mm from cod-end. Experimental net

Due to operational difficulties only two of the tows with the experimental net and four tows with the standard net were valid. Data from the other tows was discarded. Though it can be seen from the high values in the tables that there were apparently differences in the average numbers of fish retained in the two nets (Figure 6.1.6.2) and in the distributions (Figure 6.1.6.1), due to the small sample size no significant differences were found between the catch for any species in either net. Any conclusions drawn from this trial would be highly speculative.

Table 6.1.6.2 Summary of Mann-Whitney tests performed on catch data from pairing 16; the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole						
Dab	5%					
Haddock	151%	288%				
Megrim	218%	218%		102%	207%	351%
Plaice	2%	3%	0%	3%		
Whiting	228%	1043%	46%	993%		

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.1.6.1 Summary of Mann-Whitney tests performed on catch data from pairing 16; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole				
Dab				
Haddock	57%	210%		
Megrim		44%	122%	147%
Plaice		130%		
Whiting	29%	306%		

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

6.2 Year 2.

6.2.1 Effect of using 100mm cod-end.

The vessels used in this trail were the Floralie and the Deux Orchidees

The experimental method employed was parallel tows. Three gear configurations (pairings) were used:

Pairing 1: Deux Orchidees 100mm cod-end –Experimental net
Floralie 100mm cod-end –Experimental net

Pairing 2 Deux Orchidees 80mm cod-end –Standard net
Floralie 100mm cod-end–Experimental net

Pairing 3 Deux Orchidees 100mm cod-end–Experimental net
Floralie 90mm cod-end. –Standard net

6.2.1.1 Pairing 1:

Parallel Hauls: Deux Orchidees 100mm cod-end – Experimental net
Floralie 100mm cod-end –Experimental net

Six parallel tows were conducted during this trial. Box-plots show all species other than haddock and whiting were being caught in similar numbers. Haddock catches on the Floralie were highly variable, and whiting were only caught in two of the six tows on the Floralie.

Mann-Whitney tests on numbers showed no significant differences between numbers caught.

Length profile graphs show similar distributions of fish being caught. Whiting catches for the Floralie were very low. Mann-Whitney tests are summarised in Table 6.2.1.1 and 6.2.1.2. No significant differences between numbers caught in any of the length categories for any species were found.

Graphs of proportion retained at length show no obvious differences in selectivity between nets. This result is as anticipated and would seem to indicate this method ensures that the two nets are fishing the same populations of fish.

Table 6.2.1.1 Summary of Mann-Whitney tests performed on catch data from pairing 1; the percentages represent the catch in the Floralie's net expressed as a percentage of the catch in the Deux Orchides' net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	125%	125%		62%	159%	94%
Dab	101%	92%				
Haddock	69%	85%	59%	85%	0%	
Megrim	79%	79%			81%	79%
Plaice	168%	162%				
Whiting	19%	32%	12%	32%	0%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.2.1.2 Summary of Mann-Whitney tests performed on catch data from pairing 1; the percentages represent that proportion of the catch in the Floralie's net expressed as a percentage of that in the Deux Orchides' net

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole		58%	112%	90%
Dab				
Haddock	22%	220%	0%	
Megrim		81%	103%	
Plaice				
Whiting	98%	106%	0%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

6.2.1.2 Pairing 2:

Parallel Hauls: Deux Orchidees 80mm cod-end – Standard net
Floralie 100mm cod-end. - Experimental net

Eight parallel tows were undertaken in this phase of the trial. Boxplots of numbers caught show large reductions in the number of dab and whiting caught with the 100mm cod-end, this is borne out by Mann Whitney tests. These results also indicate a significant reduction in the catch of black sole.

The graphs of length profile show that for black sole, dab, haddock and plaice there was a reduction in the number of smaller fish caught with similar numbers of larger specimens being recorded for each of these species. There was an almost complete absence of any whiting in the 100mm mesh.

Mann Whitney tests on the different length categories are summarised in Table 6.2.1.3 and 6.2.1.4, they indicate a significant reduction in the discard rate of black sole, the experimental net generating only 7% of the levels caught with the standard net. However there was also a significant reduction in the category 1 (200-400g) black sole. This relatively low catch of black sole below about 32 cm in the test cod-end can clearly be seen in Figure 6.2.1.1 and 6.2.1.2. There was also a significant reduction in the numbers of discards of plaice as can be seen in Figure 6.2.1.3, and an absence of whiting of any size.

Graphs of proportions retained at length appear to show evidence of varying selectivity with length for all species but whiting. Figure 6.2.1.4 shows a clear shift in the proportion of plaice retained in the test cod-end that occurs around the minimum legal landing size.

Overall the experimental net seems to be effective in the reduction of discards of plaice, dab and whiting, this is done at the expense of landings of black sole and whiting which amounted to a loss of around €33.80 per hour (Figure 6.2.1.5). This result was in accordance with expectations.

Table 6.2.1.3 Summary of Mann-Whitney tests performed on catch data from pairing 2; the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	*24%	*25%	7%	*6%	*31%	120%
Dab	***19%	66%	***18%			
Haddock	38%	102%	18%	101%		
Megrim	107%	108%	54%	0%	28%	180%
Plaice	65%	112%	*23%	112%		
Whiting	*3%	*3%	*3%	*3%	0%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.2.1.4 Summary of Mann-Whitney tests performed on catch data from pairing 2; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole	*7%	*30%	*154%	**503%
Dab				
Haddock	62%	224%		
Megrim	3%	0%	46%	148%
Plaice	**39%	**157%		
Whiting	118%	73%	0%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

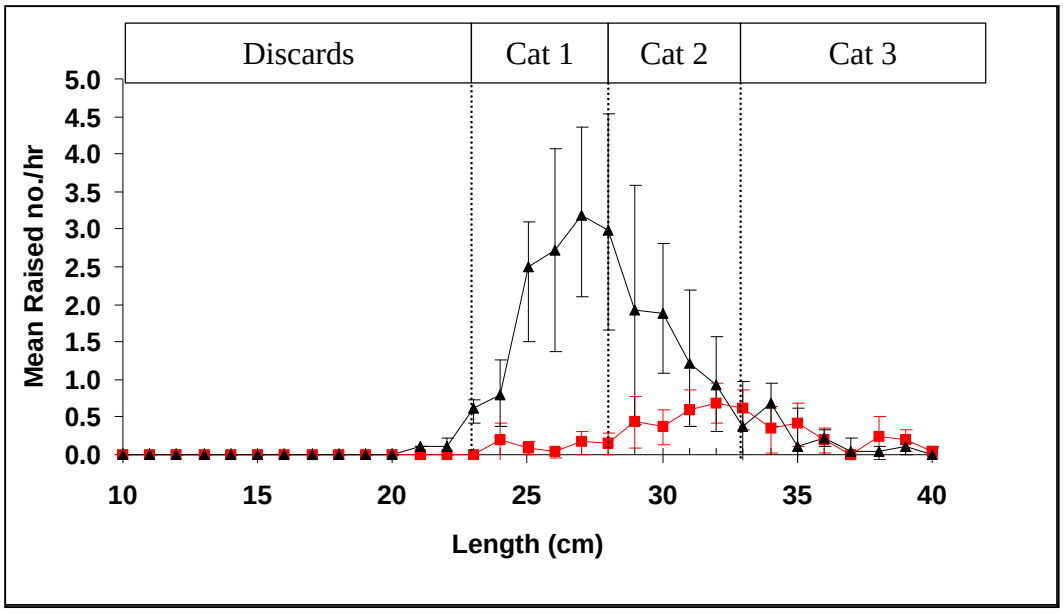


Figure 6.2.1.1. Comparison of length distribution of **Black Sole** for Pairing 2, Standard net in black (6 hauls) and experimental net (8 hauls) in red. Also shown are bootstrapped 95% percentile confidence intervals.

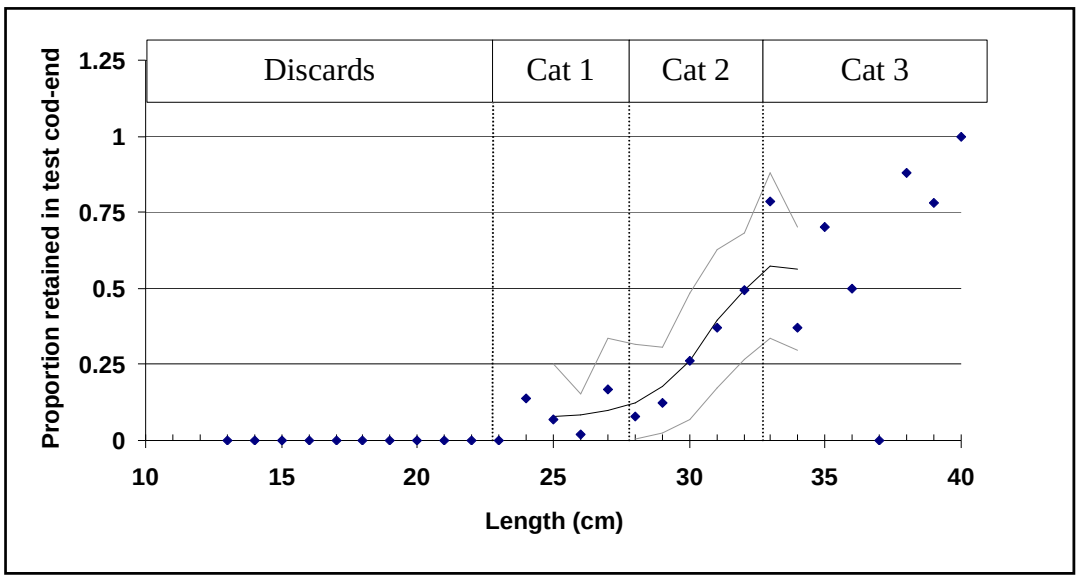


Figure 6.2.1.2 Catch comparison for **Black Sole** from 6 parallel tows for which data was collected from Pairing 2. Black line is weighted moving average of bootstrapped mean proportion of fish retained in the test cod-end, bounded by the weighted moving average of the 95% confidence percentiles.

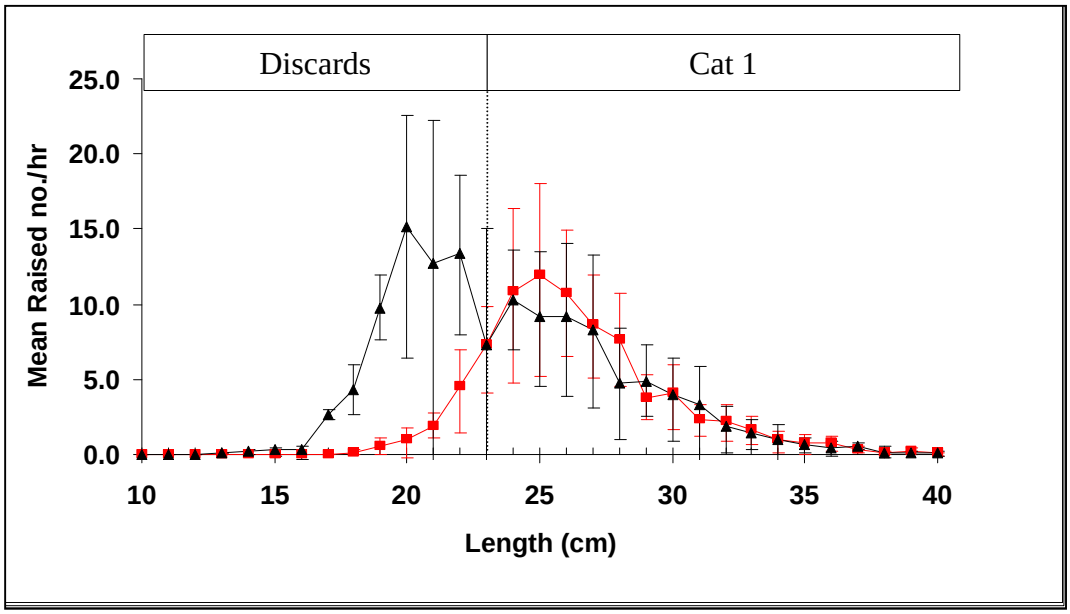


Figure 6.2.1.3. Comparison of length distribution of **Plaice** for Pairing 2, Standard net in black (8 hauls) and experimental net (8 hauls) in red. Also shown are bootstrapped 95% percentile confidence intervals.

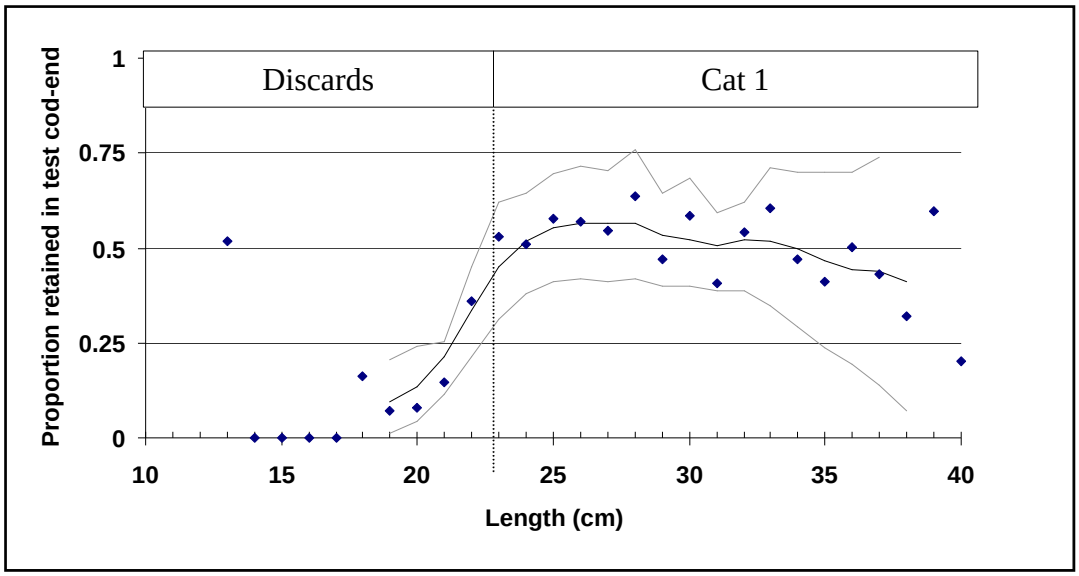


Figure 6.2.1.4: Catch comparison for **Plaice** from 8 parallel tows for which data was collected from Pairing 2. Black line is weighted moving average of bootstrapped mean proportion of fish retained in the test cod-end, bounded by the weighted moving average of the 95% confidence percentiles.

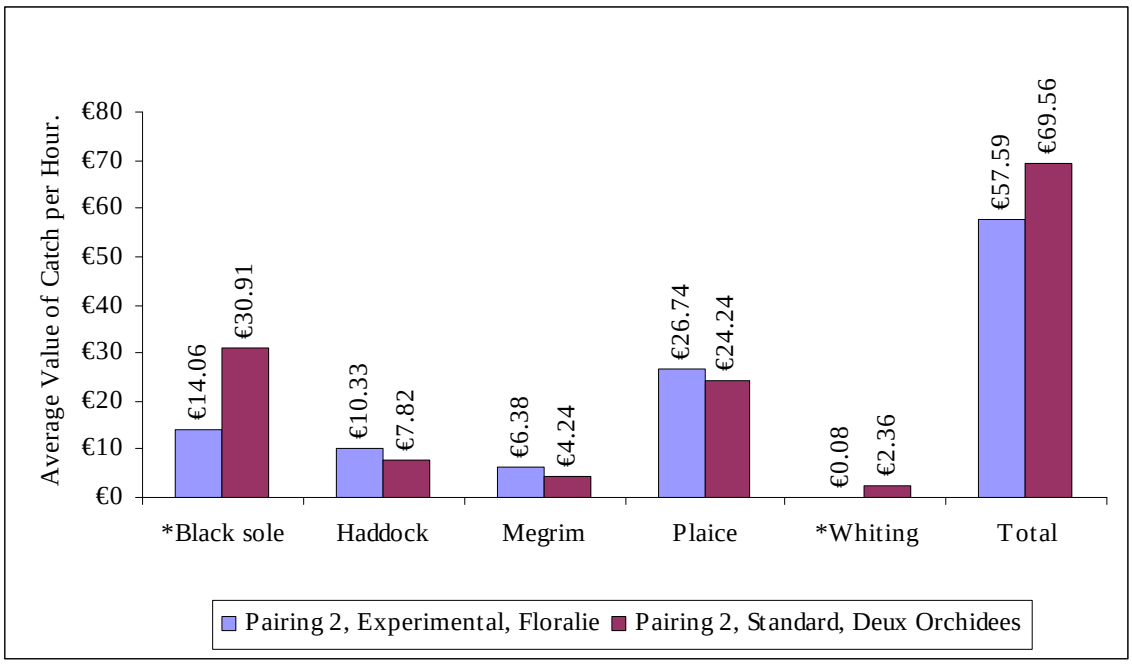


Figure 6.2.1.5; Mean value of measured landings using two net types for pairing 2. Asterisks indicate cases where a significant difference in numbers of landings was found: * for a =0.05; ** for a =0.01; *** for a =0.001.

6.2.1.3 Pairing 3:

Parallel Hauls: Deux Orchidees 100mm cod-end –Experimental net

Floralie 90mm cod-end. – Standard net

Nine parallel tows were undertaken in this phase of the trial. Boxplots and Mann-Whitney tests of numbers of fish landed show a significant reduction in the numbers of dab, megrim, plaice, black sole and whiting in the 100mm cod-end compared to the 90mm net.

Mann-Whitney tests are summarised in Table 6.2.1.5 and 6.2.1.6. Along with length distribution graphs they show that there were significant reductions in the number of discards of plaice and whiting (Figure 6.2.1.6), there was also an accompanying loss of marketable catch of whiting. The proportion of whiting retained in the test cod-end was low for all length categories. For black sole (Figure 6.2.1.7) and megrim (Figure 6.2.1.8) there was no significant reduction in discard numbers. Neither net type catching many fish below minimum length, but for both species there was a significant loss of marketable fish.

Graphs of proportion of fish retained at length clearly show an increase in proportion retained in the experimental net for plaice (Figure 6.2.1.9), and to a lesser degree black sole and haddock. Other species show no clear relationship between proportion retained and length.

Overall the catches in the experimental net were poor, even when compared to how the same boat/net combination performed in their previous trial (pairing 1). The causes of this outcome are uncertain. However from graphs of proportion retained there appears to be some evidence of a reduction in the discards of dab, plaice, and black sole at the expense of landings of megrim and black sole. Though the results in this trial were not as clear as might have been hoped there is still some evidence that the experimental net was fishing as expected.

Table 6.2.1.5; Summary of Mann-Whitney tests performed on catch data from pairing 3; The percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	**17%	**16%	36%	***1%	**15%	74%
Dab	*5%	45%	*4%			
Haddock	38%	60%	36%	60%	62%	
Megrim	***23%	***22%	32%	*18%	***13%	51%
Plaice	*29%	57%	*6%	57%		
Whiting	**27%	*24%	**29%	*23%	99%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.2.1.6. Summary of Mann-Whitney tests performed on catch data from pairing 3; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole	239%	**5%	101%	**303%
Dab				
Haddock	91%	249%	300%	
Megrim	137%	69%	**55%	**215%
Plaice	*43%	*145%		
Whiting	92%	109%	589%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

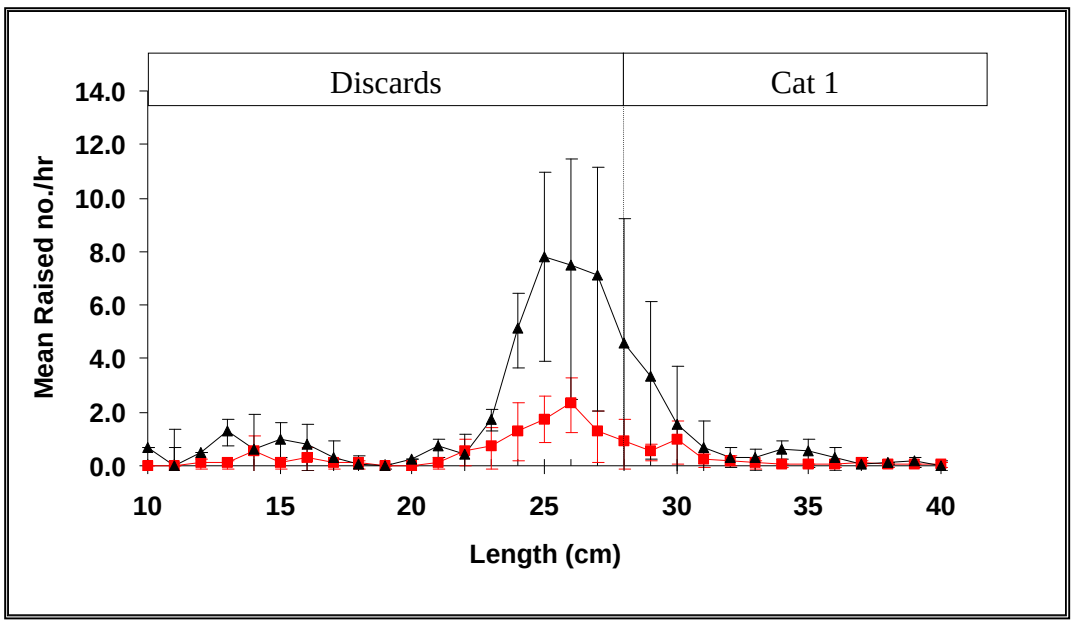


Figure 6.2.1.6. Comparison of length distribution of **Whiting** for Pairing 3; Standard net in black (9 hauls) and experimental net (9 hauls) in red. Also shown are bootstrapped 95% percentile confidence intervals.

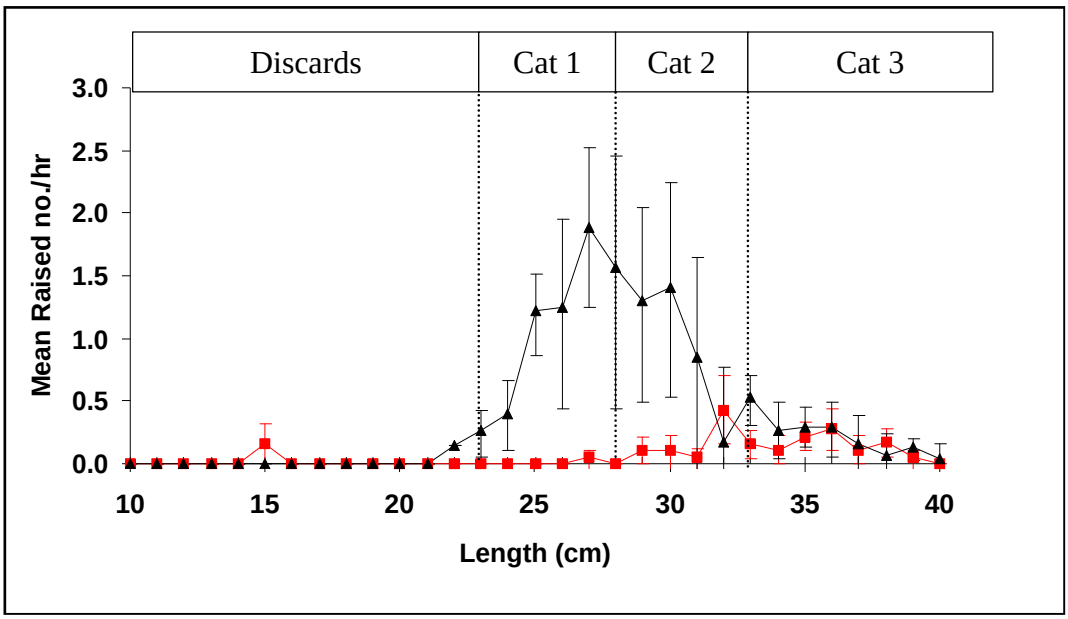


Figure 6.2.1.7 Comparison of length distribution of **Black Sole** for Pairing 3; Standard net (9 hauls) in black and experimental net (6 hauls) in red. Also shown are bootstrapped 95% percentile confidence intervals.

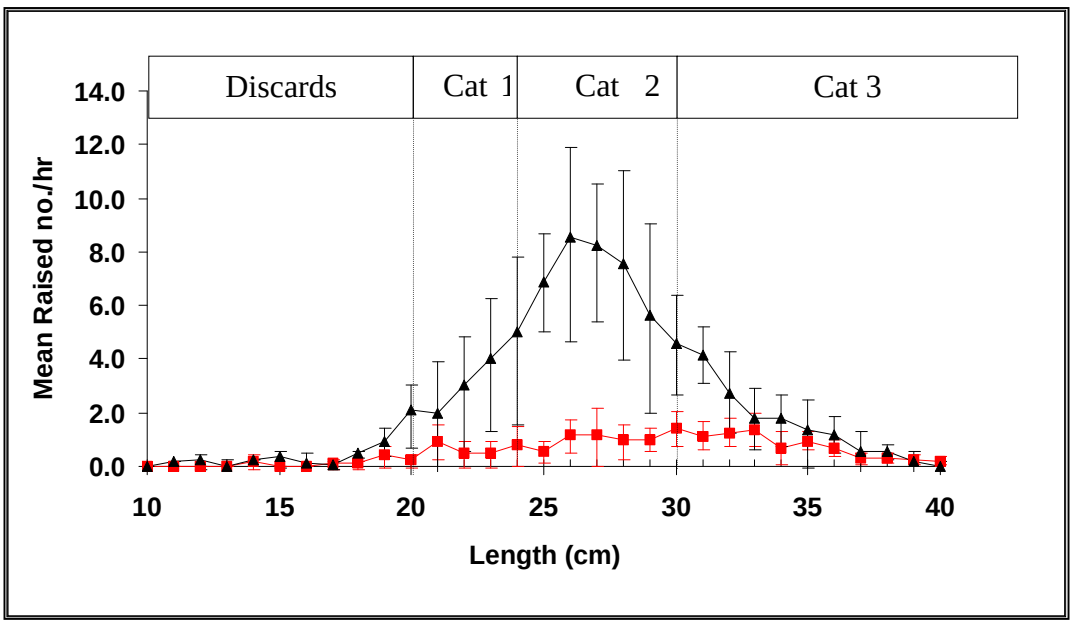


Figure 6.2.1.8 Comparison of length distribution of **Megrim** for Pairing 3; Standard net in black (9 hauls) and experimental net (9 hauls) in red. Also shown are bootstrapped 95% percentile confidence intervals.

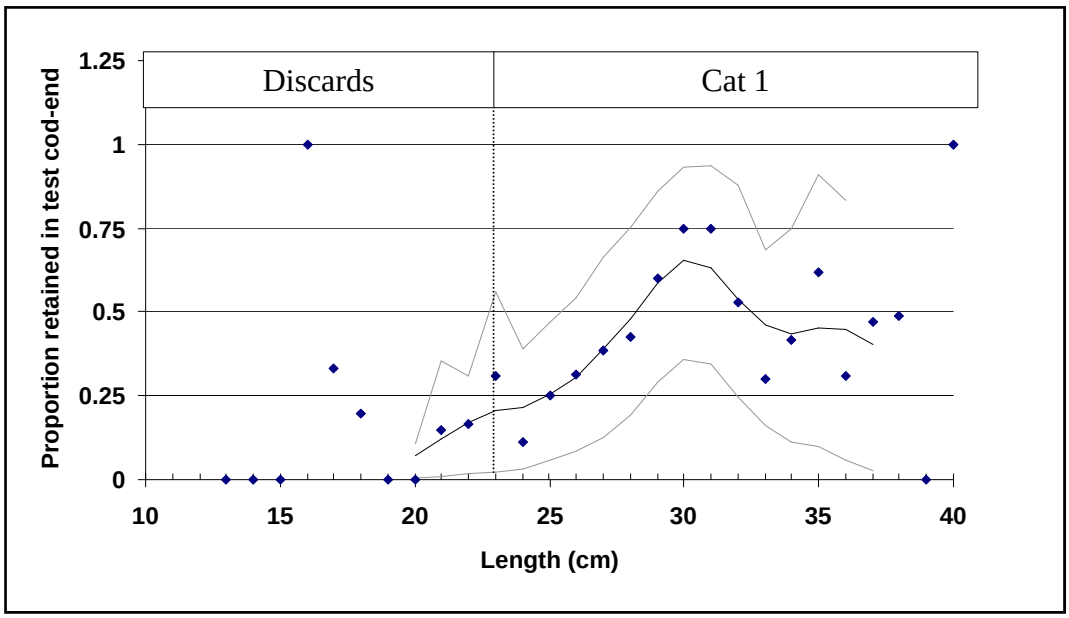


Figure 6.2.1.9: Catch comparison for **Plaice** from 9 parallel tows for which data was collected from Pairing 3. Black line is weighted moving average of bootstrapped mean proportion of fish retained in the test cod-end, bounded by the weighted moving average of the 95% confidence percentiles.

6.2.2 Effect of 80mm square mesh panel.

The vessels used in this trail were the Maid of Nazareth and the Elsie Marie. Experimental method employed was parallel tows. Three gear configurations (pairings) were used:

Paring 4: Elsie Marie 80mm square mesh panel –experimental net
Maid Of Nazareth 80 mm square mesh panel –experimental net
Pairing 5: Elsie Marie 80mm square mesh panel –experimental net
Maid of Nazareth standard net
Pairing 6: Elsie Marie standard net
Maid of Nazareth 80mm square mesh panel –experimental net

6.2.2.1 Pairing 4:

Parallel Hauls: Elsie Marie 80mm square mesh panel –experimental net
Maid Of Nazareth 80 mm square mesh panel– experimental net

Five parallel tows were conducted during this trial. Box plots and Mann-Whitney tests showed no significant differences in numbers of fish landed for any species. There were no significant differences in numbers of fish landed in length categories as can be seen in Table 6.2.2.1.
Length distribution graphs showed very similar catches for black sole and haddock
Chi^2 test showed a difference in the overall distribution of the catch of plaice. On the length distribution graph (Figure 6.2.2.1) this can be seen as a smaller catch of small plaice combined with a slightly larger catch of bigger fish on the Maid of Nazareth. However the 95% confidence intervals on the data are very wide.
PCA analysis (Figure 6.2.2.2) shows that there are similar patterns in the catches of several of the species between the two boats. The vectors for plaice are virtually superimposed indicating very similar patterns in catch; the same is true

of megrim. Whiting catches also show a strong positive relationship to one another. Overall the catches in the two experimental nets were very similar. This result is as anticipated and would seem to indicate this method ensures that the two nets are fishing the same populations of fish and provides reassurance that this sampling method was a valid approach.

Table 6.2 2.1 Summary of Mann-Whitney tests performed on catch data from pairing 4; The percentages represent the catch in the Maid of Nazareth's net expressed as a percentage of the catch in the Elsie Marie's net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	112%	115%	30%	234%	114%	60%
Dab	145%					
Haddock	100%	99%	101%	99%	141%	
Megrim	151%	151%			282%	94%
Plaice	71%	147%	33%	147%		
Whiting	40%	43%	37%	43%	79%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001

Table 6.2 2.2 Summary of Mann-Whitney tests performed on catch data from pairing 4; The percentages represent that proportion of the catch in the Maid of Nazareth's net expressed as a percentage of the catch in the Elsie Marie's net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole	14%	160%	102%	63%
Dab				
Haddock	110%	84%	120%	
Megrim		152%	81%	
Plaice	87%	110%		
Whiting	109%	94%	160%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001

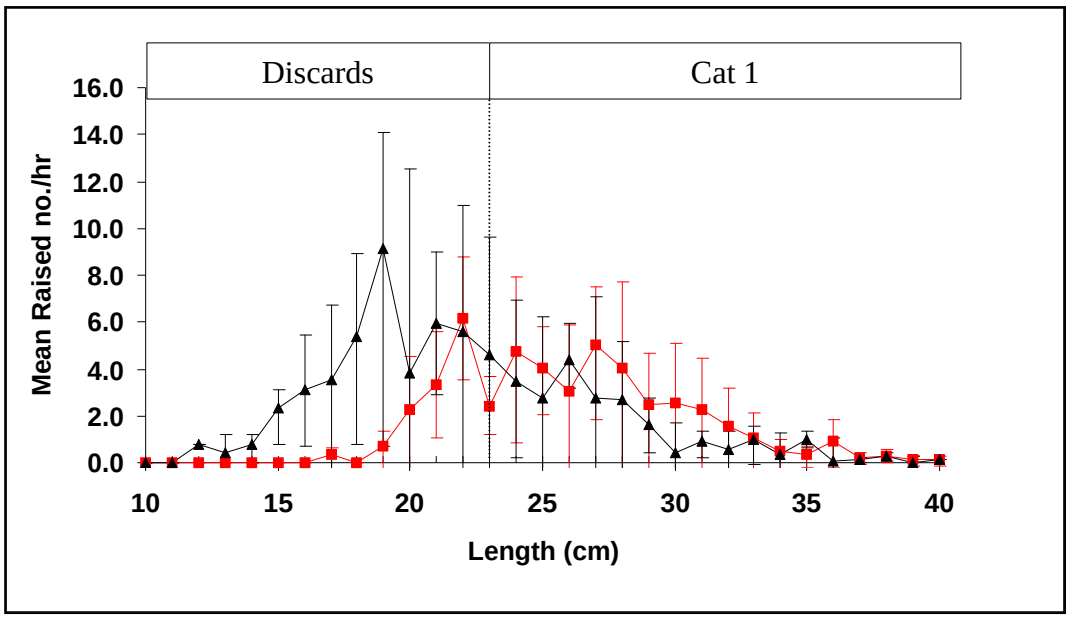


Figure 6.2.2.1. Comparison of length distribution for **Plaice** for pairing 4; catch from Elsie Marie in red (5 hauls); catch from Maid Of Nazareth in black (5 hauls). Also shown are 95-percentile ranges.

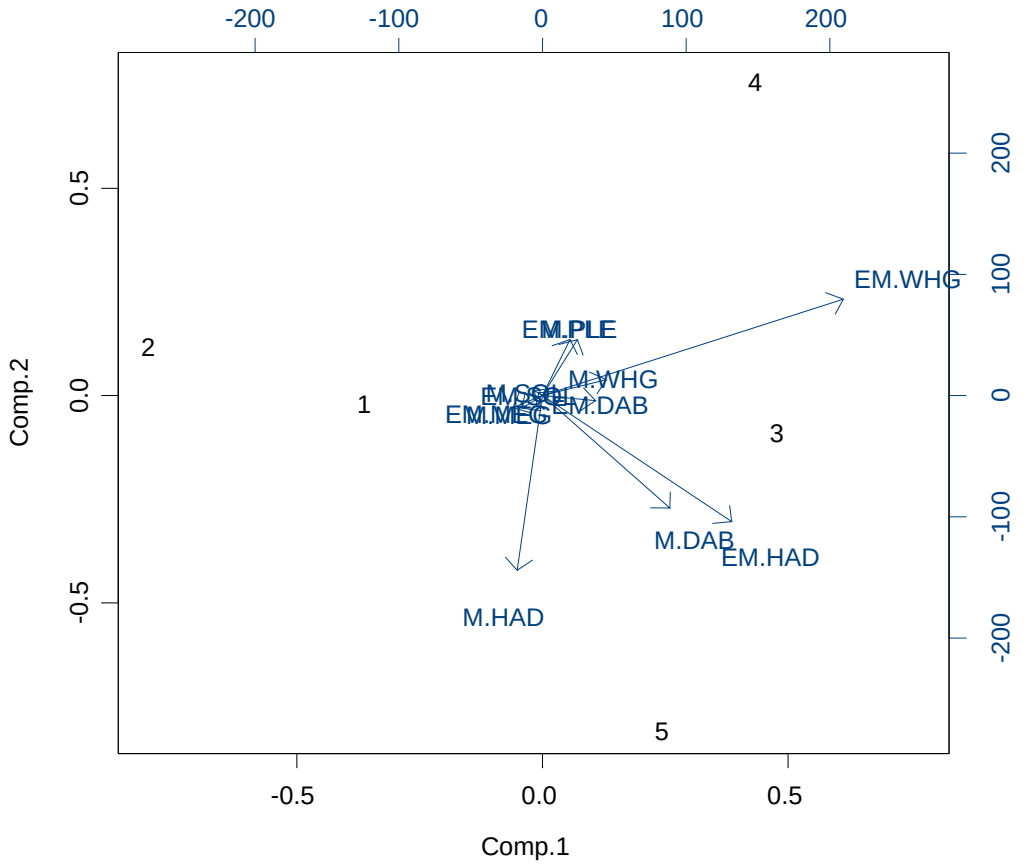


Figure 6.2.2.2. PCA biplot for pairing 4, Prefix: EM-Elsie Marie, M-Maid Of Nazareth; Followed by 3 letter code: SOL-Sole, DAB-Dab, HAD-Haddock, MEG-Megrim, PLE-Plaice, WHG-Whiting. Components 1 and 2 between them account 96% .of the variance. (Numbers 1-5 refer to the 5 parallel tows)

6.2.2.2 Pairing 5:

Parallel Hauls: Elsie Marie 80mm square mesh panel – experimental net
Maid of Nazareth standard net

Eight parallel tows were completed during this phase of the trials. Box plots show reduced catches of all species in the experimental net. Mann-Whitney tests (Table 6.2.2.3.) show that only the reduction in whiting landings was significant. Mann-Whitney tests also show that there is a significant reduction in the landings of whiting, plaice and megrim, though only in whiting was a significant reduction in discard numbers observed. In no species was there a significant reduction of the discard rate. Table 6.2.2.4 indicates a change in length distribution of black sole with category 1 fish making up less of the sole catch in the experimental net as can be seen in Figure 6.2.2.3. Graphs of proportion retained in experimental net at length show higher catches of small haddock, sole, megrim and plaice in the experimental net.

There is a significant loss of marketable megrim (Figure 6.2.2.4) and plaice landed; however neither net caught much plaice as can be seen in Figure 6.2.2.5. There was also a significant reduction in whiting landed. In terms of the value of measured species there was a total reduction of around €130 per hour, a loss of around 60% (Figure 6.2.2.6). The results from pairing 5 also seem unexpected. On reviewing the data by haul it became apparent that during this period of sampling several different observers briefly employed to collect data from the Elsie Marie. Sample sizes were often low, leading to unrepresentative samples being taken. In only two tows were haddock recorded. When the level of landings in the experimental net on the Elsie Marie in this pairing is compared with the landings on the same vessel with the same net during the previous sampling phase (pairing 4) it can be seen that the landings in this trail are much smaller. This may be due to a real change in the numbers of fish retained in the net or to be inadequate sampling. It is however unlikely to be due the presence of the TCM feature.

Table 6.2.2.3 Summary of Mann-Whitney tests performed on catch data from pairing 5; the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	74%	62%	502%	42%	64%	120%
Dab	22%					
Haddock	57%	39%	61%	39%	0%	
Megrim	30%	*21%	247%	*17%	*17%	74%
Plaice	50%	*14%	134%	*14%		
Whiting	**19%	**13%	*25%	**12%	85%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.2.2.4 Summary of Mann-Whitney tests performed on catch data from pairing 5; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole	740%	*58%	97%	132%
Dab				
Haddock	79%	258%	0%	
Megrim	796%	63%	69%	153%
Plaice	306%	64%		
Whiting	101%	97%	482%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

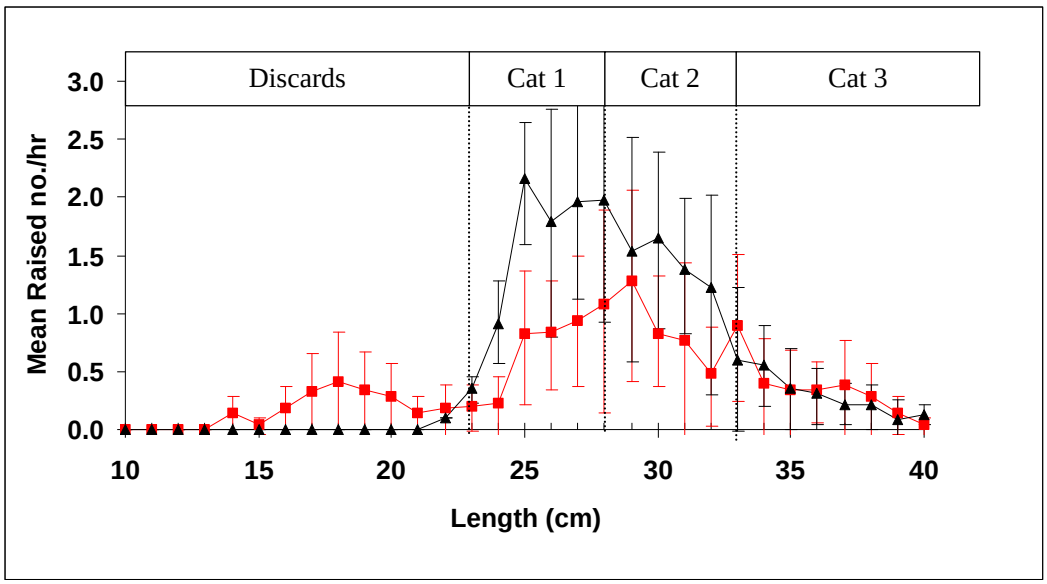


Figure 6.2.2.3. Comparison of length distribution for **Black Sole** for pairing 5; catch from experimental net in red (7 hauls); catch standard net in black (8 hauls). Also shown are 95-percentile ranges.

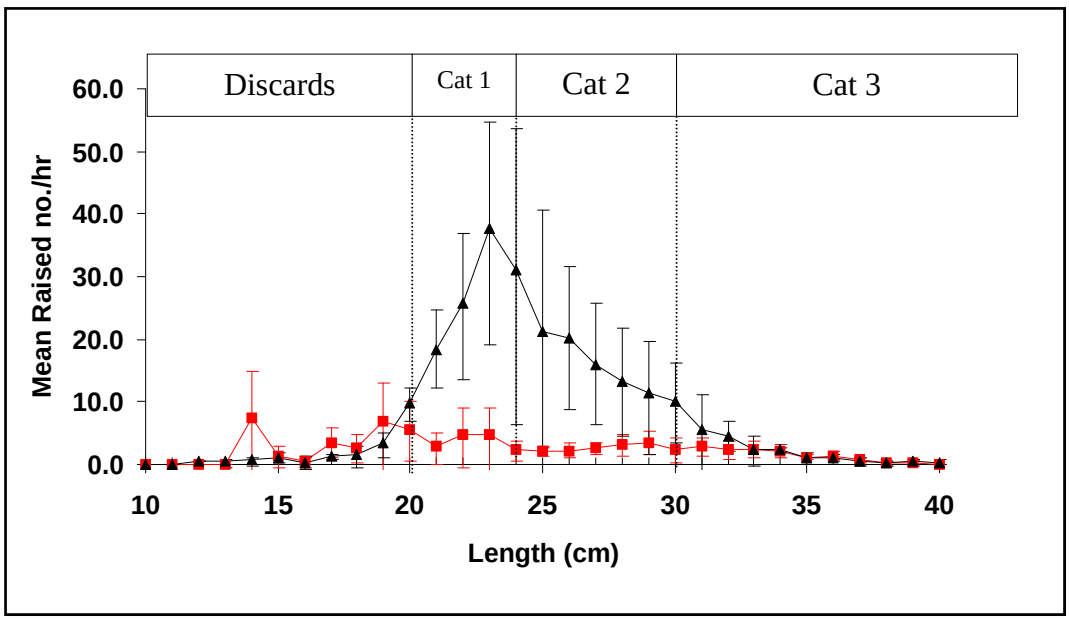


Figure 6.2.2.4. Comparison of length distribution for **Megrim** for pairing 5; catch from experimental net in red (8 hauls); catch standard net in black (8 hauls). Also shown are 95-percentile ranges.

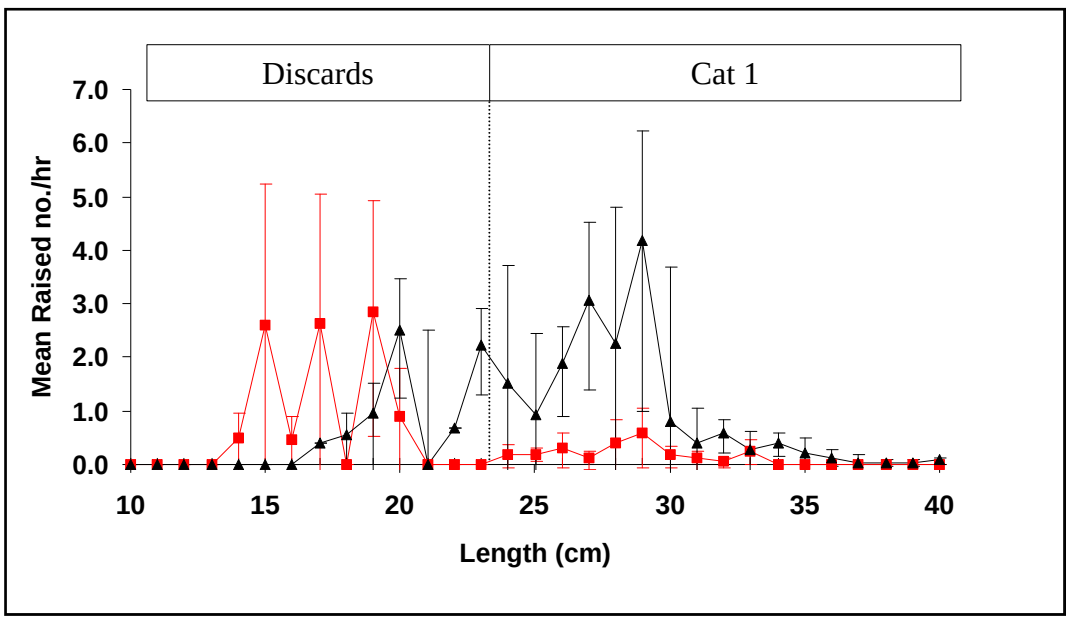


Figure 6.2.2.5. Comparison of length distribution for **Plaice** for pairing 5; catch from experimental net in red (6 hauls); catch standard net in black (8 hauls). Also shown are 95-percentile ranges.

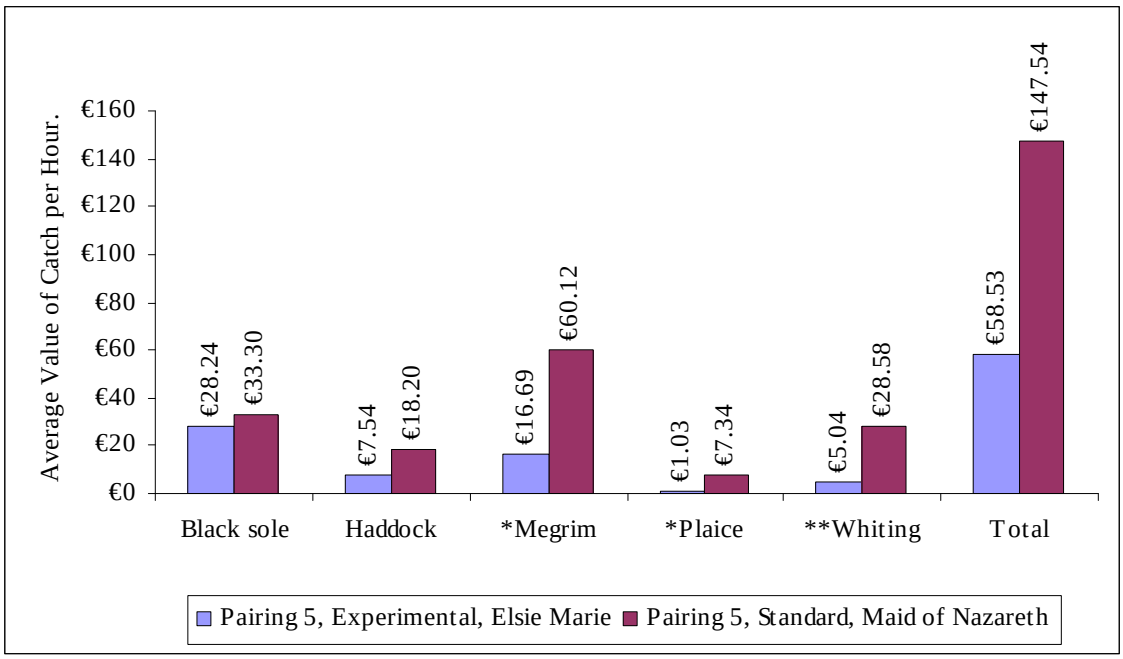


Figure 6.2.2.6; Mean value of measured landings using two net types for pairing 5. Asterisks indicate cases where a significant difference in numbers of landings was found: * for a =0.05; ** for a =0.01; *** for a =0.001.

6.2.2.3 Pairing 6:

Parallel Hauls: Elsie Marie standard net
Maid of Nazareth 80mm square mesh panel – Experimental net

Eight valid parallel tows were completed during this phase of the trials. Box plots and Mann-Whitney tests (Table 6.2.2.5.) show that the overall catches in the two nets do not significantly differ. It can be seen that, with the exception of plaice, the landings of all species were similar between nets. For plaice the catch in the experimental net was over four times that in the standard net, though it can be seen from the length profile graph (Figure 6.2.2.7) that very few plaice were caught in either the standard or the experimental net. For megrim there was a significant reduction in landings, those in the experimental net are 1/6 of those in the standard net. The discard rates for megrim and plaice were both less in the experimental net (Table 6.2.2.6) There was also a decrease in the number of category 1 megrim caught; this can clearly be seen on Figure 6.2.2.8, the change in the proportion of fish retained in the experimental net with length can clearly be seen in Figure 6.2.2.9. In terms of value, the catch was similar in both nets (Figure 6.2.2.10). Though there was a decrease in the numbers of category 1 black sole caught the slight increase in numbers of bigger fish meant the value of black sole landings increased.

Overall in the experimental net there was a reduction in the proportion of discards for megrim and plaice and an apparent increase in landings of plaice and whiting. The proportion-retained graphs appear to show that for megrim, plaice and whiting there is evidence that the experimental net is retaining less undersized fish. There is no significant difference in the catches of haddock retained between the two nets and the discards rate remains the same. The catches of dab are virtually identical.

Table 6.2.2.5 Summary of Mann-Whitney tests performed on catch data from pairing 6; the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	82%	104%	2%	*54%	147%	97%
Dab	155%					
Haddock	151%	145%	153%	146%	63%	
Megrim	58%	67%	*14%	*26%	99%	87%
Plaice	67%	*456%	23%	*456%		
Whiting	108%	163%	58%	162%	*242%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.2.2.6 Summary of Mann-Whitney tests performed on catch data from pairing 6; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole	1%	**65%	*156%	142%
Dab				
Haddock	106%	71%	67%	
Megrim	*23%	**37%	**177%	*193%
Plaice	*30%	*204%		
Whiting	63%	131%	180%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

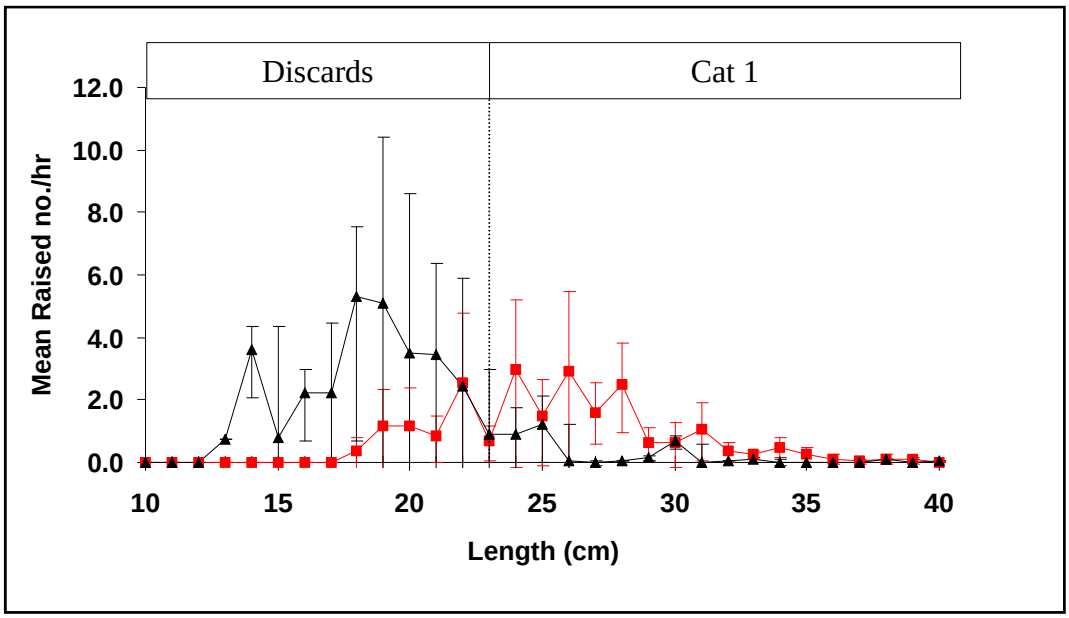


Figure 6.2.2.7. Comparison of length distribution for **Plaice** for pairing 6; catch from experimental net in red (6 hauls); catch standard net in black (8 hauls). Also shown are 95-percentile ranges.

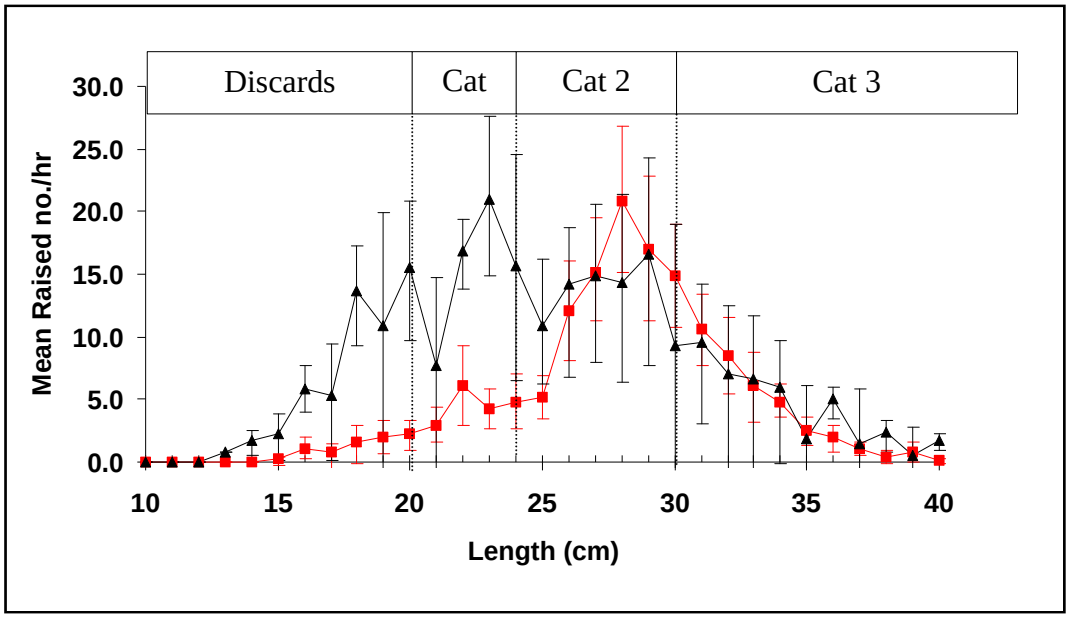


Figure 6.2.2.8. Comparison of length distribution for **Megrim** for pairing 6; catch from experimental net in red (8 hauls); catch standard net in black (8 hauls). Also shown are 95-percentile ranges.

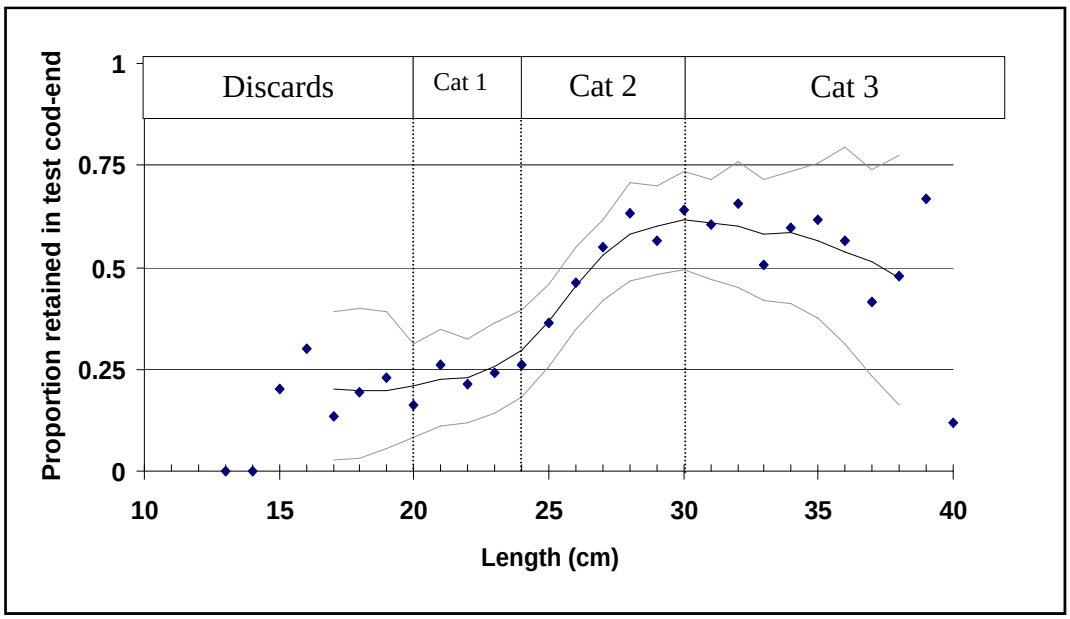


Figure 6.2.2.9. Catch comparison for **Megrim** from parallel tows for which data was collected from Pairing 6. Black line is weighted moving average of bootstrapped mean proportion of fish retained in the test cod-end, bounded by the weighted moving average of the 95% confidence percentiles.

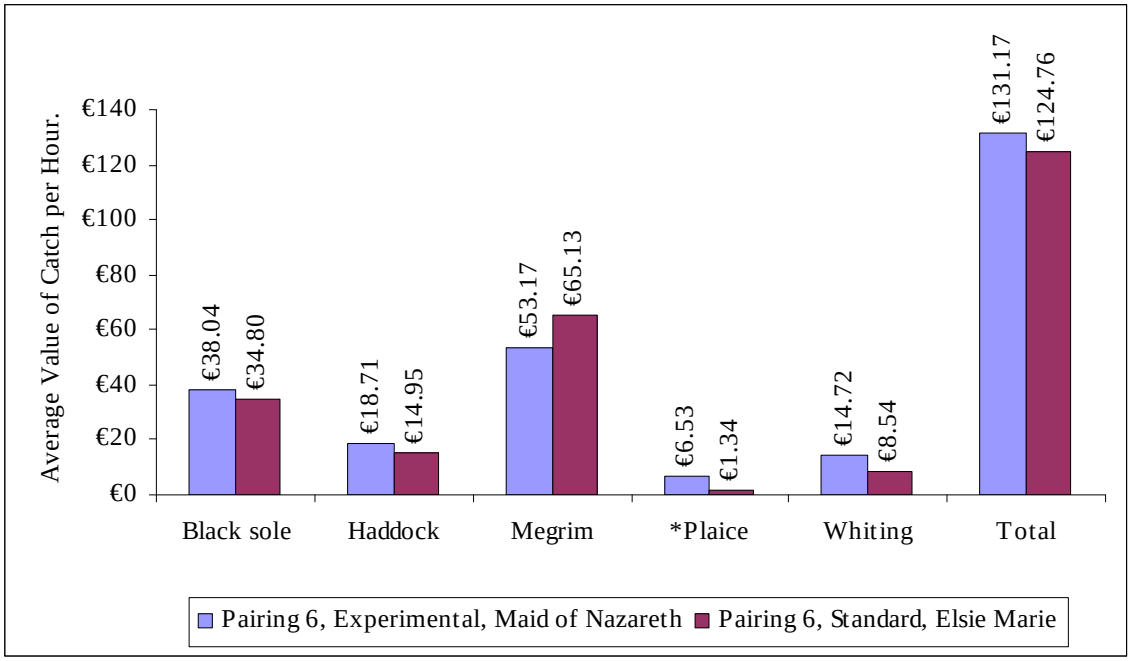


Figure 6.2.2.10; Mean value of measured landings using two net types for pairing 6. Asterisks indicate cases where a significant difference in numbers of landings was found: * for a =0.05; ** for a =0.01; *** for a =0.001.

6.2.3 Pairing 7: Effect of using 100mm cod-end.

Alternate Hauls: Naomh Deararca. 100mm, -experimental net
Naomh Deararca. 80mm, -standard net.

Nineteen of the intended 24 hauls were used in the analysis; eleven hauls were made using the experimental net, eight using the standard net. Two hauls were lost due to bad weather, one lost due to a failure of the power block on day 7 and two were lost when a net became entangled around the propeller.

Box-plots show that there were only slight reductions in the numbers of fish being caught in the experimental net; the only exception to this was sole, where the catch was 35% of that in the standard net (Table 6.2.3.1). Selectivity ogives and L_{50}s for the two nets were estimated from the catch curves for Black Sole. The ogives are compared in figure 6.2.3.4. There is a clear increase in the L_{50} for the net with the 100mm codend; its L_{50} was 26.6cm as compared to 23.9cm for the net with the 80mm codend (table 6.2.3.3). Neither net caught many megrim. The catches of plaice were almost identical.
There was also a significant reduction in the discard rate of whiting (Table 6.2.3.2).
Length profile graphs show the reduction in smaller black sole (Figure 6.2.3.3) whiting (Figure 6.2.3.1) and also appear to show a reduction in the cohort of haddock around 20cm in length (Figure 6.2.3.2), though this was not picked up by the Mann-Whitney tests.
Overall, in the experimental net there is a reduction of whiting and haddock discards at the expense of landings of black sole.

Table 6.2.3.1 Summary of Mann-Whitney tests performed on catch data from pairing 7; the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net.

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	*35%	*38%	*7%	**17%	81%	87%
Dab	50%	140%				
Haddock	61%	87%	49%	89%	*21%	
Megrim	118%	98%			97%	98%
Plaice	106%	108%	100%	109%	0%	
Whiting	59%	73%	31%	74%	45%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.2.3.2. Summary of Mann-Whitney tests performed on catch data from pairing 7; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole	*17%	**51%	**210%	214%
Dab				
Haddock	123%	75%	*4%	
Megrim			75%	75%
Plaice	75%	110%	0%	
Whiting	*65%	*115%	83%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

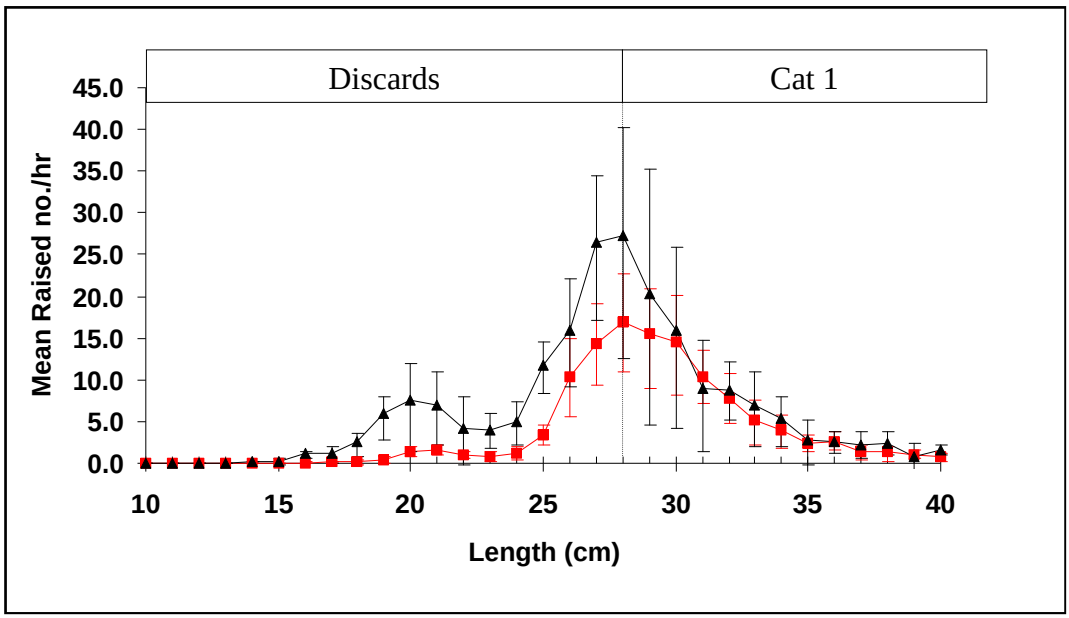


Figure 6.2.3.1. Comparison of length distribution for **Whiting** for pairing 7; catch from experimental net in red (11 hauls); catch standard net in black (8 hauls). Also shown is 95-percentile range,

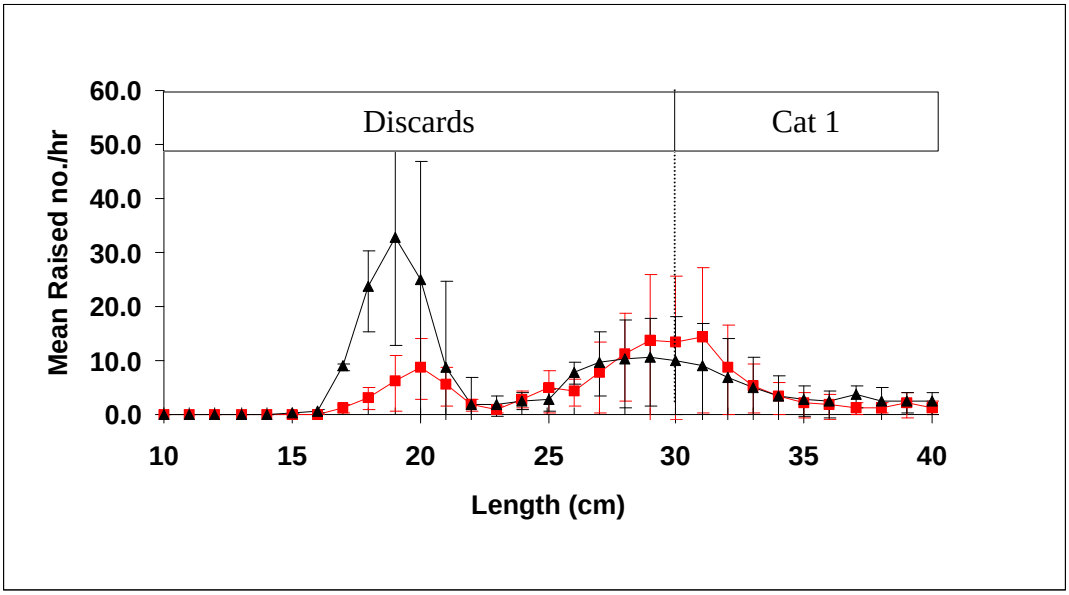


Figure 6.2.3.2. Comparison of length distribution for **Haddock** for pairing 7; catch from experimental net in red (11 hauls); catch standard net in black (8 hauls). Also shown is 95-percentile range.

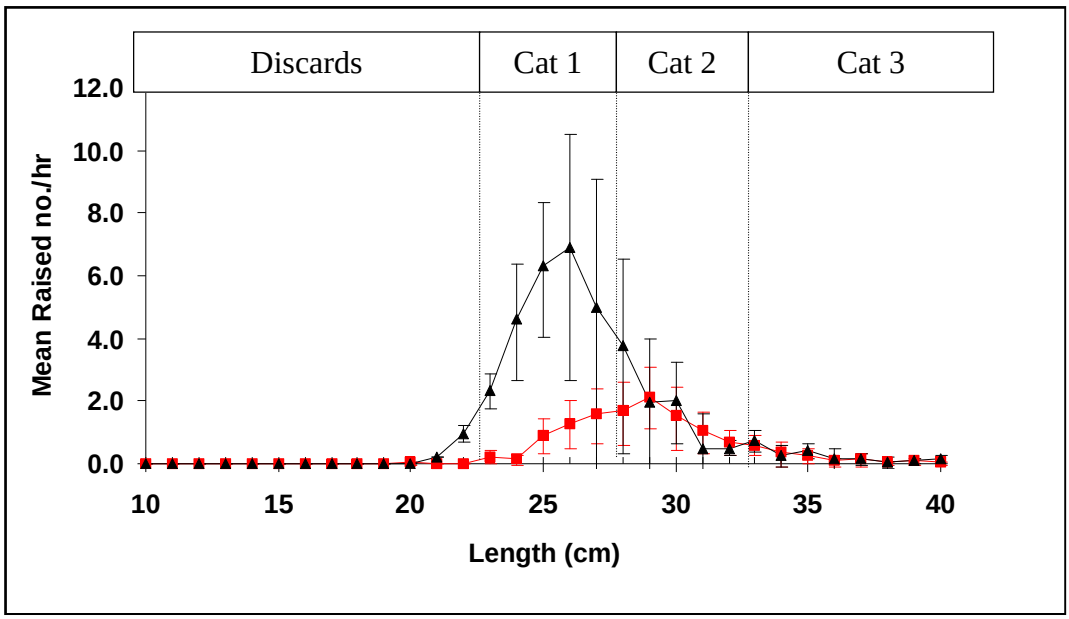


Figure 6.2.3.3. Comparison of length distribution for **Black Sole** for pairing 7; catch from experimental net in red (10 hauls); catch standard net in black (8 hauls). Also shown is 95-percentile range.

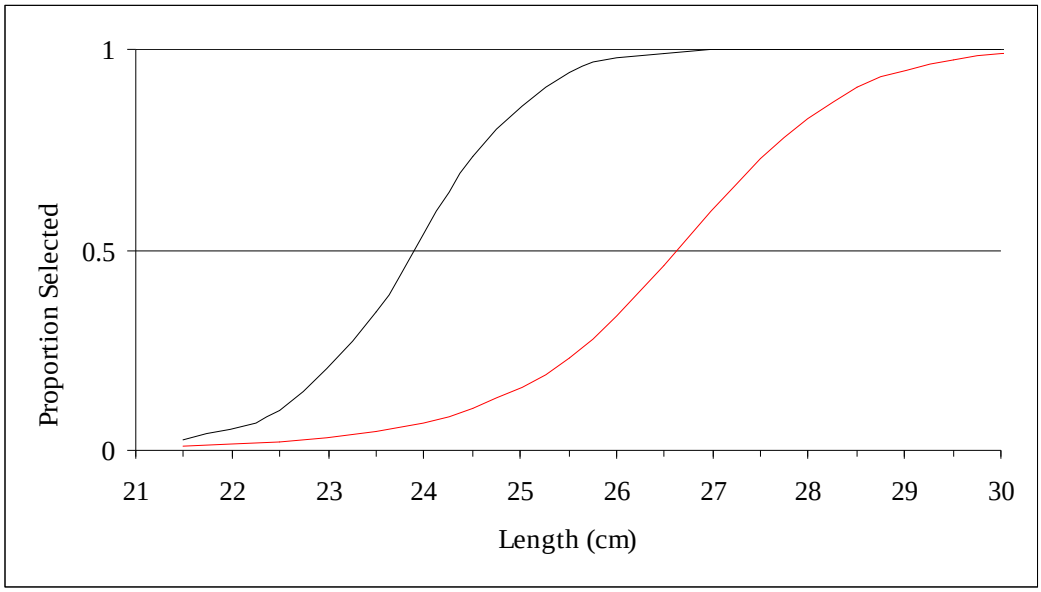


Figure 6.2.3.4: Comparison of Estimated selectivity ogives for **Black Sole**, TCM (100mm codend-RED) and Standard (80mm codend- BLACK).

Table 6.2.3.3 Summary of results of calculations to estimate selectivity ogives for two nets.

Calculated Values	100mm TCM	80mm Normal Net
Z	1.39	1.84
a	8.80	10.05
L50%	26.66	23.91
L75%	27.61	24.56

6.2.4 Pairing 8: Effect of using 90mm cod-end.

Alternate hauls: Gerlisa 90mm cod-end. - Experimental net
Gerlisa 80mm cod-end. - Standard net

Twenty parallel hauls were completed for this trial, ten with each net. The two nets were of greatly different design, the standard net being a single purpose scraper net designed mainly to catch flatfish and nephrops, while the experimental net was a dual purpose net with higher headline height to also catch whiting and haddock.

Box-plots show slight reductions in numbers of fish caught in the experimental net. This is supported by the Mann-Whitney tests that found the reduction in numbers of dab haddock and whiting to be significant (Table 6.2.4.1). It can also be seen that most of the reductions in numbers in these species was due to the reduction in discards. There was also a reduction in the numbers of category 3 (>400g) black sole caught. It can be seen however (Figure 6.2.4.1) that overall the length distribution for black sole is remarkably similar for both nets. A substantial reduction for the cohort of haddock with mean size around 20cm is evident in Figure 6.2.4.2. The graph of length distribution for whiting (Figure 6.2.4.3) shows a reduction in numbers of smaller fish, with similar numbers of large fish being caught.
Overall in the experimental net there was a reduction in the discards and also the landings of whiting and haddock.

Table 6.2.4.1. Summary of Mann-Whitney tests performed on catch data from pairing 8; the percentages represent the catch in the experimental net expressed as a percentage of the catch in the standard net

	Numbers					
Species	Catch	Landings	Discards	Cat 1	Cat 2	Cat 3
Black Sole	85%	87%	53%	105%	85%	*48%
Dab	*52%	203%	*51%			
Haddock	**47%	65%	**44%	66%	39%	
Megrim					0%	118%
Plaice	71%	75%	65%	75%	123%	
Whiting	*51%	89%	***27%	88%	92%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

Table 6.2.4.2. Summary of Mann-Whitney tests performed on catch data from pairing 8; the percentages represent that proportion of the catch in the experimental net expressed as a percentage of that in the standard net.

	Proportions			
Species	Discard Rate	Cat 1	Cat 2	Cat 3
Black Sole	61%	121%	102%	57%
Dab				
Haddock	*76%	*240%	158%	
Megrim				
Plaice	79%	116%	339%	
Whiting	**48%	***172%	*194%	

Shaded boxes represent significant results,
* for a =0.05; ** for a =0.01; *** for a =0.001.

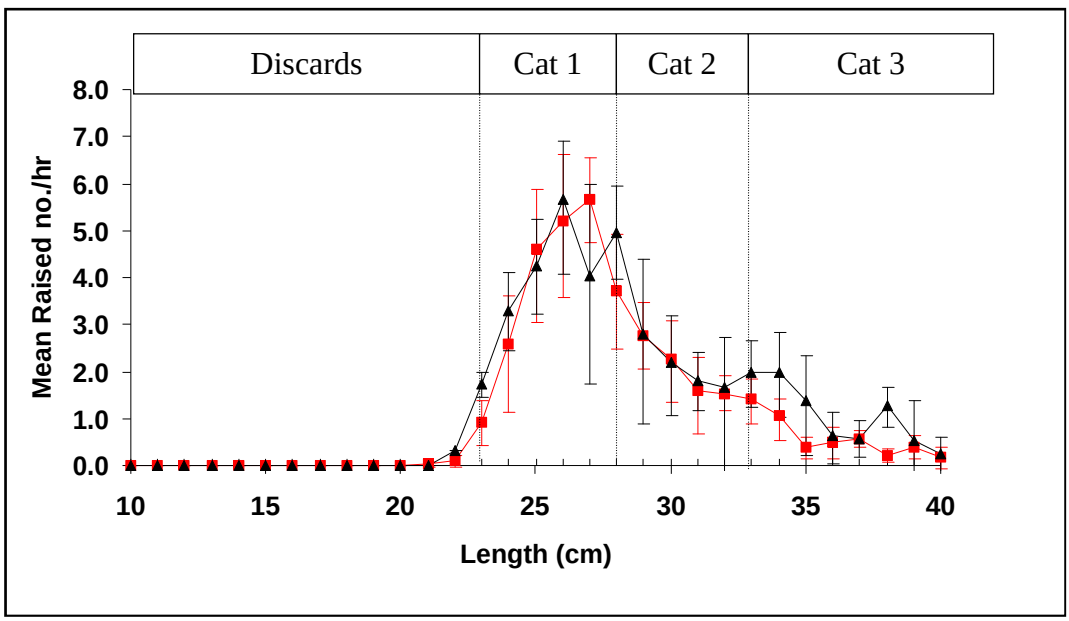


Figure 6.2.4.1. Comparison of length distribution of **Black Sole** for Pairing 8; Standard net in black (10 hauls) and experimental net (10 hauls) in red. Also shown are bootstrapped 95% confidence intervals.

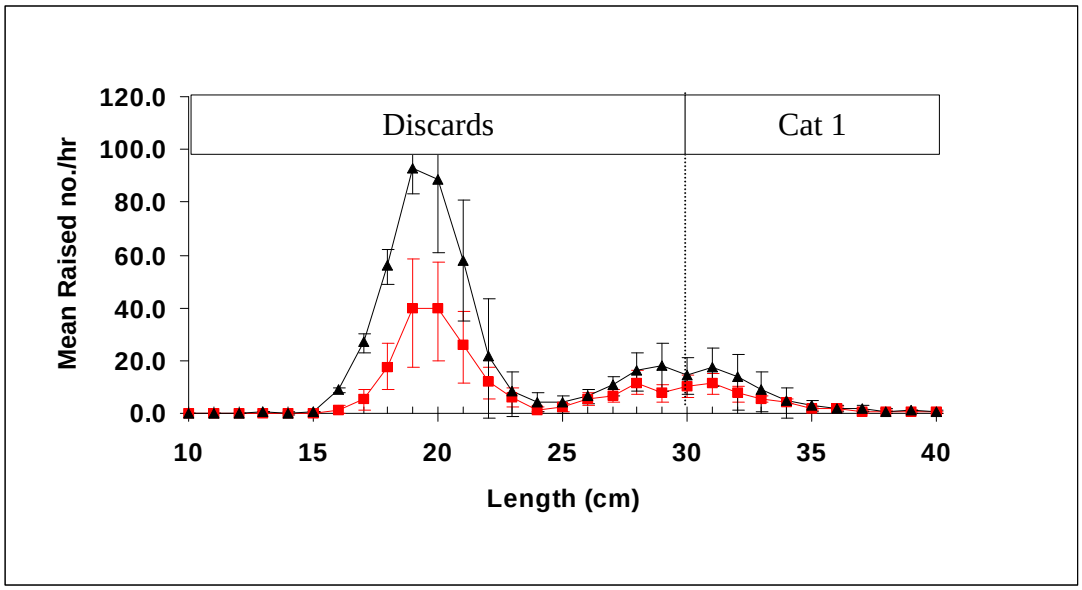
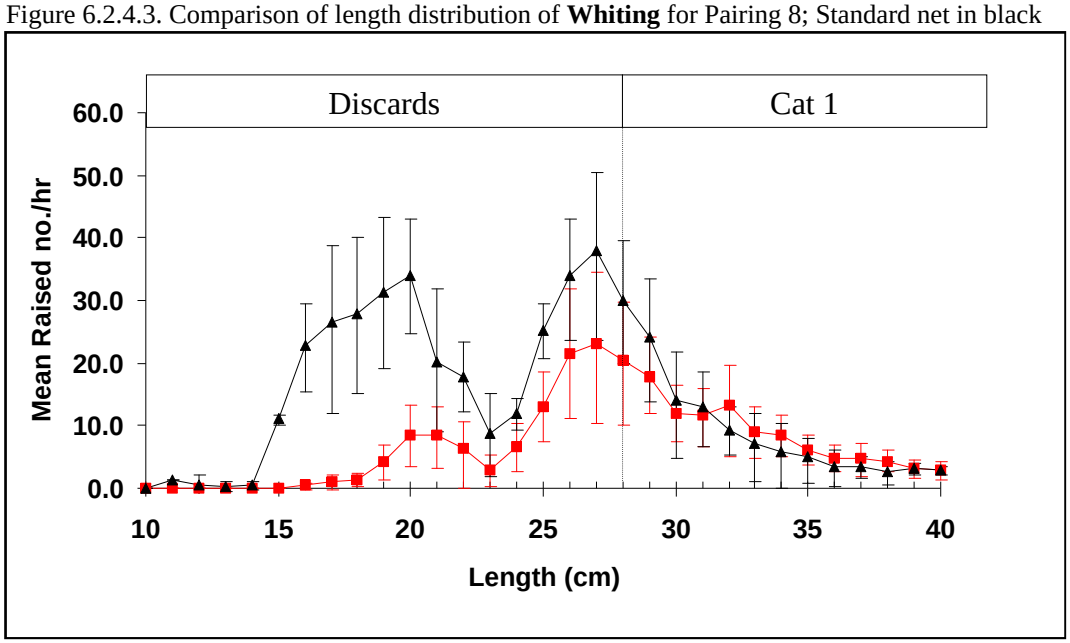


Figure 6.2.4.2. Comparison of length distribution of Haddock for **Pairing** 8; Standard net in black (10 hauls) and experimental net (10 hauls) in red. Also shown are bootstrapped 95% confidence intervals.

Figure 6.2.4.3. Comparison of length distribution of **Whiting** for Pairing 8; Standard net in black



(10 hauls) and experimental net (10 hauls) in red. Also shown are bootstrapped 95% confidence intervals.

6.3 Discard Rates

The comparisons of overall discard rates in terms of numbers (figure 6.3.1) and mass (figure 6.3.2) between standard nets and two types of TCM nets used throughout the whole period of the trials are presented below. It can be seen that black sole discards are minimal, and almost absent with 100mm codends. Dab discards are very high, above 90% in all cases; it is uncommon for dab to be landed, marketable sized fish are uncommon and the processors do not have any market demand for them. Megrim discards are halved when 100mm codends are used; 80mm square mesh panels are only slightly less effective.

The use of square mesh panels has only a slight effect on the discard levels for haddock, megrim and plaice; the 100mm codends are more effective for these species but still discard levels are above 50%.

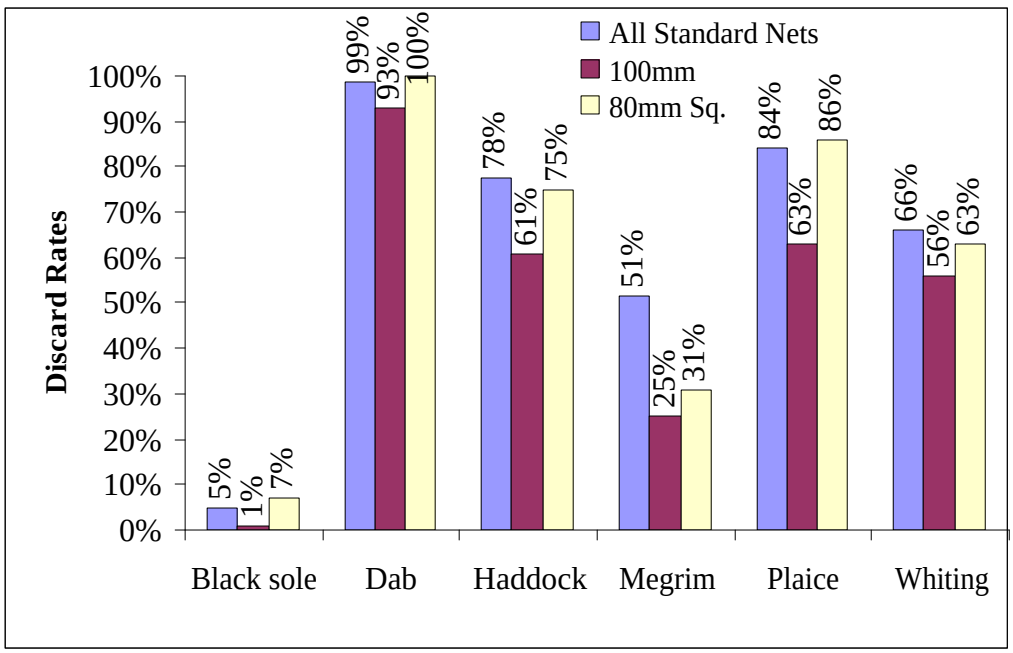


Figure 6.3.1. Average discard rate **(numbers discarded/numbers caught)** for fishery (all boats using standard nets) compared with the average discard rates obtained using nets with 100mm cod-ends and with 80mm square mesh panels for the whole period of the trials.

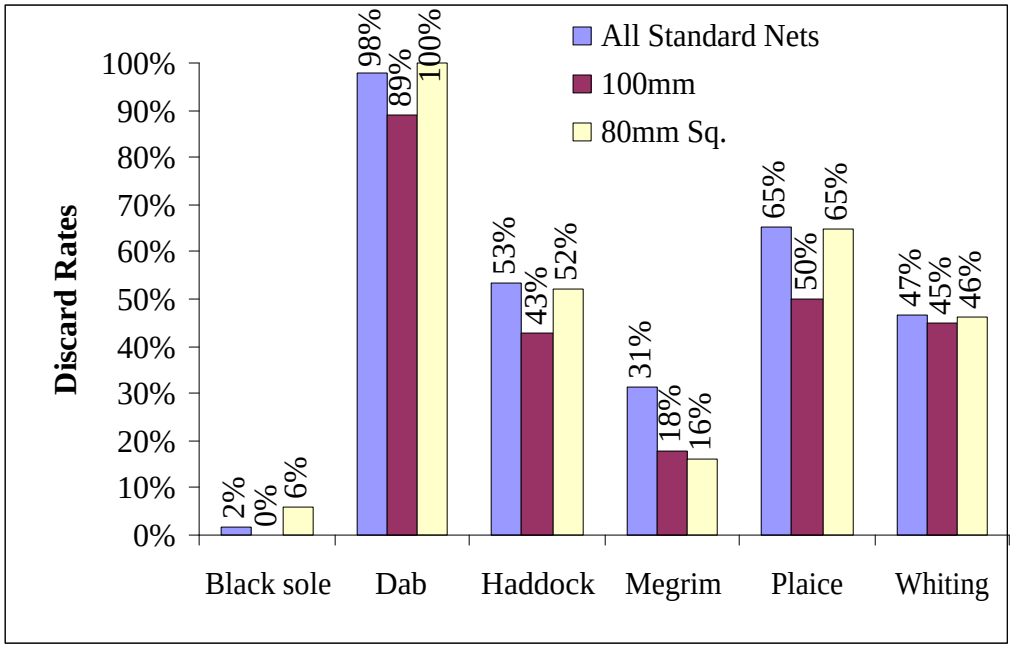


Figure 6.3.2. Average discard rate **(mass discarded/mass caught)** for fishery (all boats using standard nets) compared with the average discard rates obtained using nets with 100mm cod-ends and with 80mm square mesh panels for the whole period of the trials.

7 Discussion.

The objectives of the project, namely:

1. Identify and apply sampling and analytical methods appropriate to the commercial setting,
2. To establish discard rates for the fishery,
3. Investigate the effects of a specific range of technical conservation methods on the landings and discards generated by the fishery were met.

7.1 Development of Sampling Methodology in a Commercial Setting.

7.1.1 Alternate hauls.

During the analysis of the results from the first sampling period it became apparent that even though the area of Dingle Bay fished is not very big there were obvious differences in the types of catches obtained in different areas of the bay and at different times. This is as expected and agrees with the findings of Ehrich et al., (1998). The trawling routes were very much dictated by the prevailing wind direction so it was often difficult to predict or plan a systematic coverage of the bay. For this reason differences in the catch between hauls were quite high and confidence intervals on the data greater than would have been desired. Identifying definitively whether the variation was due to the nets under investigation or due to other factors was difficult. Some variability between hauls is inevitable due to the time difference between tows. Based upon this experience parallel tows were adopted where possible during the second phase of the fieldwork. Despite the limitations valuable data was collected, it is clear that catches in the experimental nets were often lower than those in the standard net.

7.1.2 Parallel Hauls

Two pairs of boats were used in the parallel tows. Due to the fact that many of the towing routes are narrow and bounded by rock it was not always possible to do textbook parallel hauls. In these cases the two skippers made every attempt to cover the same grounds, either by towing in opposite directions or by one vessel following behind and to the side of the other vessel. This type of towing might compromise the intended purpose of parallel hauls, which is that each net is sampling from the same population of fish. To test whether this was the case at the beginning of each of these trials a number of control tows were made with each of the boats towing their experimental nets. It was expected in this configuration that the landings from both boats would be similar. There was no significant difference in either of the control trials although small differences in catch could be seen from the length profile graphs and financial returns, these are summarised in Table 7.1.1.

Table 7.1.2.1. Summary of control parallel hauls. Significant Mann-Whitney results are **bold**, results indicated from length profile graphs in normal text.

Pairing	Boat / Boats	Experimental net	Summary of Effects.
1	Floralie / D.Orchidees	100mm Cod-end	Slightly less haddock and whiting discarded from Deux Orchidees' net. Slightly fewer landings of haddock, plaice and whiting from Deux Orchidees' net. Similar catches.6% difference in value of catch
4	Maid.of.Naz./ Elsie Marie	80mm Square Mesh	Fewer small plaice discarded from Elsie Marie's net Fewer megrim landed from Elsie Marie's net, fewer whiting from Maid of Nazareth's Net. V. similar catches in both nets. 30% difference in value of catch

Based upon this one would have confidence that the method was, to a large degree, effective at eliminating the differences in catch caused by factors external to the boats. The results obtained by the use of parallel tows in this manner were far more encouraging than those from the alternate hauls and the effects observed were more as expected.

7.1.3 Observers

To facilitate the speedy completion of the trial work two observers were required at any one time, one being the author, the other provided by either BIM or the MI. Ideally one person would have been used as the second observer for the whole trials, but since no-one was available to commit to the project for the whole period several observers were employed. In practice too many observers were used, often being drafted in at short notice and only available for a single day. This inevitably, and through no fault of the observers, led on occasion to inconsistent reporting as they became familiar with the sampling protocols. The data from those observers that were available for more than a day was much more uniform and generally of excellent quality.

The sampling of the discard fraction of catches is most prone to problems due to the fact that since it is the last portion of the catch to be measured time constraints may impinge upon the quantity of data recorded, especially on the final tow of the day. As one progresses down the discard sample the fish measured become progressively smaller and smaller. If for any reason, lack of time for instance, the observer is unable to finish the whole box of discards it can lead to an underestimation of the numbers of especially the smaller discards. Maybe a simpler sampling procedure could have been used. One alternative, simpler sampling method has been investigated by Tamsett et al., (1999) where rather than sampling landings and discards separately a random sample of the total catch was taken, separated into landings and discards and measured, the ratio of landings to discards was then used to estimate total discards from the total volume of fish marketable fish at the end of sorting. This would be an advantage in that for the observer at least, the procedure is far simpler; it would however be more disruptive to the normal procedures of the crew and may not have been acceptable to them.

7.2 Effects of Technical Conservation Measures.

7.2.1 Large mesh codends.

Increasing the size of the cod-end of the net has the effect of reducing the numbers of undersized fish landed. This was seen in all of the trials for which useful results were obtained, and in this respect is consistent with the results of other studies (Lowry et al., 1996). There was a decrease in the overall landings associated with the decrease in discards in every trial. There was also a decrease in the value of landings of between 17% and 60%. The effects of each trial are summarised in table 7.2.1.1, the salient points are included in figure 7.2.2.1.

Table 7.2.1.1 Summary of effects of using large mesh cod-ends. Significant Mann-Whitney results are **bold**, results indicated from length profile graphs in normal text.

Pairing	Experimental net	Summary of Effects.
13	100mm Cod-end	Decrease in discards of **whiting** and **haddock** and possibly dab. Decrease in landings of **megrim** and **haddock,** and possibly whiting 40% decrease in value of catch. (Black Sole not measured)
2	100mm Cod-end	Decrease in discards of **dab, plaice, whiting** and black sole and haddock. Decrease in landings of **black sole, whiting**. 17% decrease in value of catch
3	100mm Cod-end	Evidence of decrease in proportion of **black sole, dab, megrim, plaice,** and **whiting.** Decrease in landings of **black sole, megrim** and **whiting** 60% decrease in value of catch, poor catch in experimental net.
7	100mm Cod-end	Evidence of decrease in proportion of small **black sole, whiting,** haddock, plaice and dab Decrease in landings of whiting and black sole 35% decrease in value of catch
8	90mm Cod-end	Evidence of decrease in proportion of small **haddock, whiting** and **dab.** No obviously large decreases on landings for any one species. 34% decrease in value of catch.

Table 7.2.1.2. Summary of results of trials in which large mesh codends were compared with standard mesh codends.

Species	Decrease in Discards	Decrease in Landings	Number of Trials
Whiting	5	4	5
Haddock	4	1	5
Megrim	1	2	5
Black Sole	3	3	4
Plaice	3		5
Dab	4		5

Increasing the size of the codend mesh has reduced the amount of discards for all the species investigated. It is clear that both roundfish and flatfish have an increased chance of escaping from the large mesh codend nets. This is as expected and is in agreement with other studies (Laurenson and Beveridge 1997). The reduction is not however confined to discards. The reduction in landings of whiting, haddock, megrim and black sole has commercial significance, especially in the case of haddock and to an even greater extent black sole. Looking through the length profile graphs and the discard rates of black sole it can be seen that large numbers of discards are exceptional; the standard 80mm cod end selects effectively for legal sized black sole. This is backed up by the selectivity ogive calculated for black sole in trial 7, the L_{50} for the net with the 80mm codend was estimated to be 23.9cm, the legal size of black sole is 24cm, any increases in mesh size will therefore instantly reduce the landings of fish above 23.9 cm. This is seen as the reduction in value of black sole landed in three of the four trials for which sole was measured. Other studies have shown that increasing the codend mesh size from 70mm to 80mm can lead to reductions in catch rate of whiting below 22cm. (Briggs et al., 1999).

The overall reduction in value of catch was between 60% and 17%, due in the main to haddock and black sole.

7.2.2 Square Mesh Panels

The results of these trials were mixed, as can be seen in figures 7.2.2.1 and 7.2.2.2.

Table 7.2.2.1.1 Summary of effects of inserting square mesh panels. Significant Mann-Whitney results are **bold**, results indicated from length profile graphs in normal text.

Pairing	Experimental net	Summary of Effects.
11	80mm Square Mesh	Reduction in discards of **black sole,** small plaice and dab Decrease in landings of megrim and whiting. 10% decrease in value of catch
12	90mm Square mesh	*Increase* in discards of **whiting.** Slight decrease in discards of dab. *Increase* in landings of **whiting** and megrim. Slight decrease in plaice landings. 9% decrease in value of catch. (Black Sole not measured)
5	80mm Square Mesh	Decrease in discards of **whiting** and dab, slight *increase* in black sole, Decrease in landings of **megrim, plaice** and **whiting.** 60% decrease in value of catch: poor overall catch in experimental net.
6	80mm Square Mesh	Decrease in discards of **megrim** and plaice, and decreases in small whiting. Decrease in landings of **black sole and megrim.** *Increase* in **whiting** and **plaice,** (very few plaice caught). 5% increase in value of catch

Table 7.2.2.2: Summary of results of trials in which nets incorporating square mesh panels were compared with standard nets. Pairing 5 is excluded.

Species	Decrease in Discards	Decrease in Landings	Increase in Discards	Increase in Landings	Number Of trials
Whiting	2		1	1	3
Haddock					3
Megrim	1	2		1	3
Black Sole	1	2			3
Plaice	2	1		1	3
Dab	2				3

Some of these results stand out as being unusual. There was an apparent increase in both landings and discards of whiting in the experimental net for Pairing 12, however the catch of whiting in the standard net was low compared with that in similar trial around the same time; the reduction therefore could be due to an unusually low catch of whiting in the standard net. It was decided (see results section 6.2.2.2) that the results from pairing 5 were probably not due to the square mesh panel therefore the results are not used in assessing the tcm feature.

The use of square mesh panels had only a slight effect on the value of landings, which varied from a 10% reduction to a 5% increase. The effect on landings of individual species varied with trials showing both decreases and increases of plaice and megrim landings. There was one case of a decrease in landings of black sole and one case of an increase in whiting. Discards were reduced in half of the cases examined. Unexpectedly most of these reductions were in flatfish species. The only fish showing no reaction during these trials was haddock. Other studies have shown that the introduction of a square mesh panel can increase the numbers of certain species of roundfish escaping from similar trawl nets (Arkley 1990 in Armstrong et al., 1997). It would have been expected that round-fish species such as whiting and haddock would be far more likely to benefit from square mesh panels than the flatfish (Madsen et al., 1999a, van Marlen, 2003. Pairing 12 showed evidence of a reduction in whiting below around 25cm. Madsen et al., (1999a) also found that larger fish had better possibilities of escaping through square mesh panels. In this study there may be evidence of this occurring, for haddock in pairing 6 where there is an apparent dip in the numbers of haddock around 20 to 22cm long, a similar pattern was also seen in pairing 5.

The panels had little effect on overall value of the catch. It is difficult to identify any common patterns. Other studies have also had difficulties in finding significant differences in catches with square mesh panels, Bullough et al., (2001) undertook 92 tows totalling 784 hours using one boat towing a twin trawl net. A comparison was made of a standard cod-end to one with a 90mm square mesh panel. Cod, haddock, whiting and angler were examined, only whiting showed a significant difference between nets. It has been postulated elsewhere

(Briggs et al., 1999) that with boats of the size and power of those used in this trails that during hauling the net can settle onto the seabed. When this occurs the diamond meshes of the net open more than they would during the tow allowing fish to escapes from a large area of the net. If this were the case here then it would be expected that the effect of the square mesh panels would have been masked due to the fact that the 80mm diamond mesh would then have a very similar opening as the 80mm square mesh.

7.2.3 Other TCM Features.

The summary of results from the other trials is presented below (table 7.2.3.1). Both of these trials were conducted using alternate tows.

7.2.3.1 Summary of effects of net modifications on catches. Significant Mann-Whitney results are **bold**, results indicated from length profile graphs in normal text.

Pairing	Experimental net	Summary of Effects.
14	Separator Trawl	Decrease in discards of **black sole**, plaice and dab and an increase in **whiting**. Decrease in landings of **black sole** and plaice, an *increase* in whiting and megrim Increase in quality of catch. 39% decrease in value of catch.
15	Large Mesh coversheet	Slight decrease in **black sole**, plaice and dab discards. Decrease in landings of black sole. 16% increase in value of landings in experimental net.

The separator trawl had the effect of decreasing discards for some species whilst increasing discards of others; this was accompanied by a loss of revenue. Much more intensive sampling with this net would really be required to fully investigate the usefulness of this net in the fishery. The net has two cod-ends, both of which need to be sampled from, ideally two observers would be employed on the boat to accomplish this. Catches in the two cod-ends could then be compared. Altering the mesh size of one or the other cod-ends could then be investigated, as could the effect of altering the mesh size of the separator sheet. This would constitute a study in it's own right, but was beyond the scope of this study.

The large mesh cover sheet used in pairing 15 had very minimal effect on the catches retained. Discard and catch numbers were similar. The value of the catch increased.

7.2.4 Discard Rates.

The discards rates for most species were found to be very high for all nets used. They are within the range expected from other studies. Alverson et al., (1994) compiled overall discards rates for global fisheries. Discard rates for the 20 fisheries with the highest discard ratios by numbers for the period 1988 to 1990 were given. These included non-pelagic trawling for haddock, plaice and whiting in the NE Atlantic. The average discard rate for whiting was 73% (Alverson et al., 1994) compared to a rate of 66% found here for the standard trawl, and 56% and 63% for the large mesh codends and the square mesh panel respectively. It can be seen that in all cases the rates are lower then in the bay than in those recorded by Alverson et al., (1994)

For haddock the rate of 67% in Alverson et al., (1994) compares with rates of 78%, 61% and 75% found here for standard net, large mesh cod ends and square mesh panels respectively. Again the rates are all similar to one another. It can be seen that the use of large mesh cod-ends brings the rate below that reported by Alverson et al., (1994).

Discard rates for plaice are very much higher in this fishery however compared with Alverson et al., (1994). Discard rates of 84%, 63% and 86% were found for standard net, large mesh cod ends and square mesh panels respectively, compared with a rate of 30% in Alverson et al., (1994). This very high rate for all net types in the bay could reflect the importance of the grounds being fished as a nursery and on growing area for plaice.

7.2.5 Survival of Escapees and Discards.

The survival of discards and escapees depends upon many factors such as the species involved, size of the individual, the bulk of the catch, the species

composition of the catch, and the type of gear used as well as the onboard handling (Alverson et al., 1994); for fish that become trapped at the surface due to expansion of their air bladder survival rates are probably very low, maybe as low as 2%. Survival of discards from beam trawling is estimated to be less than 10%; survival from otter trawls is slightly higher than that in the beam trawl. Longer tows result in higher mortality rates; escapees from nets fare slightly better than discards with around 40% of sole escaping from beam trawls surviving (van Beek, van Leeuwen and Rijnsdorp 1989). Sangster et al., (1996) found survival rates for haddock and whiting escaping from 70mm to 110mm cod-ends was not related to mesh size. The rates were of 48-79% for haddock and 52-86% for whiting. Other studies looking at survival rates for cod and pollock have found mortality rates close to zero (Haliday and Pinhorn, 2002). Larger fish seem to have better chances of survival then smaller fish of the same species. The level of mortality will inevitably vary greatly according to the sizes of fish in the population, in areas where there are high concentrations of small fish are there may be substantial mortalities even when large mesh nets are employed. Lowry et al., (1996) concluded that increasing cod–end mesh size would reduce the number of discards and increase the survival rate of the escapees as there would be more large fish escaping, but that the small escapees would still have a high mortality. In addition to the direct mortality caused by contact with the net there may be an additional mortality associated with the behavioural impairment of escaped fish due to the stress of being in the net (Ryer et al,, 2004).

7.2.6 Effect on Fishery of using TCMs

It is clear that the 100mm cod ends are far more effective at reducing discards than the square mesh panels. However there is a large decrease in the value of landings associated with the larger cod-ends as marketable sized fish also escape, this amounted to between 14% and 60% decreases in value in the large mesh cod ends. In the short term this would mean an inevitable loss to the income of fishers. It would be expected that this loss would be recouped in the medium to long term as the surviving fish having grown would be retained in the nets at some later date (Laurenson and Beveridge, 1997). Whether they are

there or not at that stage would depend on several factors including their survival rates subsequent to escaping, how many times they enter and escape from trawls, the life history of the species (migration) and whether anyone else using less selective gear enters the bay and catches them. In light of this, making predictions of the medium or long term financial implications based solely on information gathered in this project would be speculative. However if larger mesh cod-ends were employed initial short-term reductions in landings would undoubtedly cause difficulties not only for fishers but also for processors and their employees, increasing returns in subsequent years would reduce this problem. Predicting whether the ultimate outcome of introducing lager mesh cod ends would be a more profitable fishery would require a more intensive investigation focused on fewer net types and involving a commitment to monitor the fishery over a number of years.

Square mesh panels would have much less effect on the income of fishers. Loss of revenue was mush less using these nets. Indeed one of the nets here increased the value of landings by 5%, the net from that trial did this whilst decreasing the numbers of discards and was still being used by the fisherman as his preferred net after the trial period was over. If indeed these have a positive effect on the levels of discarding as has been shown for certain species the square mesh panel would be a much more acceptable management tool.

7.2.7 Estimating Selectivity Ogives From Catch curves.

As has been mentioned earlier in this document no small mesh cod-end covers or small mesh cod-ends were used during the trails, it was therefore not possible to calculate L_{50}'s and selectivity ogives from a direct comparison of the catch in an experimental net and the true population. It has however been shown that it is possible to use the catch curve to estimate the selectivity. The results obtained show an increase in the L_{50} with increasing mesh size and a wider selection range is seen with the large mesh cod-end. This analysis was carried out on black sole because for this species the catch curves do not show strong peaks for each age cohort as are evident in both haddock and whiting data. This means

they occur in sufficient numbers over the whole range of lengths caught to allow the comparisons between observed catch and estimated catch to be carried out. Even so for the standard net the regression to calculate the estimated selection curve are based on only three pairs of data points. Whilst not necessarily the best method for finding L_{50}, this method is obviously useful to give an indication of how a net is behaving.

As was mentioned earlier this method should be treated with some reservations as it is based upon the assumption that mortality rate is the same for fish of all ages (Sparre, 1992).

8 Conclusion

The discard rates obtained for the all measured species using the standard nets show that for dab, haddock, plaice, and whiting the number of fish are returned to the sea are more than the numbers landed. The fishery is clearly not very efficient at selecting the target catch of these species and any reduction in discard rates would be advantageous.

When the different trials are examined separately it is obvious that there is a great deal of variation in the results obtained from each separate trial. It was identified that results obtained from parallel hauls were found to be more reliable that those from alternate hauls.

It can be seen that overall the use of 100mm cod-end reduces the discard rates for all of the species measured both in terms of numbers and mass, however those boats with the larger cod-ends also had a greater reduction in the value of their catch. The boats with nets with 80mm square mesh panels also had reduced discard levels but the loss of revenue was not as great. The overall discard rates achieved with these technical conservation measures are still higher than 50% in terms of numbers for most species.

The skippers and crews have been intimately involved with all aspects of the project. Through the use of the nets, handling the catch and selling the landings they have formed and voiced their own opinions concerning the usefulness and economic viability of using the TCM features we have investigated.

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Appendices

Appendix A: Datasheets.

The sheets in this appendix were used to record data on each of the fishing trips.

Table A1: Haul data sheet

Observer:	

Trip Details:	
Departure Time	
Boat Name	
Gear Used	
Haul Date	

Haul Details	
Wind Direction and Force	
Swell (mi and Direction	
Sea State	
Ground Type	
Location (if it has a name)	
Sea Visibility (m)	
Speed Of Tow	

Time Shot (24 hr clock)	
Depth shot (fathoms)	
Lat Shot (N)	
Long Shot (W)	

Time hauled (24 hr clock)	
Depth hauled (fathoms)	
Lat hauled (N)	
Long hauled (W)	
Duration ofTow (min)	

Total Bulk (boxes)	
Total Lardings (boxes)	
Total Discards (boxes)	
Landings Measured (boxes)	
Discards Measured (boxes)	

Haul Code:	/DIN/02/

Observer/ Din / 01 /Haul No.

LANDINGS

Species	Number of Boxes
Hake	
Cod	
Haddock	
Plaice	
Whiting	
Megrim	
Black Sole	
Dab	
Anglerfish	
Turbot	
Brill	
Lemon Sole	
Sand Sole	
Ling	
John Dory	
Ray	
Squid	
M. Rounds	
M.Flats	
TOTAL	

DISCARDS

Species	Number of Boxes
LS. Dogs	
Crust.	
Others	
TOTAL	

Comments

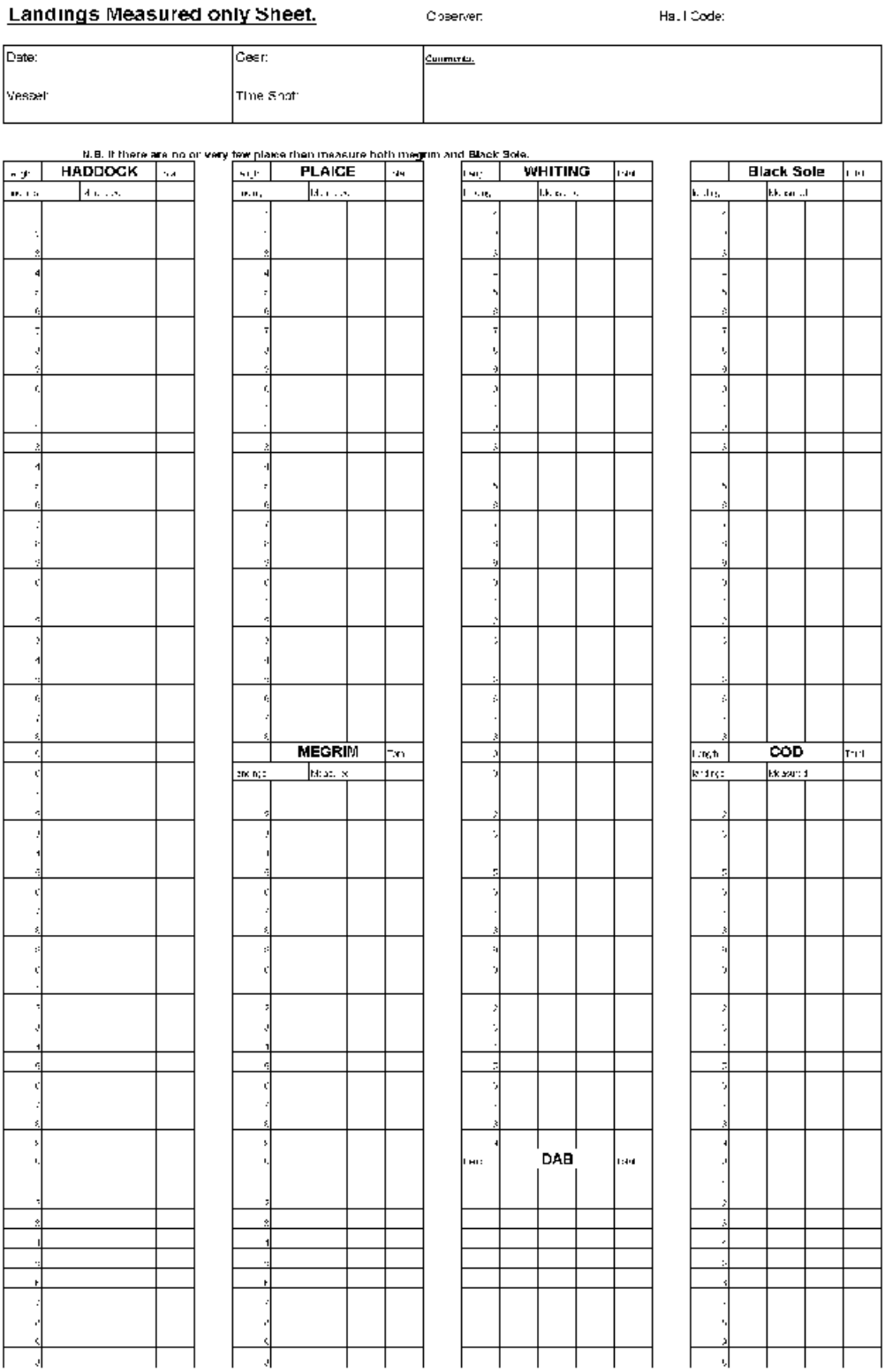


Figure A2: Landings Datasheet

Discards Measured only Sheet.

Observer: ____________ Haul Code: ____________

Date:	Gear:	Comments:
Vessel:	Time Shot:	

Depth of Non-Fish discards	

Death of Non-Commercial discards	

Length	[illegible]		

Table A3: Discards Datasheet

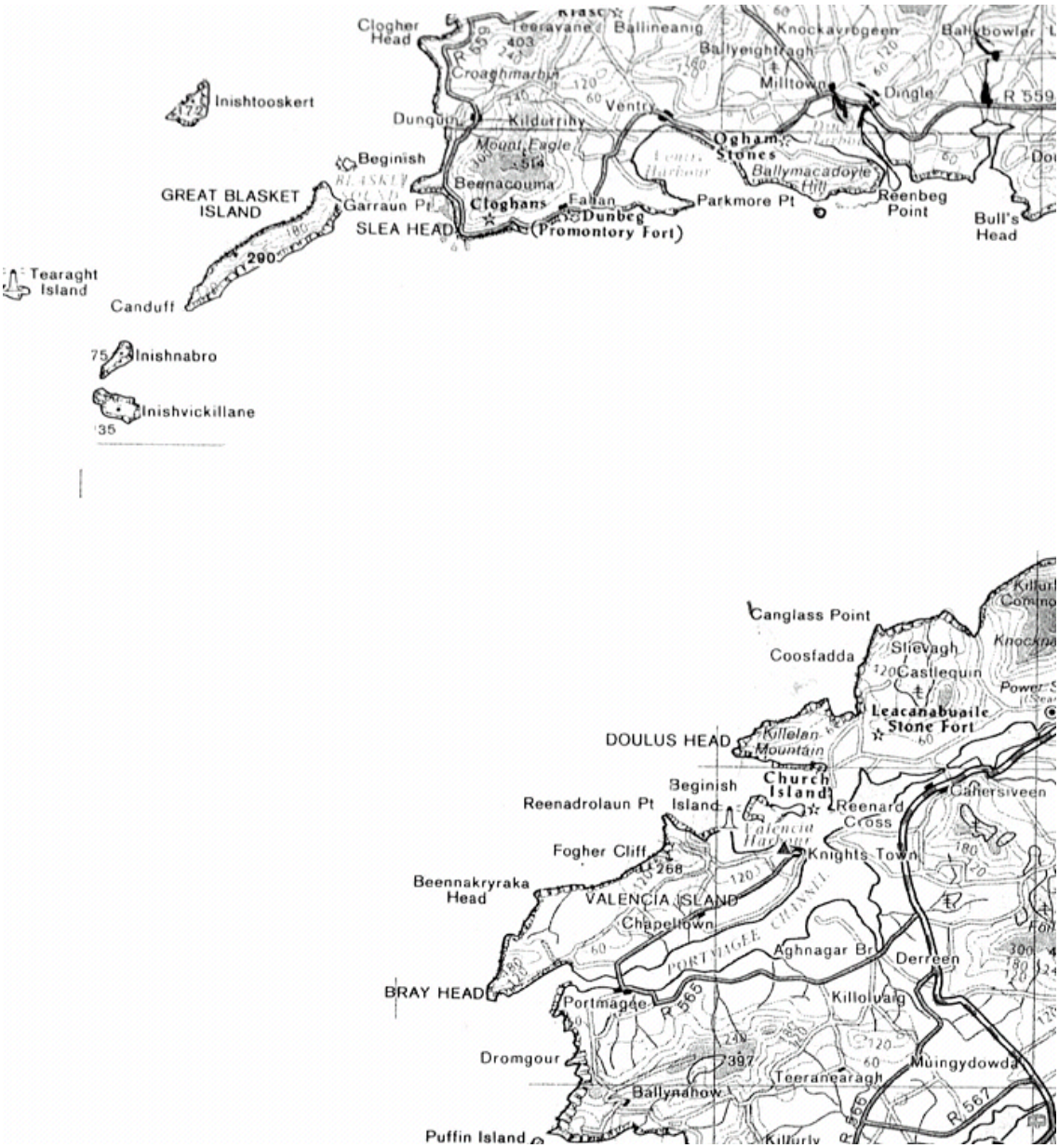


Figure A1 Map for recording tow routes.

Appendix B: Net Details.

Details of net design. The following diagrams show the basic designs of the nets containing the tcm features. The warp length to depth ratio used was 3:1 throughout. The same nets were used for both years, though some were modified for the second year by removal or insertion of mesh panels and changing cod-ends.

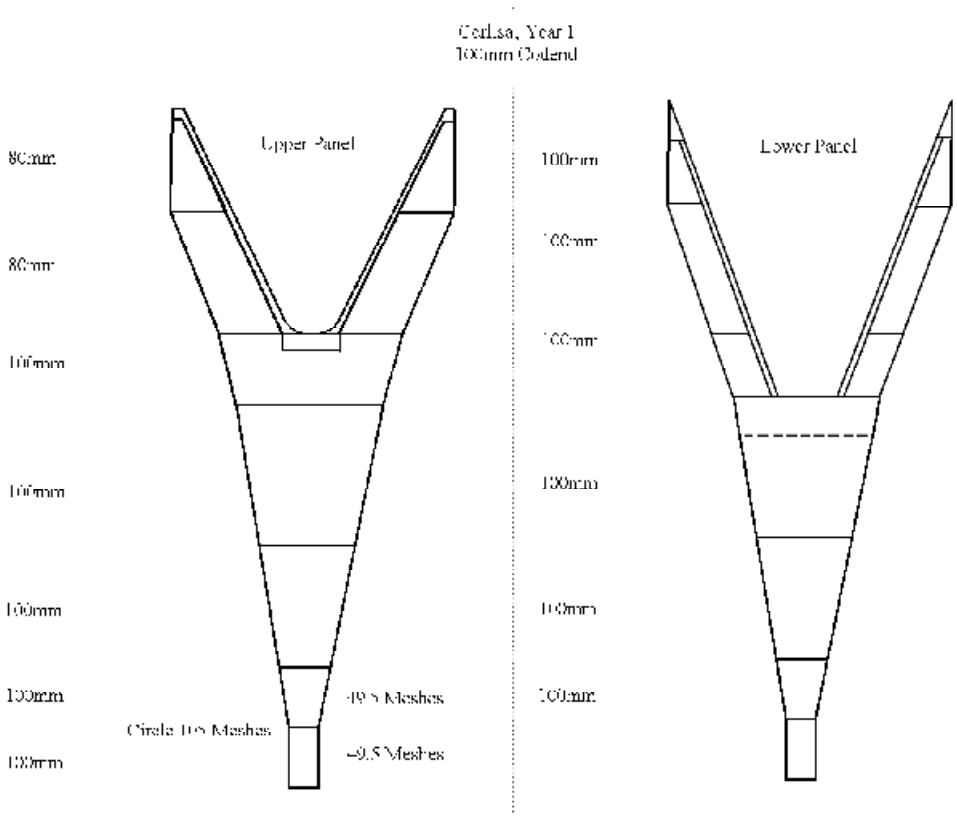


Figure B.1 Experimental net for Gerlisa, 100mm cod-end in firs year was changed for a 90mm cod-end in second year.

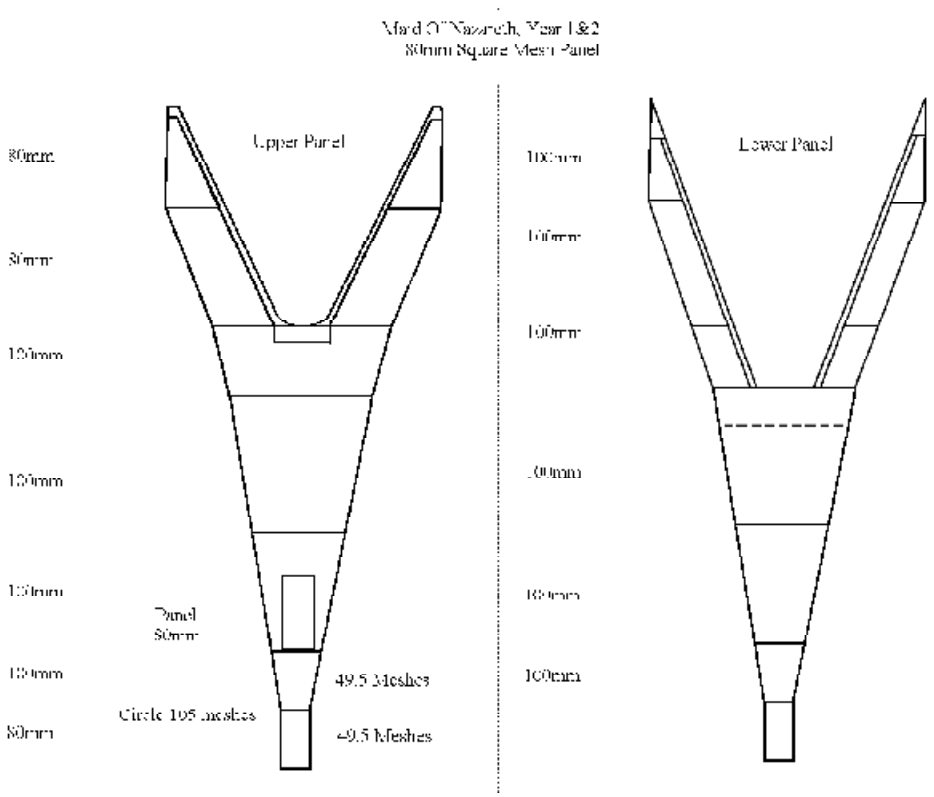


Figure B.2. Net for Maid of Nazareth. Same net used for whole trial period.

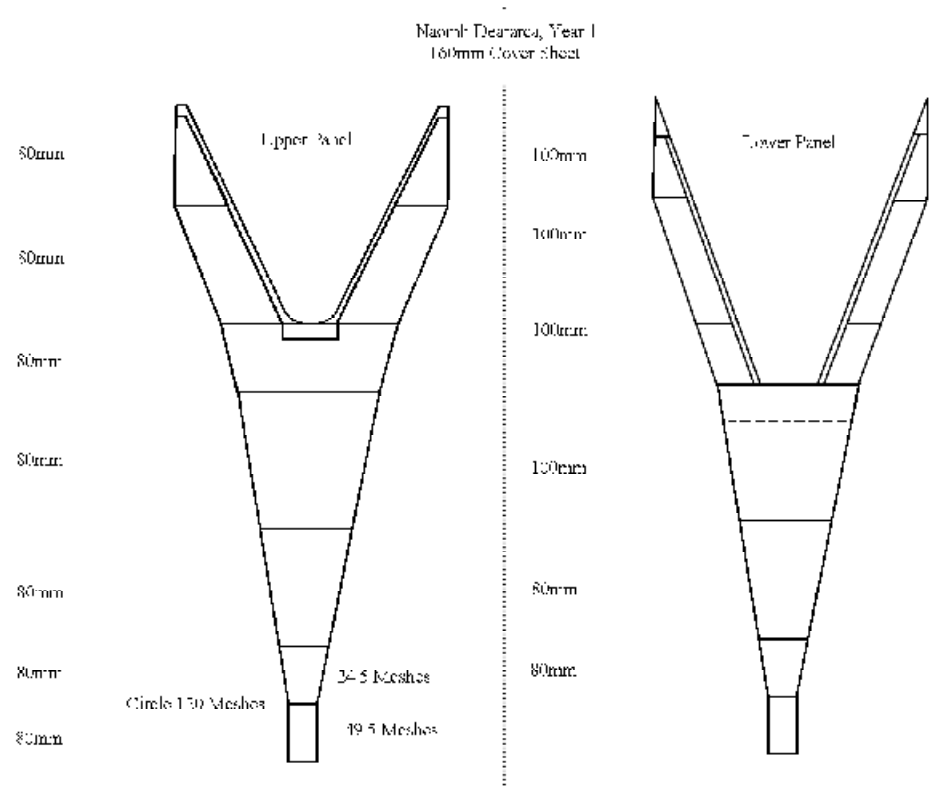
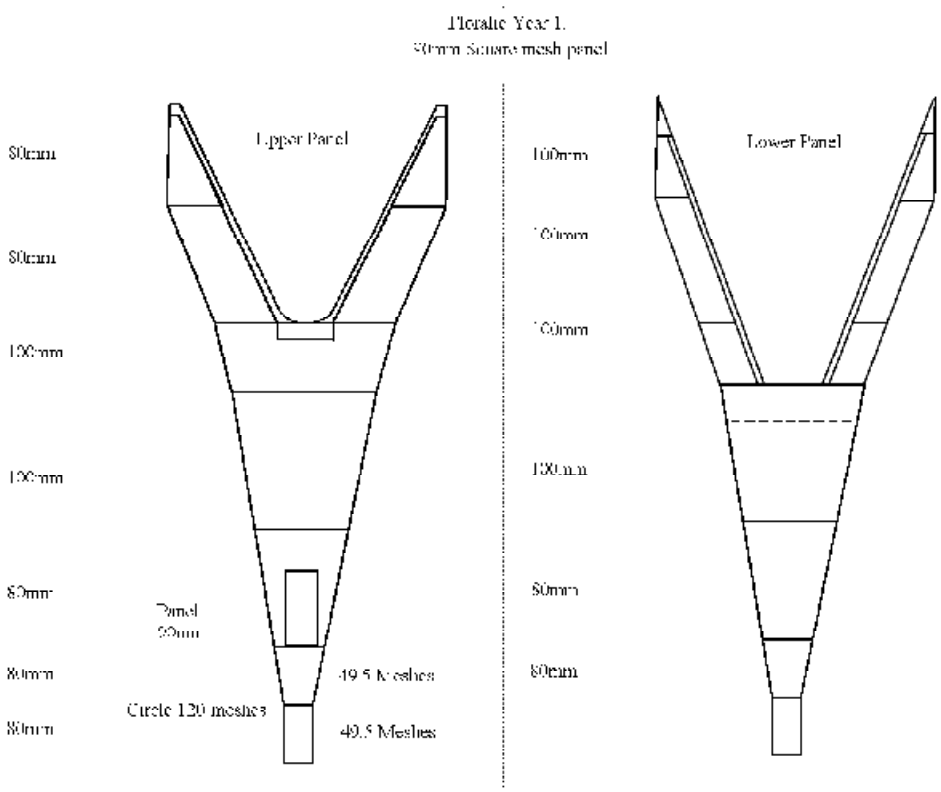


Figure B.3. Experimental net for Naomh Deararca. For second year 80mm cod-end was replaced with 100mm.



B.4. Experimental net for Floralie, for second year square mesh panel was replaced with standard netting and a 100mm cod-end was attached.

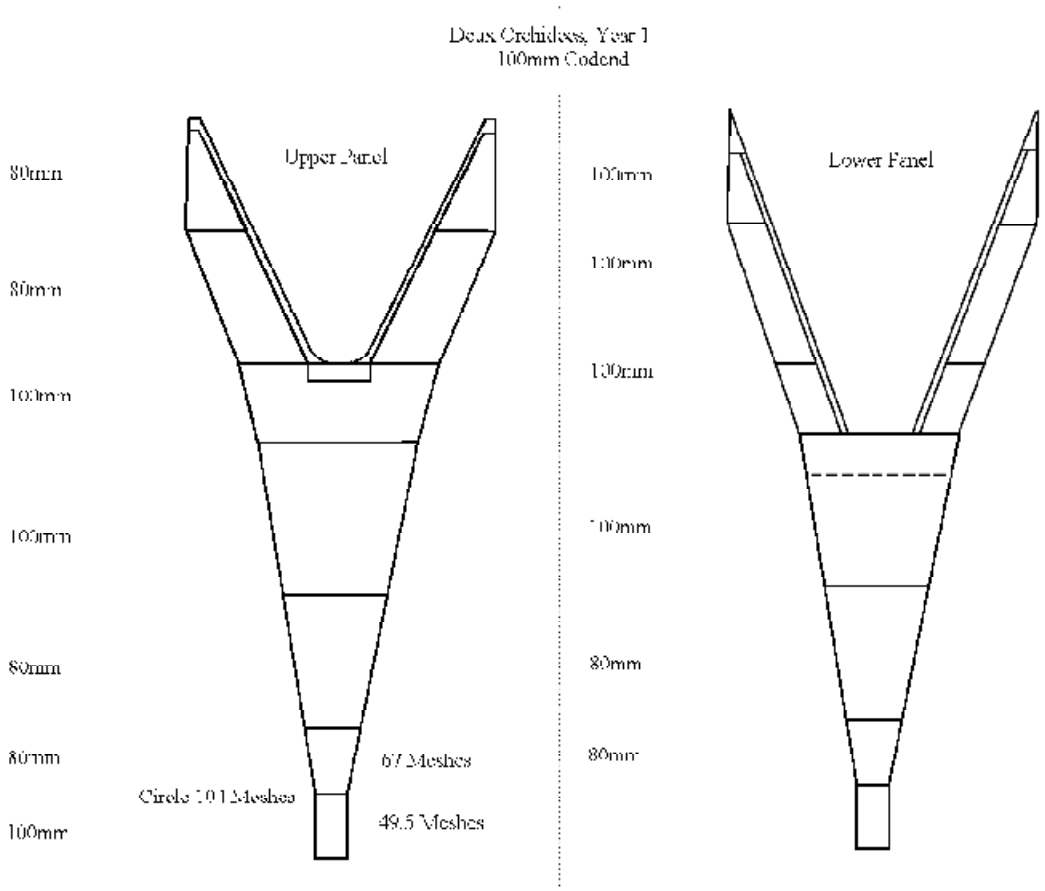


Figure B.5. Experimental net for Deux Orchidees, Same Net was used both years.

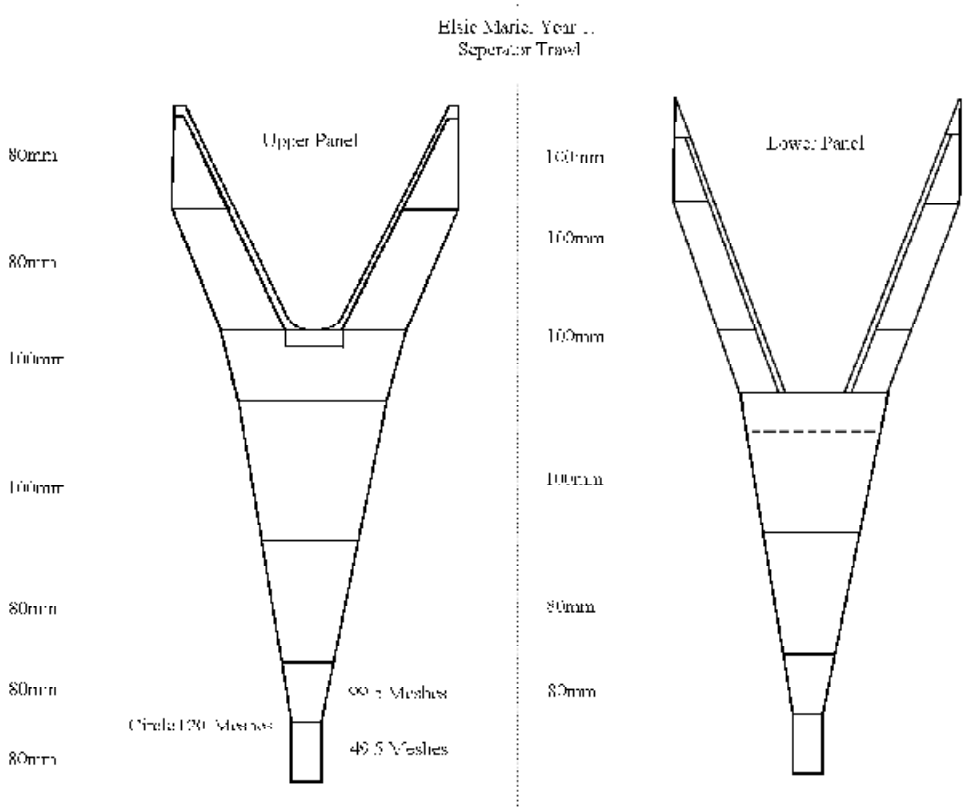


Figure B.6 Experimental Net for Elsie Marie, separator Panel was inserted 99.5 meshes above cod-end.

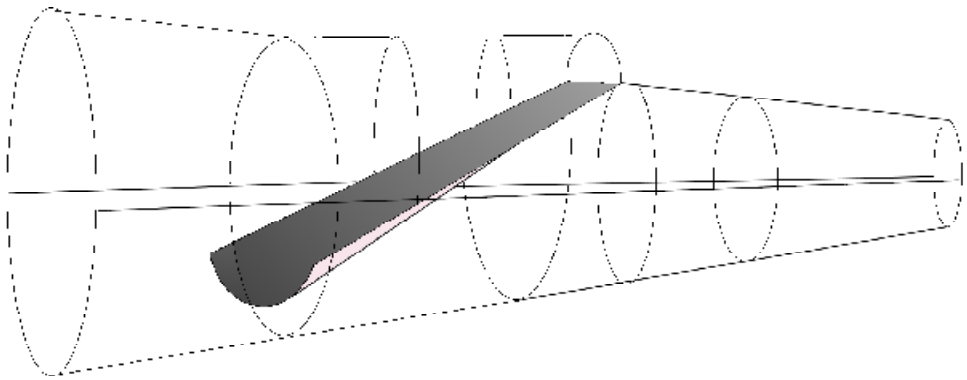


Figure B.7. Separator trawl. Separator panel and both cod-ends were all 80mm diamond mesh.

	Vessel	Elsie Marie		Naomh Dearaca		Floralie	
	Gear	Seperator	80mm Sq	160mm covershee	100 codend	90mm Sq	100mm Codend
	Vessel Type						
	Length (ft)	65		50		60	
	GRT						
	Engine Power	500 HP		150 HP		280 HP	
Otterboards	Type	Tymborn		Bison 44"		Kikeel 63"	
	Size	7'					
	Foot rope	45 fth	45 fth	24 fth	24 fth	32fth	32 fth
Codend	Mesh Size	80mm	80mm	80mm	100mm	80mm	100mm
	No of Open Meshes Round	120	120	120	105	120	105
	Codend Lenghth (No. meshes)	49.5	49.5	24.5	24.5	49.5	49.5
	Mesh Type	Diamond	Diamond	Diamond	Diamond	Diamond	Diamond
	No. of Selvedges	2	2	2	2	2	2
	Codend Material	Compact	Compact	Compact	Compact	Compact	Compact
	Knotted/ Knotles	Knotted	Knotted	Knotted	Knotted	Knotted	Knotted
	Twine Type						
	Twisted/ Braided	Braided	Braided	Braided	Braided	Braided	Braided
	Single/ Double Twine	Single	Single	Single	Single	Single	Single
	Twine Diameter	4mm	4mm	4mm	4mm	4mm	4mm
	Twine Colour	Green	Green	Green	Green	Green	Green
Square mesh panels	Mesh Type		Ultracross			Ultracross	
	Position		49.5 meshes above codend extension.			49.5 meshes above codend e:	
	Size		3m x3m.			3m x3m.	
	Mesh Opening		80mm			90mm	
	Netting Material		Composite			Composite	
	Thickness		4mm			4mm	
	Knotted/ knotless		Knotless			Knotless	
	Twisted/Braided		Braided			Braided	
	Single/ Doublle Strand		Single			Single	
	Twine Colour		Black			Black	

FigureB.8. Details of experimental net construction.

	Vessel	Deux Orchidees	Maid Of Nazareth	Gerlisa
	Gear	100mm Cod-en	80mm Square mes	100mm Codend
	Vessel Type			
	Length (ft)	50	65	65
	GRT			
	Engine Power	425 HP	440-500 HP	440-500 HP
Otterboards	Type	Dunbar 6'	Tyboom 7'	Kilkee 16'
	Size			
	Foot rope	25 fth	45 fth	40 fth
Codend	Mesh Size	100mm	80mm	100mm
	No of Open Meshes Round	104	105	105
	Codend Lenghth (No. meshes)	67	49.5	49.5
	Mesh Type	Diamond	Diamond	Diamond
	No. of Selvedges	2	2	2
	Codend Material	Compact	Compact	Compact
	Knotted/ Knotles	Knotted	Knotted	Knotted
	Twine Type			
	Twisted/ Braided	Braided	Braided	Braided
	Single/ Double Twine	Single	Single	Single
	Twine Diameter	4mm	4mm	4mm
	Twine Colour	Green	Green	Green
Square mesh panels	Mesh Type		Ultracross	
	Position		49.5 meshes above codend extension	
	Size		3m x3m.	
	Mesh Opening		80mm	
	Netting Material		Composite	
	Thickness		4mm	
	Knotted/ knotless		Knotless	
	Twisted/Braided		Braided	
	Single/ Doublle Strand		Single	
	Twine Colour		Black	

Figure B.9. Details of Experimental net construction

Appendix C: Valid Tows.

The following list details those tows that were used in the data analysis.

Boat Name	Date	Gear Code	Pairing	Haul Duration	Depth shot (m)	Observer
Elsie Marie	16-Sep-02	Standard	6	210	36	Eoghan Slattery
Elsie Marie	16-Sep-02	Standard	6	180	75	Eoghan Slattery
Elsie Marie	16-Sep-02	Standard	6	180	84	Eoghan Slattery
Elsie Marie	19-Sep-02	Experimental	5	180	36	Eoghan Slattery
Elsie Marie	19-Sep-02	Experimental	5	170	73	Eoghan Slattery
Elsie Marie	19-Sep-02	Experimental	5	180	84	Eoghan Slattery
Elsie Marie	19-Sep-02	Experimental	5	170	58	Eoghan Slattery
Elsie Marie	20-Sep-02	Experimental	5	180	40	Huan Tan
Elsie Marie	20-Sep-02	Experimental	5	170	69	Huan Tan
Elsie Marie	20-Sep-02	Experimental	5	170	86	Huan Tan
Elsie Marie	20-Sep-02	Experimental	5	180	71	Huan Tan
Deux Orchidees	16-Aug-02	Standard	2	192	36	Huan Tan
Deux Orchidees	16-Aug-02	Standard	2	195	36	Huan Tan
Deux Orchidees	16-Aug-02	Standard	2	180	64	Huan Tan
Deux Orchidees	19-Aug-02	Experimental	1	180	46	Huan Tan
Deux Orchidees	19-Aug-02	Experimental	1	190	36	Huan Tan
Deux Orchidees	19-Aug-02	Experimental	1	180	36	Huan Tan
Deux Orchidees	21-Aug-02	Experimental	3	180	55	Huan Tan
Deux Orchidees	21-Aug-02	Experimental	3	180	82	Huan Tan
Deux Orchidees	21-Aug-02	Experimental	3	180	73	Huan Tan
Deux Orchidees	01-Aug-02	Experimental	3	195	33	Lorcan O'Cinneide
Deux Orchidees	01-Aug-02	Experimental	3	195	64	Lorcan O'Cinneide
Deux Orchidees	01-Aug-02	Experimental	3	180	78	Lorcan O'Cinneide
Elsie Marie	10-Sep-02	Experimental	4	180	38	Lorcan O'Cinneide
Elsie Marie	10-Sep-02	Experimental	4	165	55	Lorcan O'Cinneide
Elsie Marie	10-Sep-02	Experimental	4	125	53	Lorcan O'Cinneide
Elsie Marie	17-Sep-02	Standard	6	210	60	Lorcan Slattery
Elsie Marie	17-Sep-02	Standard	6	180	86	Lorcan Slattery
Elsie Marie	17-Sep-02	Standard	6	195	87	Lorcan Slattery
Elsie Marie	18-Sep-02	Standard	6	190	73	Lorcan Slattery
Elsie Marie	18-Sep-02	Standard	6	180	84	Lorcan Slattery
Deux Orchidees	24-Jul-02	Standard	2	188	36	Macdara O'Cuaig
Deux Orchidees	24-Jul-02	Standard	2	178	35	Macdara O'Cuaig
Deux Orchidees	24-Jul-02	Standard	2	184	33	Macdara O'Cuaig
Deux Orchidees	25-Jul-02	Experimental	3	189	33	Macdara O'Cuaig
Deux Orchidees	25-Jul-02	Experimental	3	187	62	Macdara O'Cuaig
Deux Orchidees	25-Jul-02	Experimental	3	182	67	Macdara O'Cuaig
Deux Orchidees	30-Jul-02	Experimental	1	184	33	Macdara O'Cuaig
Deux Orchidees	30-Jul-02	Experimental	1	182	40	Macdara O'Cuaig
Deux Orchidees	30-Jul-02	Experimental	1	183	31	Macdara O'Cuaig
Deux Orchidees	31-Jul-02	Standard	2	183	33	Macdara O'Cuaig
Deux Orchidees	31-Jul-02	Standard	2	184	51	Macdara O'Cuaig
Deux Orchidees	31-Jul-02	Standard	2			Macdara O'Cuaig
Floralie	27-Oct-01	Experimental	12	210	36	Neil Cullen
Floralie	27-Oct-01	Experimental	12	225	38	Neil Cullen
Floralie	28-Oct-01	Experimental	12	265	38	Neil Cullen
Floralie	28-Oct-01	Experimental	12	210	37	Neil Cullen

Boat Name	Date	Gear Code	Pairing	Haul Duration	Depth shot (m)	Observer
Floralie	31-Oct-01	Standard	12	185	40	Neil Cullen
Floralie	31-Oct-01	Standard	12	155	38	Neil Cullen
Floralie	01-Nov-01	Standard	12	215	35	Neil Cullen
Floralie	01-Nov-01	Standard	12	235	62	Neil Cullen
Floralie	02-Nov-01	Experimental	12	240	40	Neil Cullen
Floralie	02-Nov-01	Experimental	12	215	75	Neil Cullen
Floralie	03-Nov-01	Experimental	12	220	42	Neil Cullen
Floralie	03-Nov-01	Experimental	12	195	51	Neil Cullen
Floralie	04-Nov-01	Experimental	12	220	35	Neil Cullen
Floralie	04-Nov-01	Experimental	12	225	42	Neil Cullen
Floralie	05-Nov-01	Experimental	12	213	35	Neil Cullen
Floralie	05-Nov-01	Experimental	12	168	35	Neil Cullen
Floralie	09-Nov-01	Standard	12	234	35	Neil Cullen
Floralie	09-Nov-01	Standard	12	225	51	Neil Cullen
Floralie	10-Nov-01	Standard	12	245	42	Neil Cullen
Floralie	10-Nov-01	Standard	12	225	44	Neil Cullen
Gerlisa	11-Nov-01	Experimental	13	235	40	Neil Cullen
Gerlisa	11-Nov-01	Experimental	13	240	78	Neil Cullen
Gerlisa	12-Nov-01	Experimental	13	250	36	Neil Cullen
Gerlisa	12-Nov-01	Experimental	13	225	73	Neil Cullen
Gerlisa	13-Nov-01	Standard	13	245	62	Neil Cullen
Gerlisa	13-Nov-01	Standard	13	240	82	Neil Cullen
Gerlisa	14-Nov-01	Standard	13	265	58	Neil Cullen
Gerlisa	14-Nov-01	Standard	13	240	87	Neil Cullen
Gerlisa	15-Nov-01	Experimental	13	240	62	Neil Cullen
Gerlisa	15-Nov-01	Experimental	13	520	76	Neil Cullen
Gerlisa	16-Nov-01	Standard	13	285	73	Neil Cullen
Gerlisa	16-Nov-01	Standard	13	265	86	Neil Cullen
Gerlisa	16-Nov-01	Standard	13	240	118	Neil Cullen
Gerlisa	16-Nov-01	Standard	13	335	100	Neil Cullen
Deux Orchidees	22-Nov-01	Standard	16	105	44	Neil Cullen
Deux Orchidees	22-Nov-01	Standard	16	220	58	Neil Cullen
Deux Orchidees	23-Nov-01	Experimental	16	210	58	Neil Cullen
Deux Orchidees	23-Nov-01	Experimental	16	210	92	Neil Cullen
Deux Orchidees	24-Nov-01	Standard	16	150	44	Neil Cullen
Deux Orchidees	24-Nov-01	Standard	16	135	58	Neil Cullen
Naomh Deararca	26-Nov-01	Standard	15	180	36	Neil Cullen
Naomh Deararca	26-Nov-01	Standard	15	170	38	Neil Cullen
Naomh Deararca	06-Dec-01	Experimental	15	170	47	Neil Cullen
Naomh Deararca	06-Dec-01	Experimental	15	175	40	Neil Cullen
Maid of Nazareth	23-Oct-01	Experimental	11	325	55	Tony Holmes
Maid of Nazareth	23-Oct-01	Experimental	11	245	64	Tony Holmes
Maid of Nazareth	27-Oct-01	Standard	11	240	49	Tony Holmes
Maid of Nazareth	27-Oct-01	Experimental	11	240	55	Tony Holmes
Maid of Nazareth	31-Oct-01	Experimental	11	215	41	Tony Holmes
Maid of Nazareth	31-Oct-01	Experimental	11	230	36	Tony Holmes
Maid of Nazareth	01-Nov-01	Experimental	11	260	49	Tony Holmes
Maid of Nazareth	01-Nov-01	Standard	11	245	79	Tony Holmes

Boat Name	Date	Gear Code	Pairing	Haul Duration	Depth shot (m)	Observer
Maid of Nazareth	02-Nov-01	Standard	11	230	58	Tony Holmes
Maid of Nazareth	02-Nov-01	Standard	11	180	84	Tony Holmes
Maid of Nazareth	03-Nov-01	Experimental	11	230	36	Tony Holmes
Maid of Nazareth	03-Nov-01	Experimental	11	220	49	Tony Holmes
Maid of Nazareth	05-Nov-01	Experimental	11	240	36	Tony Holmes
Maid of Nazareth	05-Nov-01	Experimental	11	180	46	Tony Holmes
Maid of Nazareth	09-Nov-01	Experimental	11	225	42	Tony Holmes
Maid of Nazareth	09-Nov-01	Experimental	11	225	55	Tony Holmes
Maid of Nazareth	10-Nov-01	Standard	11	240	35	Tony Holmes
Maid of Nazareth	10-Nov-01	Standard	11	220	40	Tony Holmes
Maid of Nazareth	11-Nov-01	Standard	11	245	36	Tony Holmes
Maid of Nazareth	11-Nov-01	Standard	11	245	55	Tony Holmes
Elsie Marie	12-Nov-01	Experimental	14	255	36	Tony Holmes
Elsie Marie	12-Nov-01	Experimental	14	240	55	Tony Holmes
Elsie Marie	13-Nov-01	Standard	14	240	36	Tony Holmes
Elsie Marie	13-Nov-01	Standard	14	110	44	Tony Holmes
Elsie Marie	14-Nov-01	Experimental	14	250	66	Tony Holmes
Elsie Marie	14-Nov-01	Experimental	14	210	86	Tony Holmes
Elsie Marie	15-Nov-01	Experimental	14	245	46	Tony Holmes
Elsie Marie	15-Nov-01	Experimental	14	260	82	Tony Holmes
Elsie Marie	22-Nov-01	Standard	14	245	29	Tony Holmes
Elsie Marie	22-Nov-01	Standard	14	95	62	Tony Holmes
Elsie Marie	23-Nov-01	Experimental	14	255	64	Tony Holmes
Elsie Marie	23-Nov-01	Experimental	14	195	86	Tony Holmes
Naomh Deararca	10-Dec-01	Standard	15	180	51	Tony Holmes
Naomh Deararca	10-Dec-01	Standard	15	185	49	Tony Holmes
Naomh Deararca	11-Dec-01	Standard	15	252	80	Tony Holmes
Naomh Deararca	11-Dec-01	Standard	15	185	66	Tony Holmes
Naomh Deararca	12-Dec-01	Experimental	15	240	49	Tony Holmes
Naomh Deararca	12-Dec-01	Experimental	15	210	56	Tony Holmes
Naomh Deararca	17-Dec-01	Experimental	15	180	47	Tony Holmes
Naomh Deararca	17-Dec-01	Experimental	15	235	75	Tony Holmes
Naomh Deararca	18-Dec-01	Standard	15	225	46	Tony Holmes
Naomh Deararca	18-Dec-01	Standard	15	90	51	Tony Holmes
Naomh Deararca	08-Jan-02	Experimental	15	270	47	Tony Holmes
Naomh Deararca	08-Jan-02	Experimental	15	230	58	Tony Holmes
Floralie	24-Jul-02	Experimental	2	120	39	Tony Holmes
Floralie	24-Jul-02	Experimental	2	120	39	Tony Holmes
Floralie	24-Jul-02	Experimental	2	120	55	Tony Holmes
Floralie	25-Jul-02	Standard	3	120	40	Tony Holmes
Floralie	25-Jul-02	Standard	3	115	55	Tony Holmes
Floralie	25-Jul-02	Standard	3	125	60	Tony Holmes
Floralie	30-Jul-02	Experimental	1	125	38	Tony Holmes
Floralie	30-Jul-02	Experimental	1	120	42	Tony Holmes
Floralie	30-Jul-02	Experimental	1	120	36	Tony Holmes
Floralie	31-Jul-02	Experimental	2	180	38	Tony Holmes
Floralie	31-Jul-02	Experimental	2	120	42	Tony Holmes
Floralie	31-Jul-02	Experimental	2			Tony Holmes

Boat Name	Date	Gear Code	Pairing	Haul Duration	Depth shot (m)	Observer
Floralie	01-Aug-02	Standard	3	120	36	Tony Holmes
Floralie	01-Aug-02	Standard	3	120	72	Tony Holmes
Floralie	01-Aug-02	Standard	3	190	59	Tony Holmes
Floralie	16-Aug-02	Experimental	2	180	35	Tony Holmes
Floralie	16-Aug-02	Experimental	2	180	40	Tony Holmes
Floralie	16-Aug-02	Experimental	2	180	47	Tony Holmes
Floralie	19-Aug-02	Experimental	1	180	40	Tony Holmes
Floralie	19-Aug-02	Experimental	1	180	36	Tony Holmes
Floralie	19-Aug-02	Experimental	1	180	38	Tony Holmes
Floralie	21-Aug-02	Standard	3	180	51	Tony Holmes
Floralie	21-Aug-02	Standard	3	180	76	Tony Holmes
Floralie	21-Aug-02	Standard	3	190	76	Tony Holmes
Maid of Nazareth	10-Sep-02	Experimental	4	180	36	Tony Holmes
Maid of Nazareth	10-Sep-02	Experimental	4	180		Tony Holmes
Maid of Nazareth	10-Sep-02	Experimental	4	120		Tony Holmes
Elsie Marie	14-Sep-02	Experimental	4	260	36	Tony Holmes
Maid of Nazareth	14-Sep-02	Experimental	4	265	34	Tony Holmes
Elsie Marie	14-Sep-02	Experimental	4	265	40	Tony Holmes
Maid of Nazareth	14-Sep-02	Experimental	4	260	46	Tony Holmes
Maid of Nazareth	16-Sep-02	Experimental	6	210	33	Tony Holmes
Maid of Nazareth	16-Sep-02	Experimental	6	180	69	Tony Holmes
Maid of Nazareth	16-Sep-02	Experimental	6	190	87	Tony Holmes
Maid of Nazareth	17-Sep-02	Experimental	6	180	85	Tony Holmes
Maid of Nazareth	17-Sep-02	Experimental	6	180	86	Tony Holmes
Maid of Nazareth	17-Sep-02	Experimental	6	180	87	Tony Holmes
Maid of Nazareth	18-Sep-02	Experimental	6	190	67	Tony Holmes
Maid of Nazareth	18-Sep-02	Experimental	6	180	87	Tony Holmes
Maid of Nazareth	19-Sep-02	Standard	5	175	35	Tony Holmes
Maid of Nazareth	19-Sep-02	Standard	5	180	66	Tony Holmes
Maid of Nazareth	19-Sep-02	Standard	5	185	86	Tony Holmes
Maid of Nazareth	19-Sep-02	Standard	5	170	62	Tony Holmes
Maid of Nazareth	20-Sep-02	Standard	5	180	42	Tony Holmes
Maid of Nazareth	20-Sep-02	Standard	5	165	73	Tony Holmes
Maid of Nazareth	20-Sep-02	Standard	5	165	87	Tony Holmes
Maid of Nazareth	20-Sep-02	Standard	5	150	75	Tony Holmes
Naomh Deararca	29-Nov-02	Experimental	7	210	36	Tony Holmes
Naomh Deararca	29-Nov-02	Experimental	7	153	38	Tony Holmes
Naomh Deararca	29-Nov-02	Standard	7	150	40	Tony Holmes
Naomh Deararca	03-Dec-02	Standard	7	150	36	Tony Holmes
Naomh Deararca	03-Dec-02	Experimental	7	150	36	Tony Holmes
Naomh Deararca	03-Dec-02	Experimental	7	155	53	Tony Holmes
Naomh Deararca	05-Dec-02	Experimental	7	155	36	Tony Holmes
Naomh Deararca	05-Dec-02	Standard	7	155	51	Tony Holmes
Naomh Deararca	05-Dec-02	Standard	7	150	58	Tony Holmes
Naomh Deararca	06-Dec-02	Standard	7	155	46	Tony Holmes
Naomh Deararca	06-Dec-02	Standard	7	150	44	Tony Holmes
Naomh Deararca	06-Dec-02	Experimental	7	145	38	Tony Holmes
Naomh Deararca	07-Dec-02	Experimental	7	145	31	Tony Holmes

Boat Name	Date	Gear Code	Pairing	Haul Duration	Depth shot (m)	Observer
Naomh Deararca	07-Dec-02	Experimental	7	135	22	Tony Holmes
Naomh Deararca	07-Dec-02	Standard	7	135	27	Tony Holmes
Naomh Deararca	09-Dec-02	Standard	7	155	46	Tony Holmes
Naomh Deararca	10-Dec-02	Experimental	7	150	35	Tony Holmes
Naomh Deararca	10-Dec-02	Experimental	7	155	38	Tony Holmes
Naomh Deararca	11-Dec-02	Experimental	7	150	82	Tony Holmes
Gerlisa	05-Feb-03	Experimental	8	175	46	Tony Holmes
Gerlisa	05-Feb-03	Experimental	8	175	67	Tony Holmes
Gerlisa	05-Feb-03	Standard	8	180	58	Tony Holmes
Gerlisa	06-Feb-03	Standard	8	180		Tony Holmes
Gerlisa	06-Feb-03	Standard	8	210	82	Tony Holmes
Gerlisa	06-Feb-03	Experimental	8	185	69	Tony Holmes
Gerlisa	07-Feb-03	Experimental	8	180	44	Tony Holmes
Gerlisa	07-Feb-03	Experimental	8	200	51	Tony Holmes
Gerlisa	07-Feb-03	Standard	8	180	58	Tony Holmes
Gerlisa	11-Feb-03	Standard	8	180	58	Tony Holmes
Gerlisa	11-Feb-03	Experimental	8	190	56	Tony Holmes
Gerlisa	12-Feb-03	Experimental	8	180	46	Tony Holmes
Gerlisa	12-Feb-03	Standard	8	180	64	Tony Holmes
Gerlisa	12-Feb-03	Standard	8	200	67	Tony Holmes
Gerlisa	13-Feb-03	Experimental	8	210	55	Tony Holmes
Gerlisa	13-Feb-03	Experimental	8	240	55	Tony Holmes
Gerlisa	14-Feb-03	Experimental	8	195	53	Tony Holmes
Gerlisa	14-Feb-03	Experimental	8	200	66	Tony Holmes
Gerlisa	14-Feb-03	Standard	8	180	58	Tony Holmes
Gerlisa	15-Feb-03	Standard	8	180		Tony Holmes
Gerlisa	15-Feb-03	Standard	8	195	69	Tony Holmes

Appendix D: Boxplots.

Boxplots of log transformed catch for all species measured for all valid tows. The plots represent the distribution of total raised numbers per hour for each tow in a particular trial. The black circle in each box is the median, the extent of the box marks the quartiles, and the whiskers delineate the range of the data and the shaded areas show the 95% confidence intervals. Outliers are represented by separate circular marks beyond the whiskers. For each of the measured species the catch from each net used in a particular trial are presented alongside one another. When comparing the same species from the different nets it can be inferred that when the 95% confidence intervals of the two boxes do not overlap then there is likely to be a significant difference between the numbers caught by the nets in question.

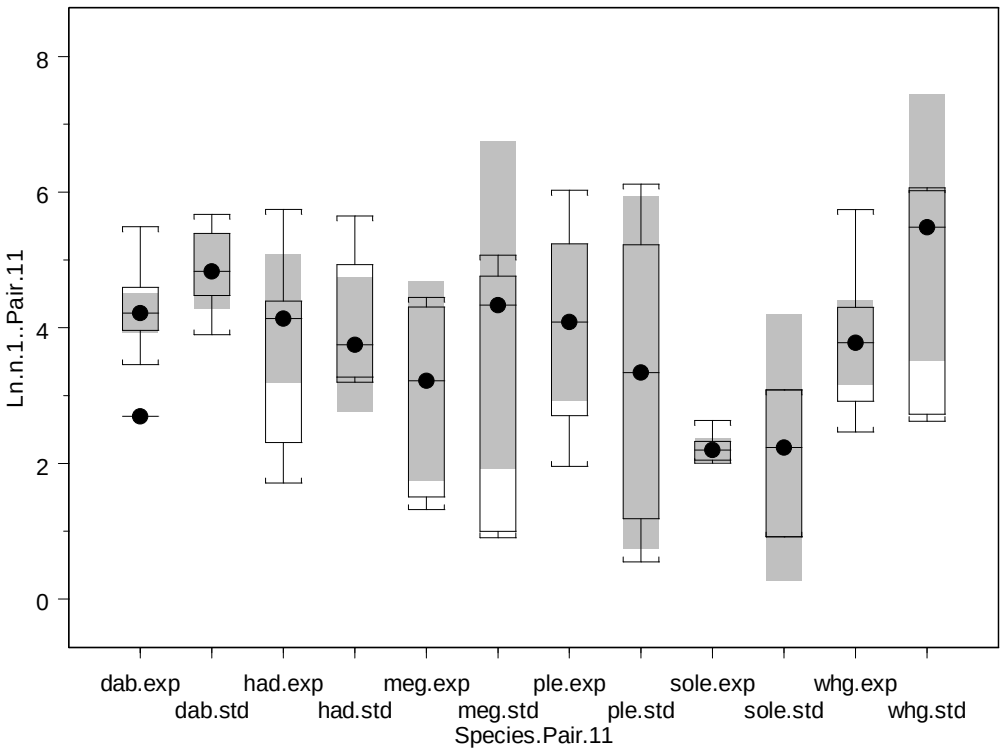


Figure D.1. Boxplots for Pairing 11; Maid of Nazareth, year 1; exp-experimental net (80mm square mesh panel), std-standard net.

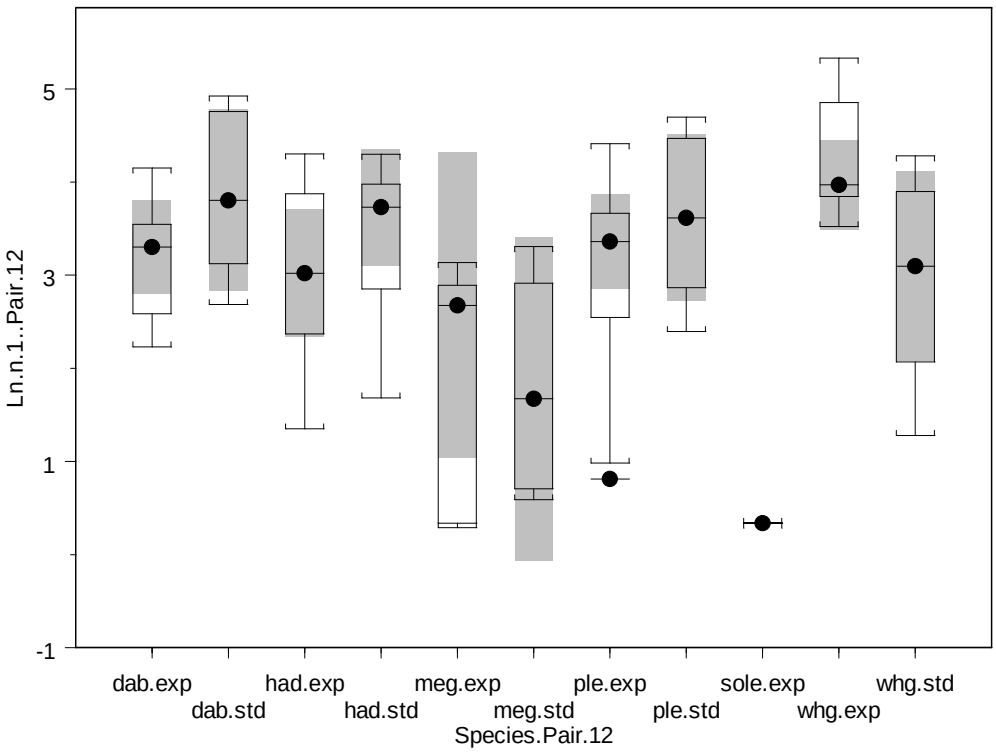


Figure D.2. Boxplots for Pairing 12; Floralie, year 1; exp-experimental net (90mm square mesh panel), std-standard net.

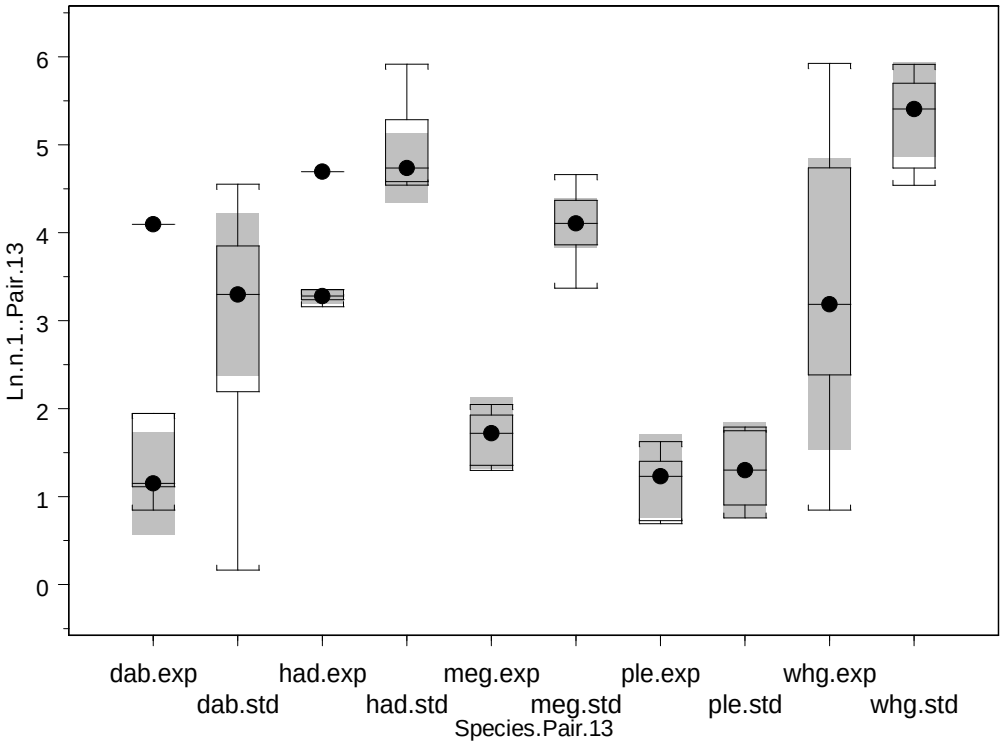


Figure D.3. Boxplots for Pairing 13; Gerlisa, year 1; exp-experimental net (100mm cod-end), std-standard net.

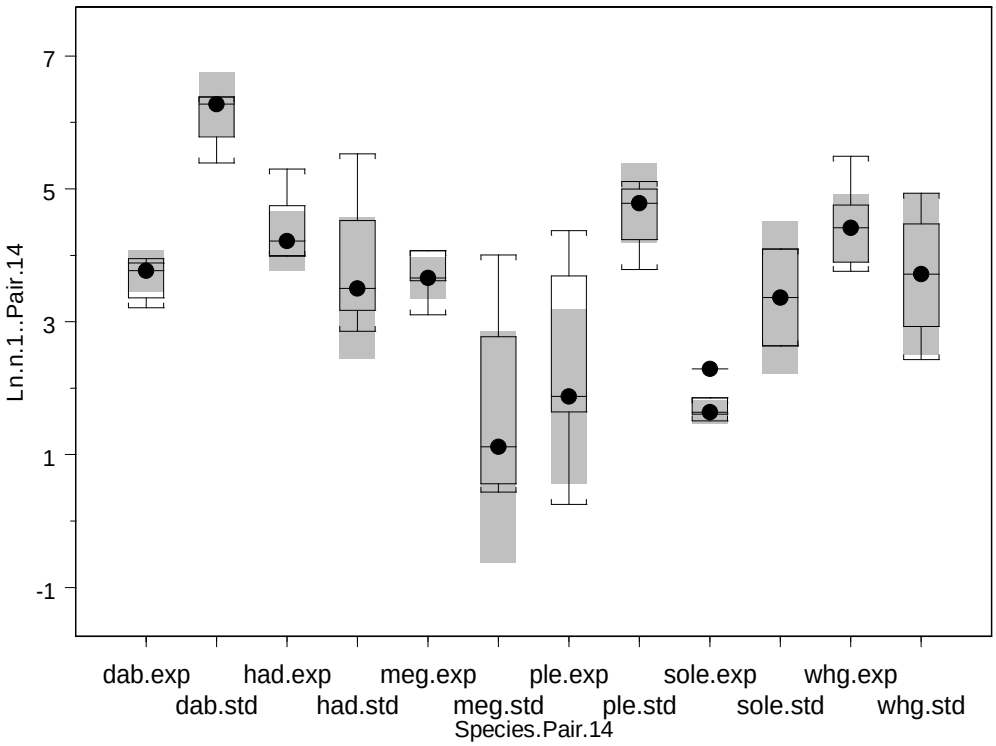


Figure D.4. Boxplots for Pairing 14; Elsie Marie, year 1; exp-experimental net (Separator trawl), std-standard net.

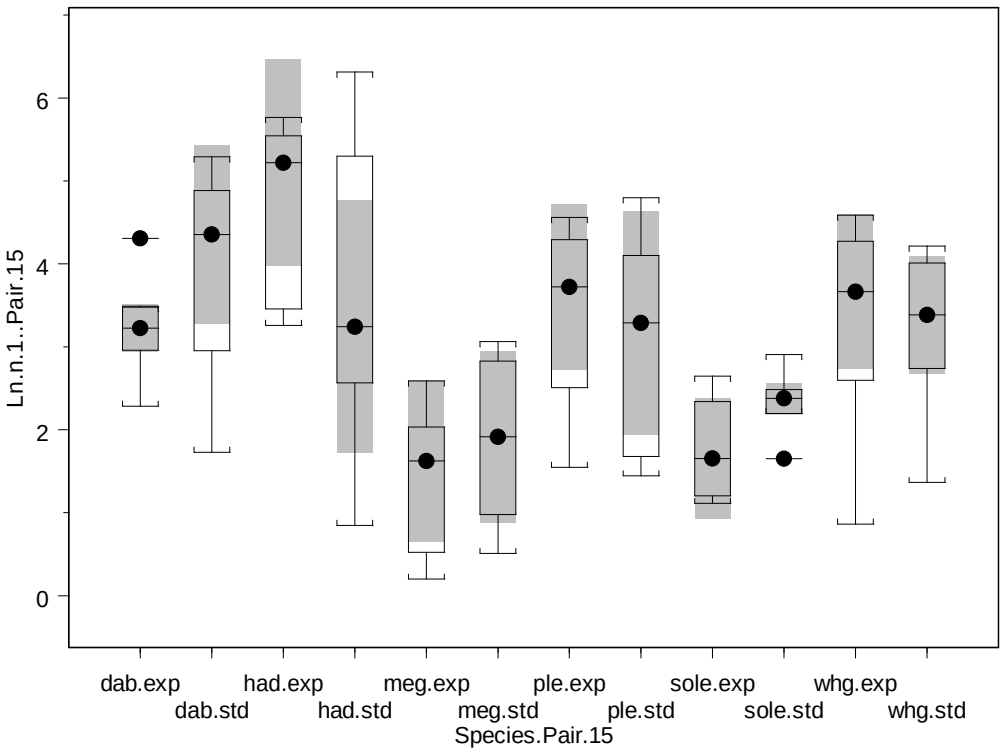


Figure D.5. Boxplots for Pairing 15; Naomh Deararca, year 1; exp-experimental net (160mm coversheet), std-standard net

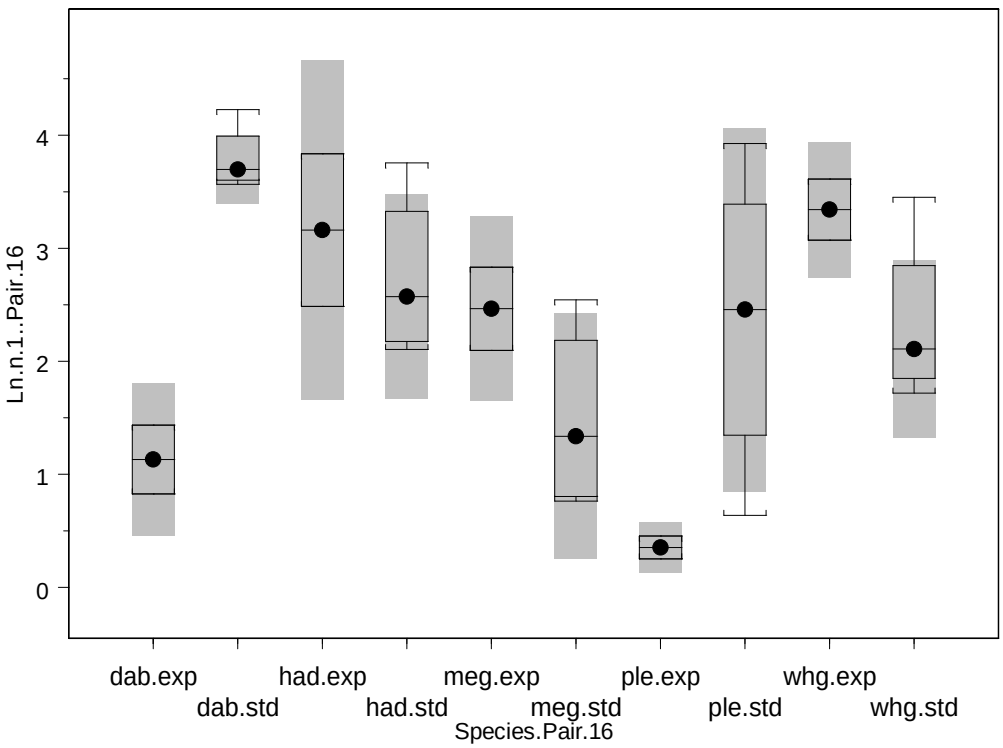


Figure D.6. Boxplots for Pairing 16; Deux Orchidees, year 1; exp-experimental net (100mm cod-end), std-standard net.

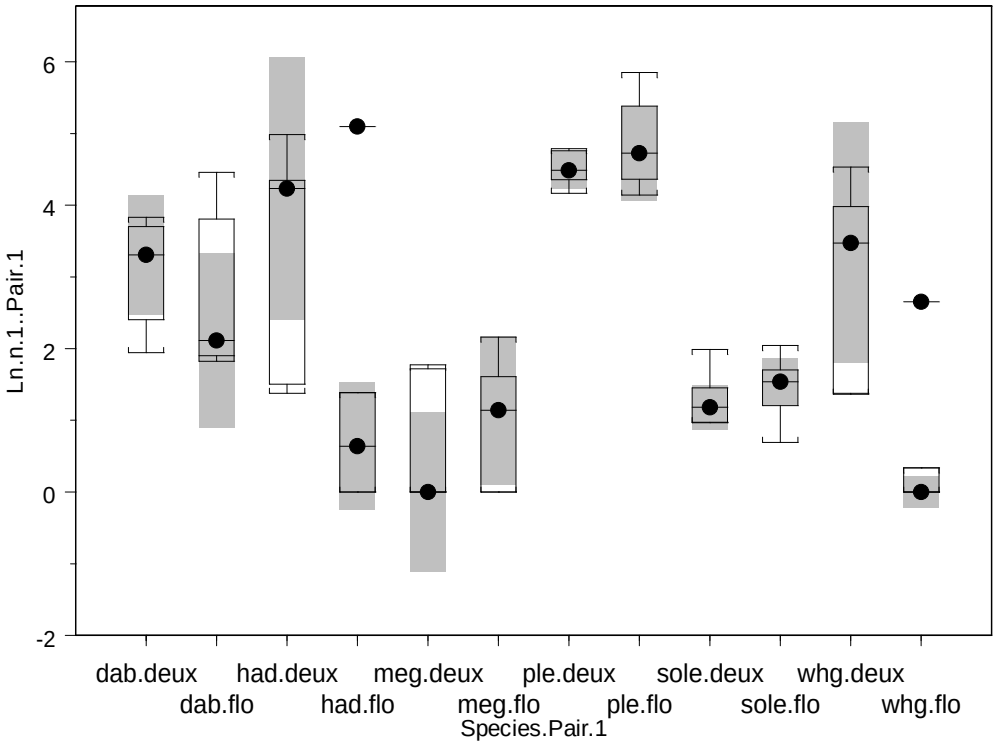


Figure D.7. Boxplots for Pairing 1; Year 2; Deu -Deux Orchidees (experimental net; 100mm cod-end), flo-Floralie (experimental net; 100mm cod-end).

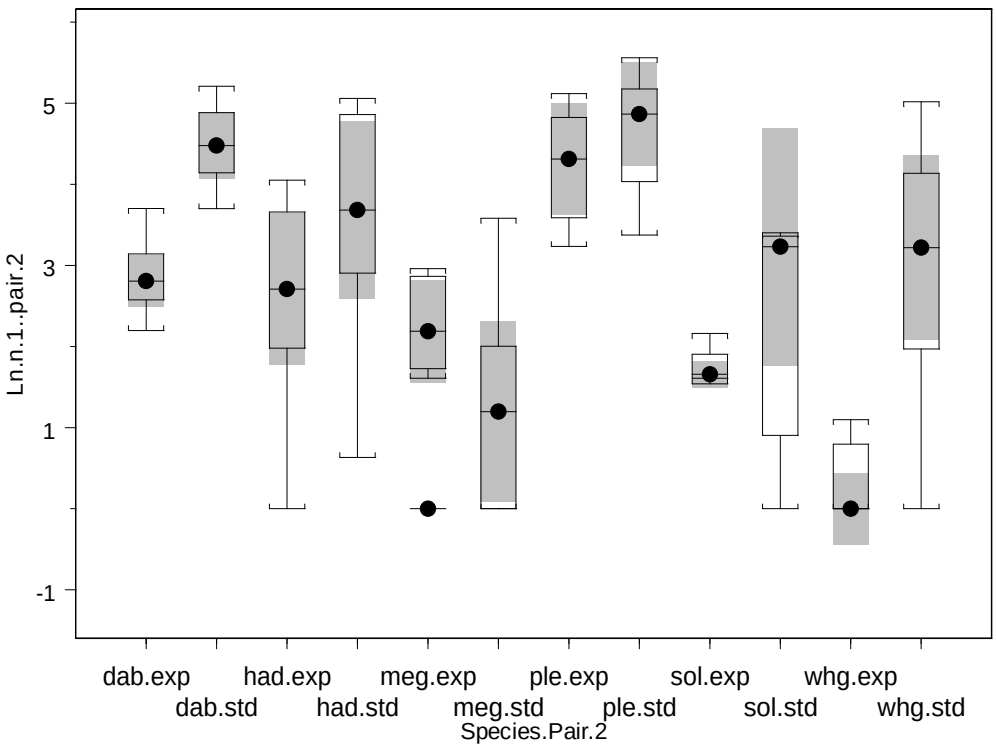


Figure D.8. Boxplots for Pairing 2; Year 2; - exp-experimental net (Floralie, 100mm cod-end), std-standard net (Deux Orchidees, 80mm cod-end).

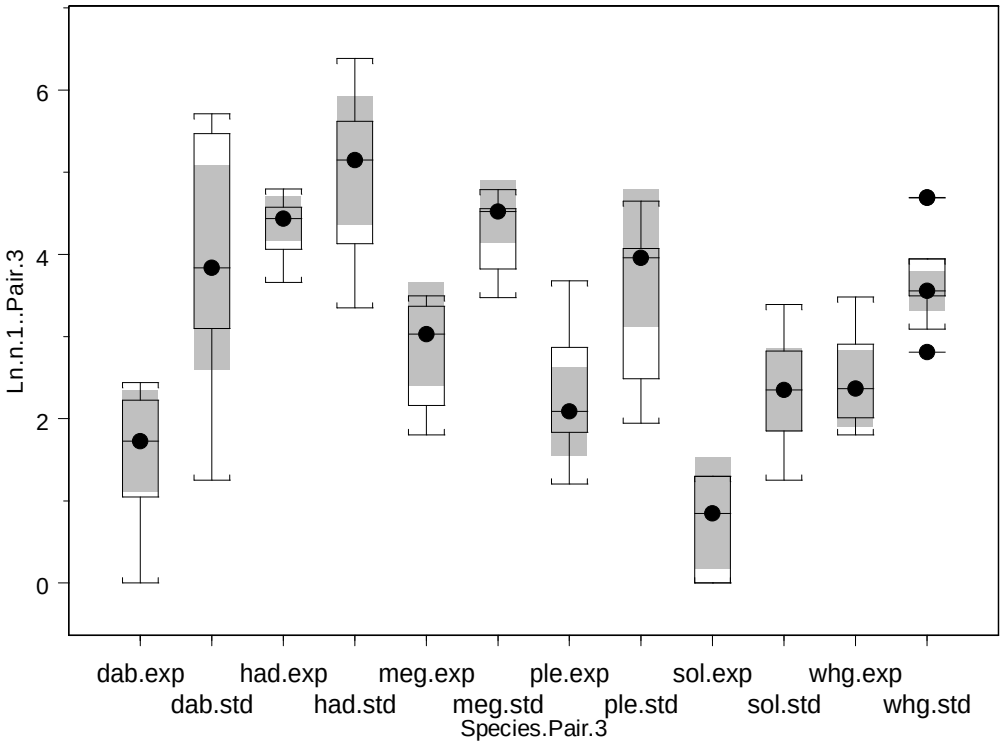


Figure D.9. Boxplots for Pairing 3; Year 2; - exp-experimental net (Deux Orchidees, 100mm cod-end), std-standard net (Floralie, 80mm cod-end).

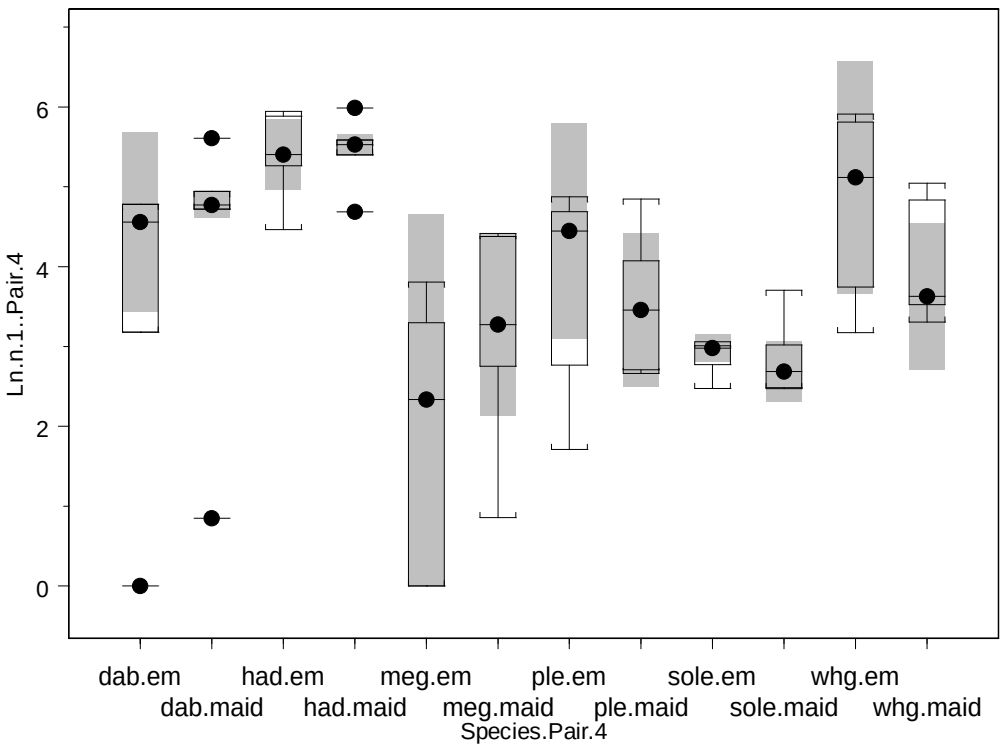


Figure D.10. Boxplots for Pairing 4; Year 2, em-Elsie Marie (experimental net; 80mm square mesh panel), maid-Maid of Nazareth (experimental net; 80mm square mesh panel).

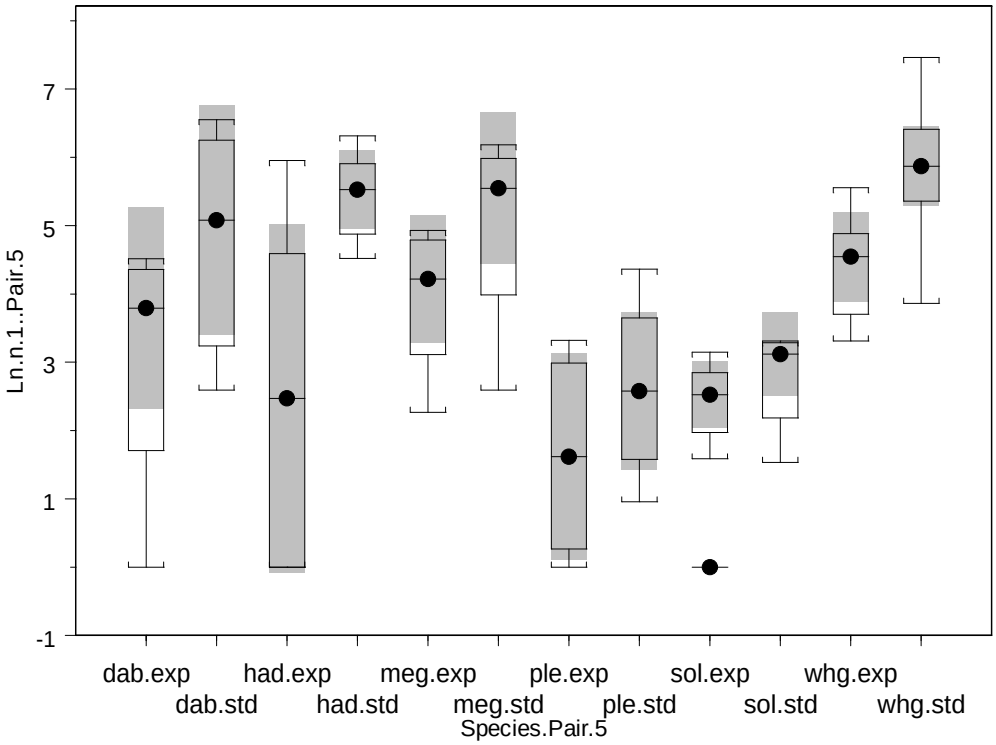


Figure D.11. Boxplots for Pairing 5; Year 2; - exp-experimental net (Elsie Marie, 80mm square mesh panel), std-standard net (Maid of Nazareth, 80mm cod-end).

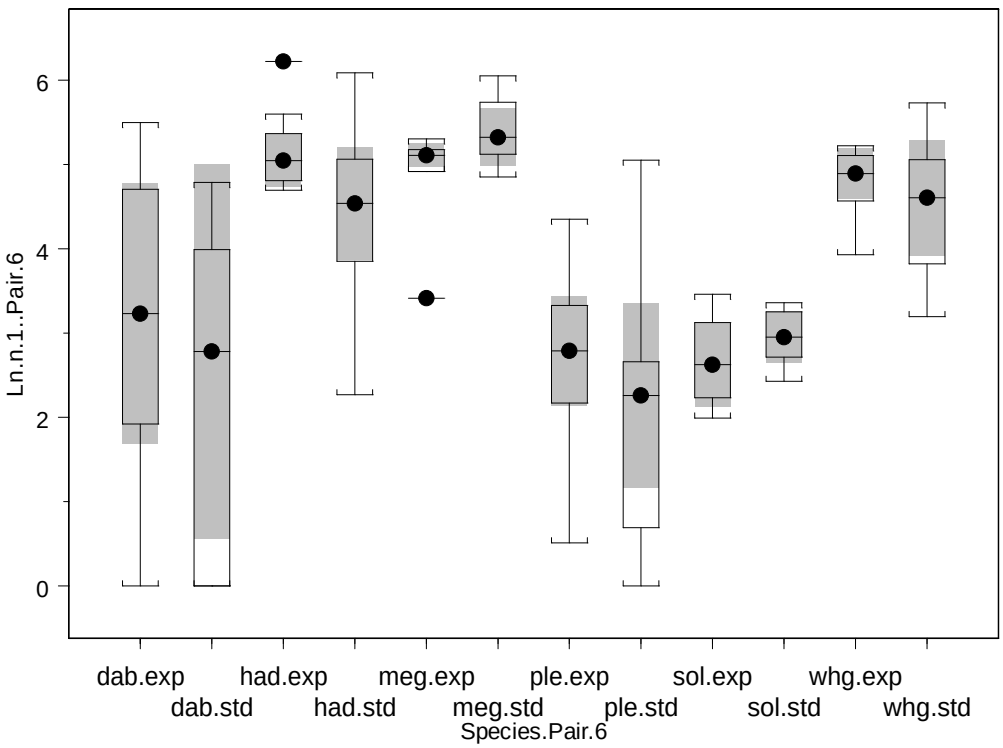


Figure D.12. Boxplots for Pairing 6; Year 2; - exp-experimental net (Maid of Nazareth, 80mm square mesh panel), std-standard net (Floralie, 80mm cod-end).

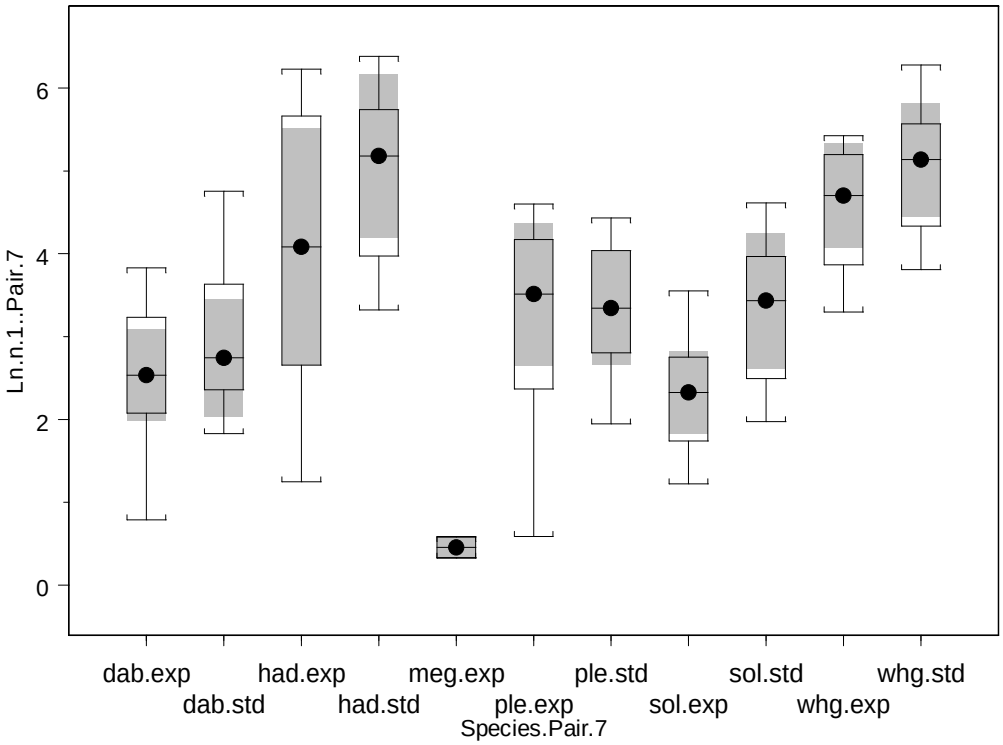


Figure D.13. Boxplots for Pairing 7; Naomh Deararca, year 2; exp-experimental net (100mm cod-end), std-standard net.

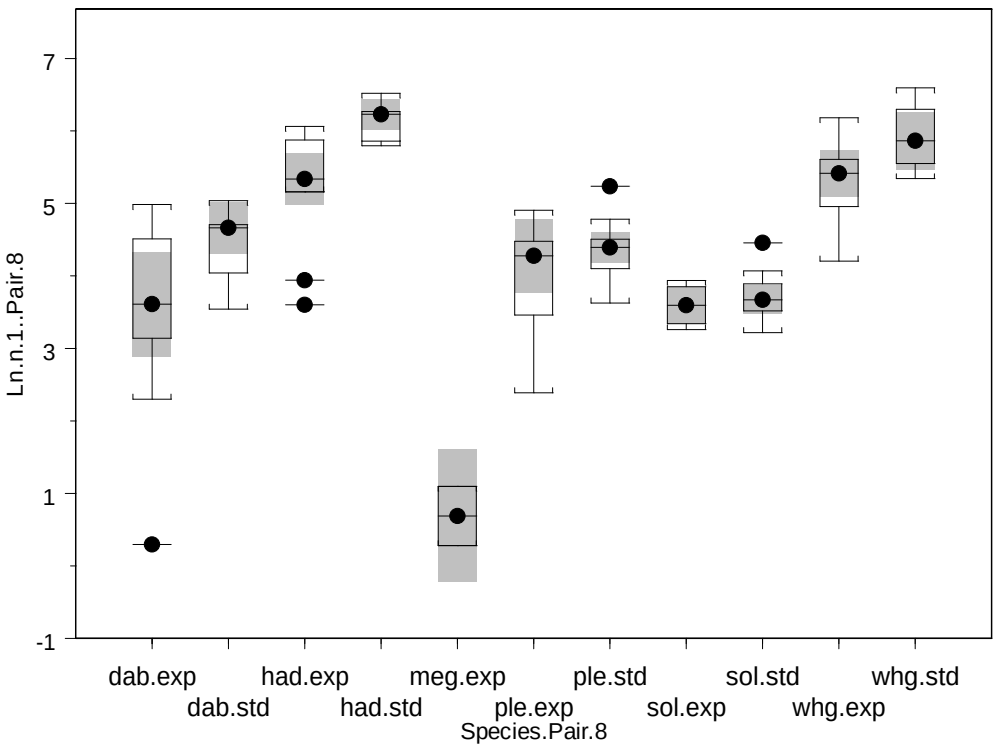


Figure D.14. Boxplots for Pairing 8; Gerlisa, year 2; exp-experimental net (100mm cod-end), std-standard net.

Appendix E: Length Profiles.

Length profiles for all species measured for valid tows. The graphs represent the average catch per hour at length. They can be used to visually compare the catches between the two nets under investigation for each trial.

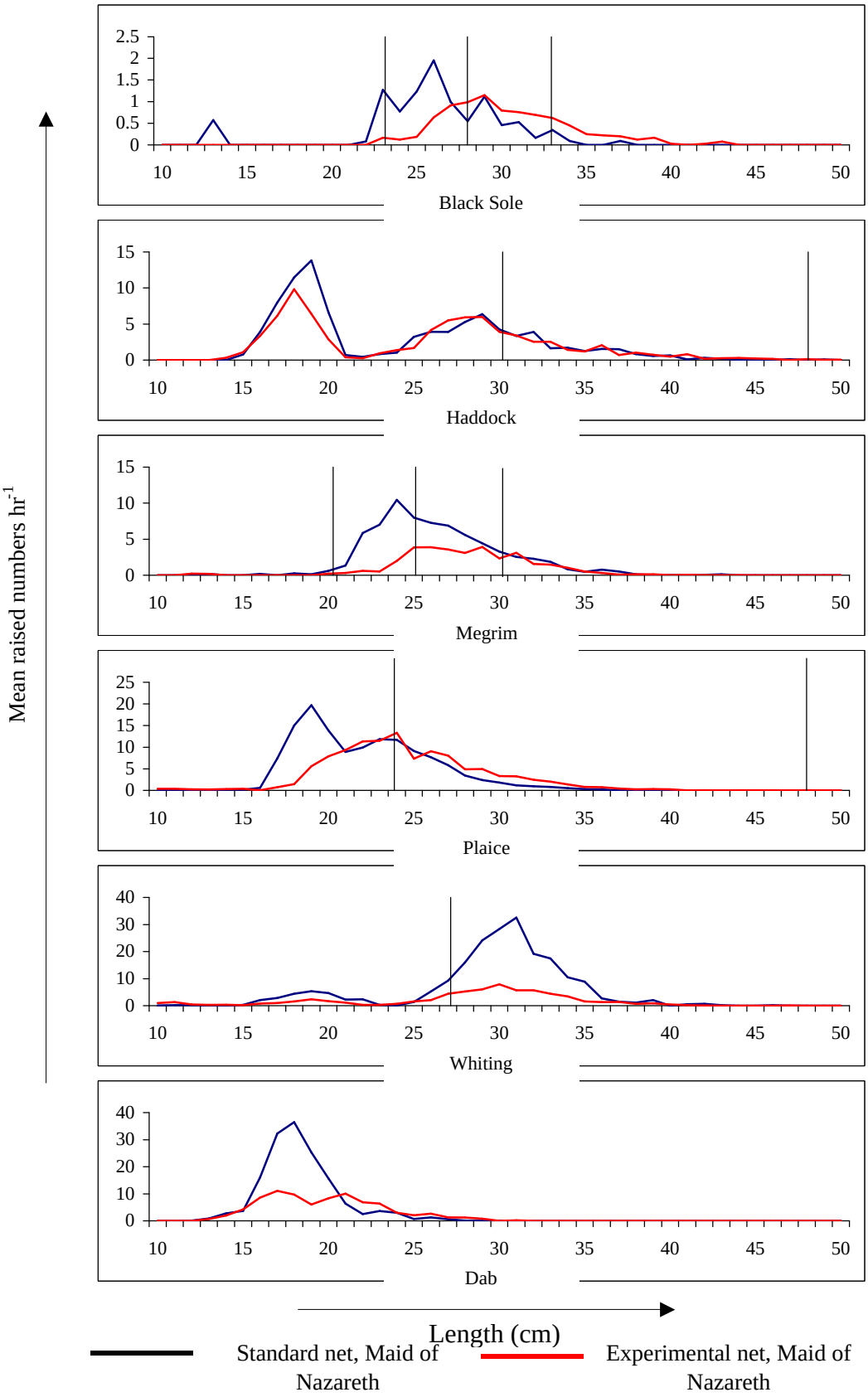


Figure E.1; Length profile for pairing 11; Maid of Nazareth, year 1; experimental net (80mm square mesh panel), standard net.

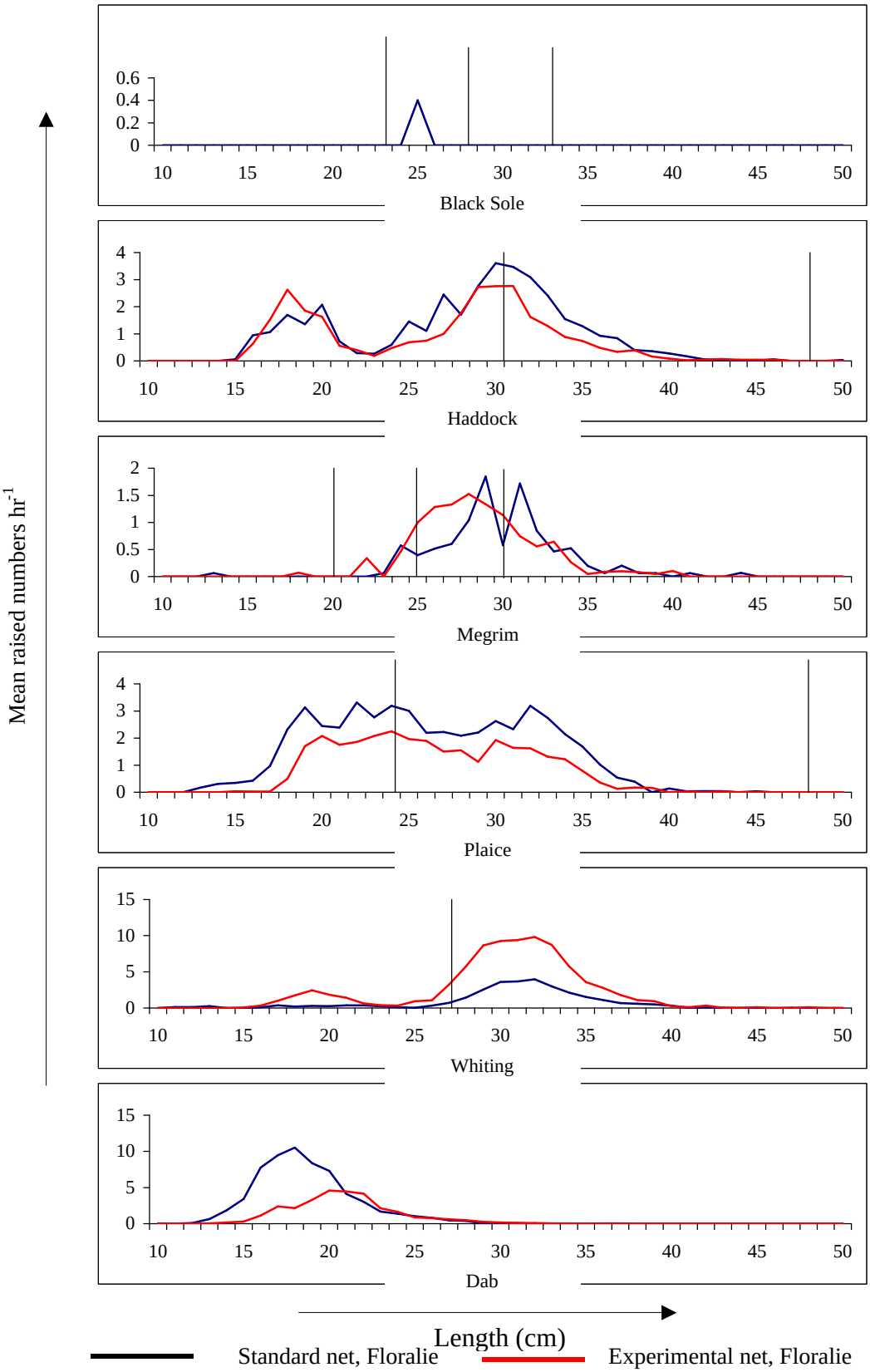


Figure E.2; Length profile for pairing 12; Floralie, year 1; experimental net (90mm square mesh panel), standard net.

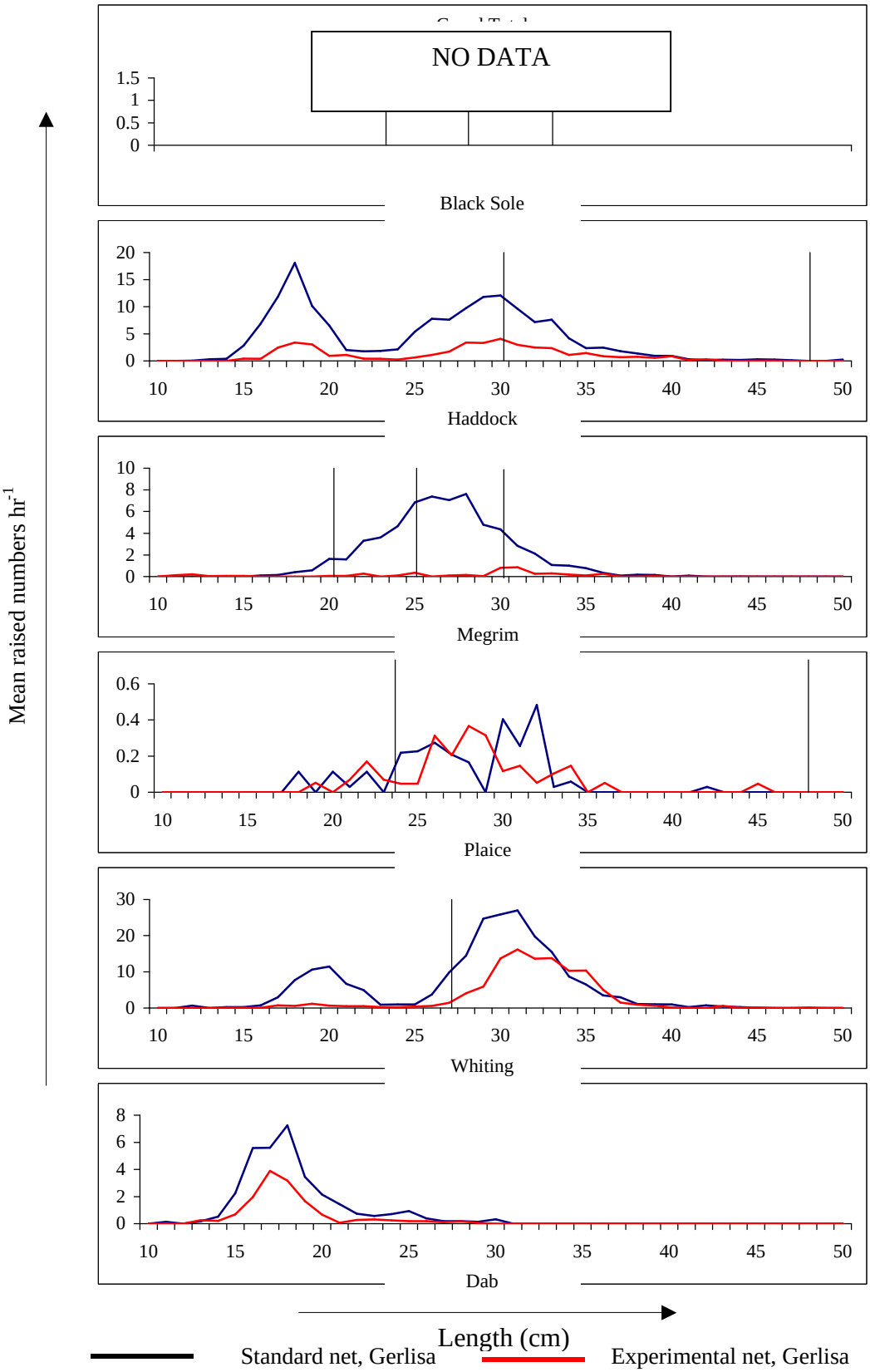


Figure E.3; Length profile for pairing 13; Gerlisa, year 1; experimental net (100mm cod-end), standard net.

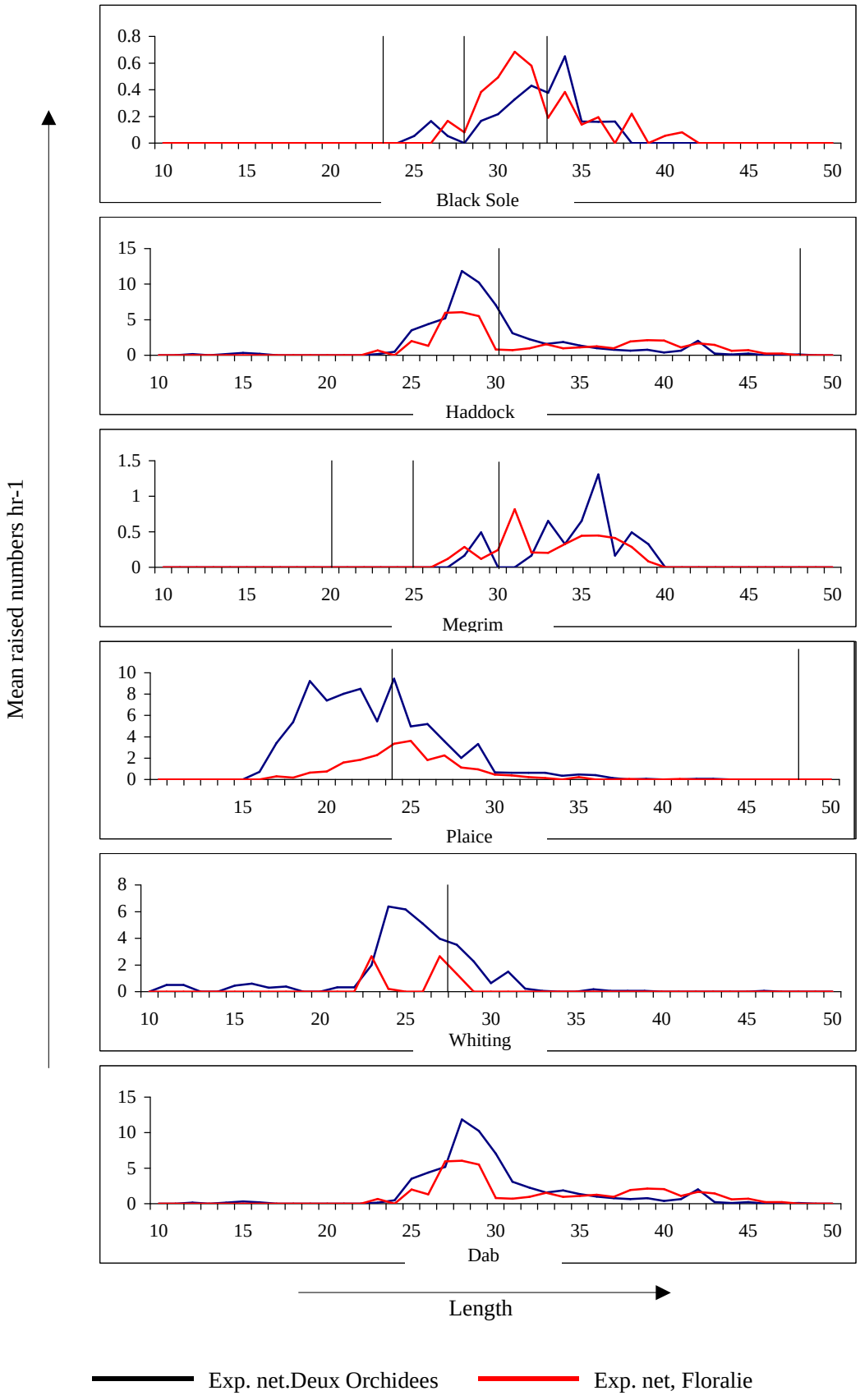


Figure E.4; Length profile for pairing 14; Elsie Marie, year 1; experimental net -Separator trawl, standard net.

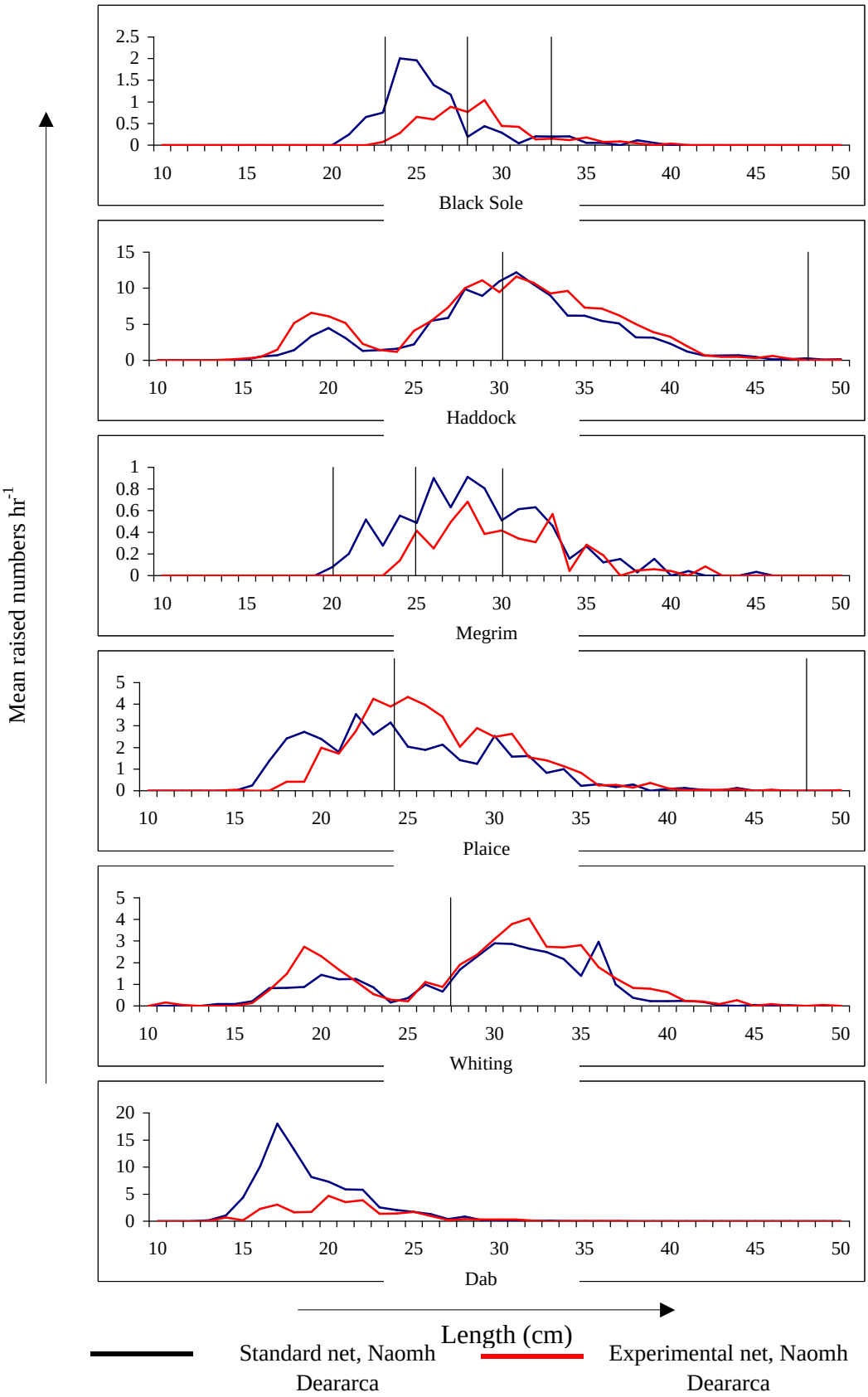


Figure E.5; Length profile for pairing 15; Naomh Deararca, year 1; experimental net (160mm coversheet), standard net

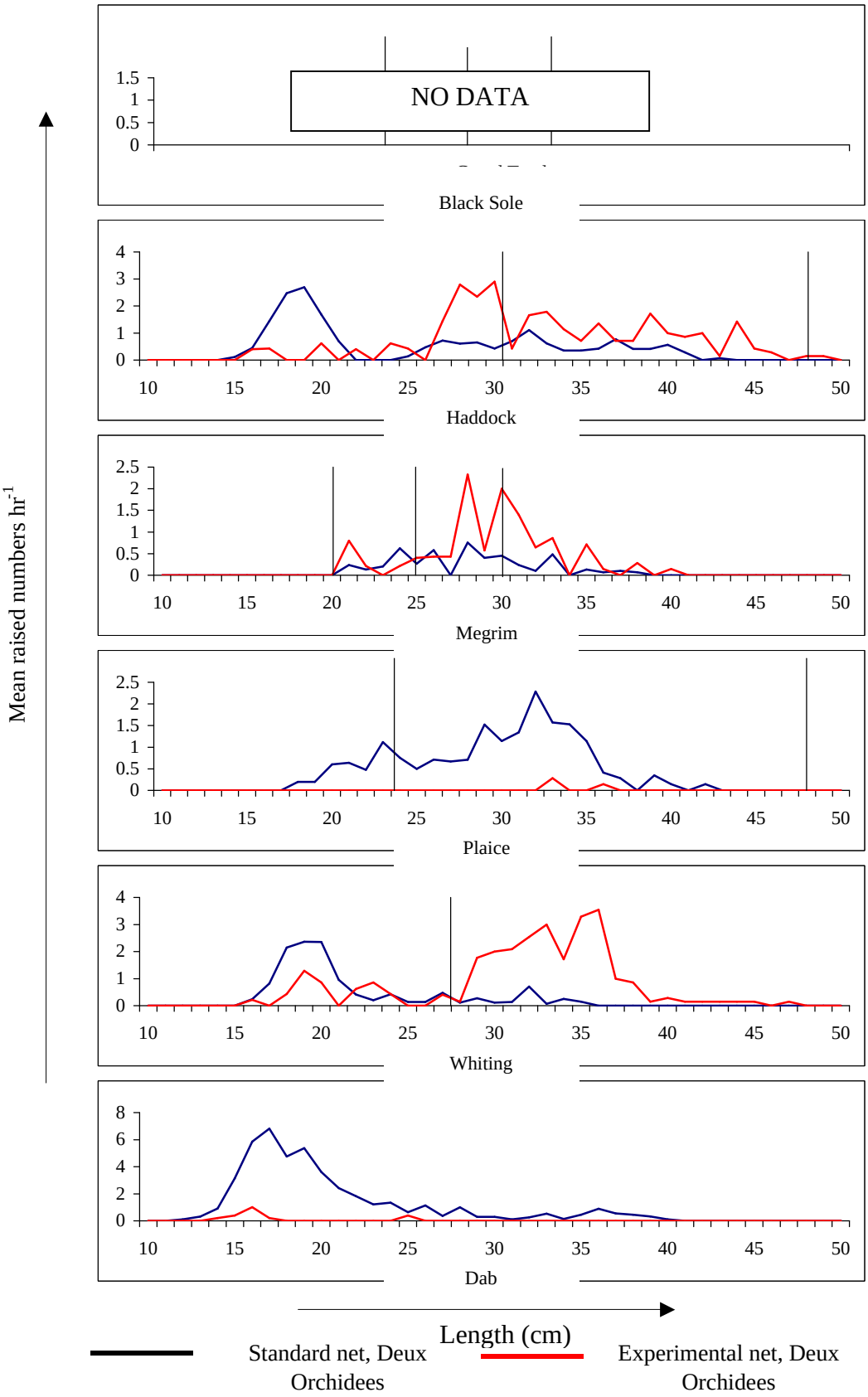


Figure E.6; Length profile for pairing 16; Deux Orchidees, year 1; experimental net (100mm cod-end), standard net.

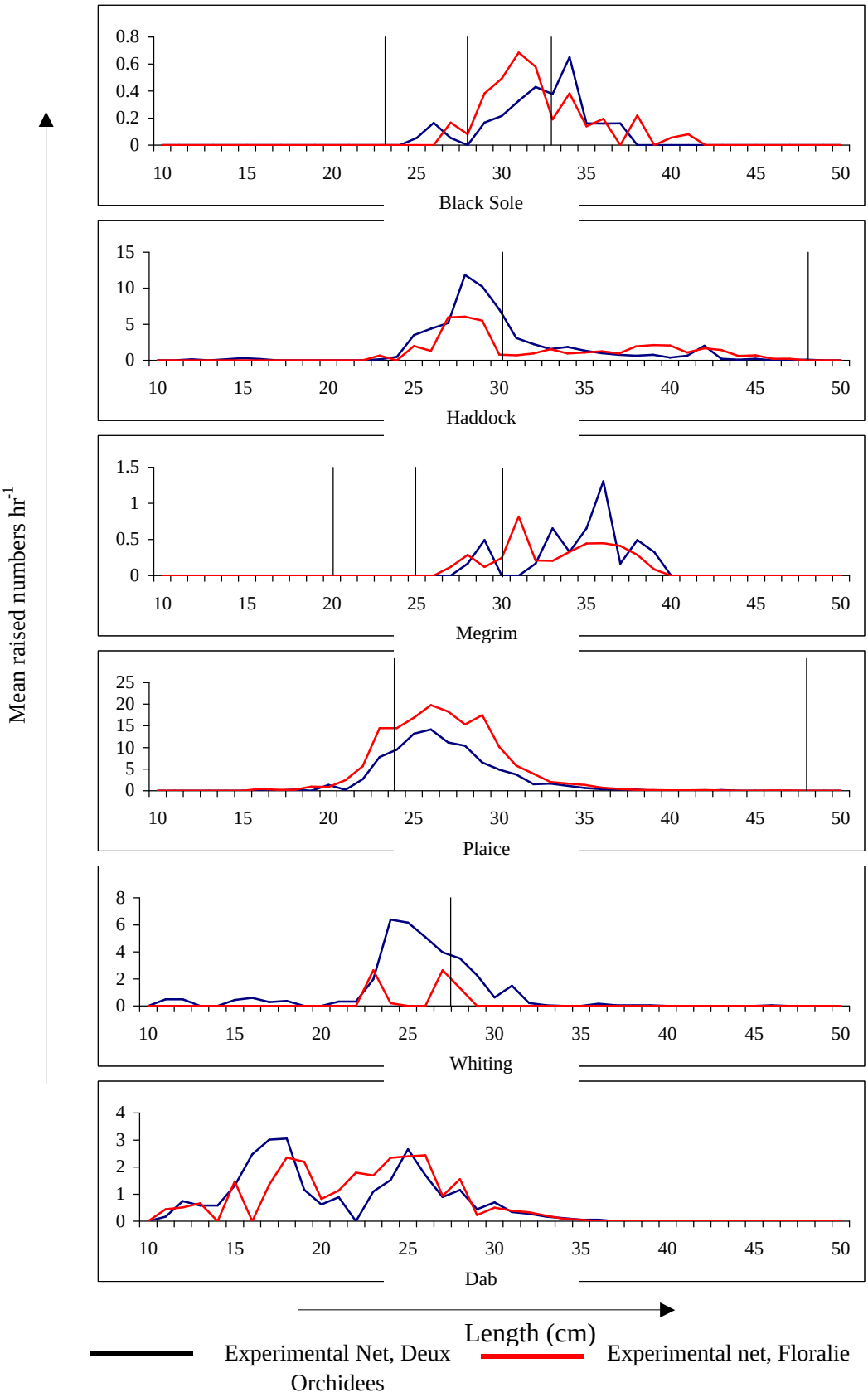


Figure E.7; Length profile for pairing 1; Year 2; Deux Orchidees, experimental net-100mm cod-end), Floralie experimental net -100mm cod-end.

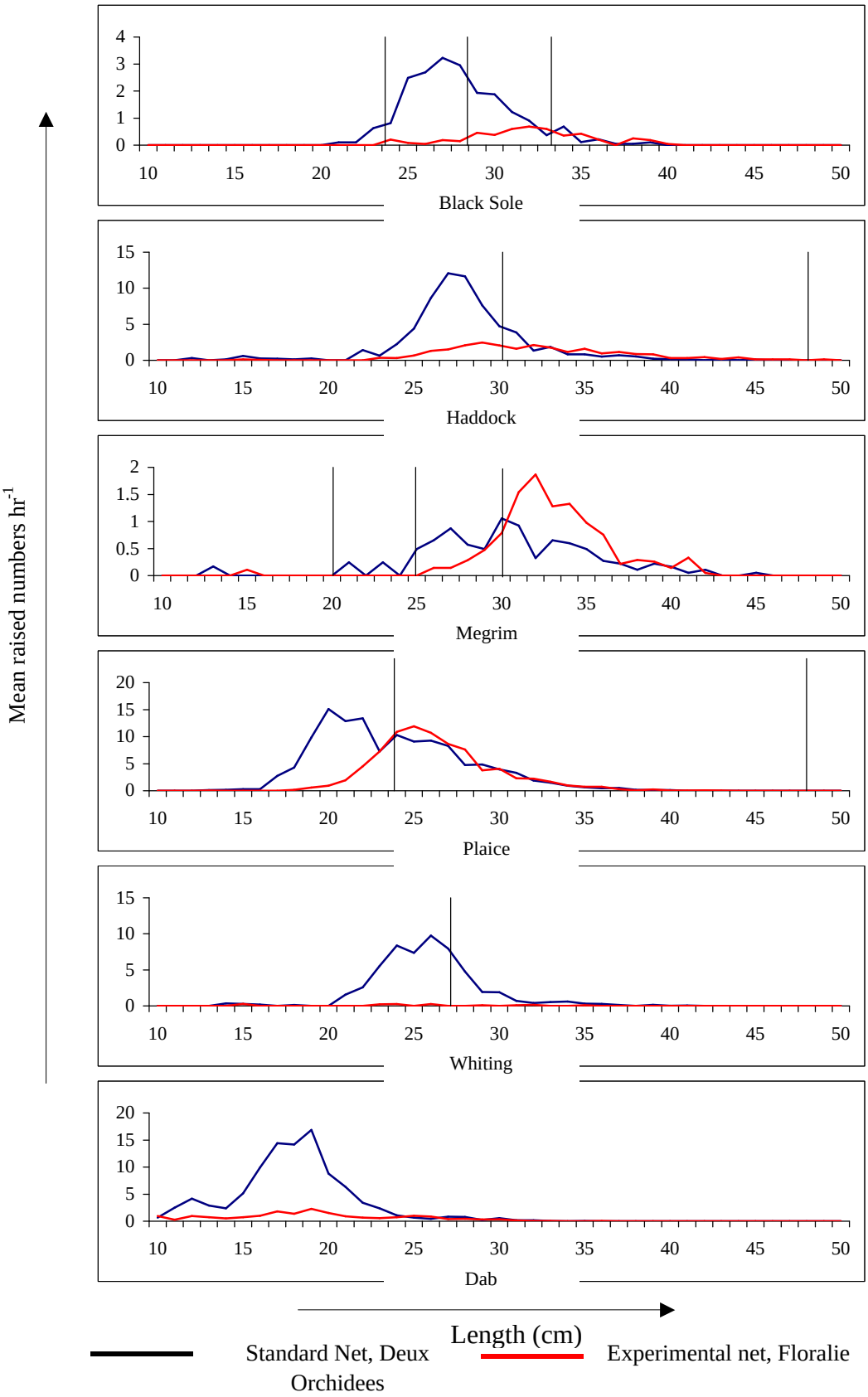


Figure E.8; Length profile for pairing 2; Year 2; - experimental net, Floralie, 100mm cod-end; standard net Deux Orchidees, 80mm cod-end.

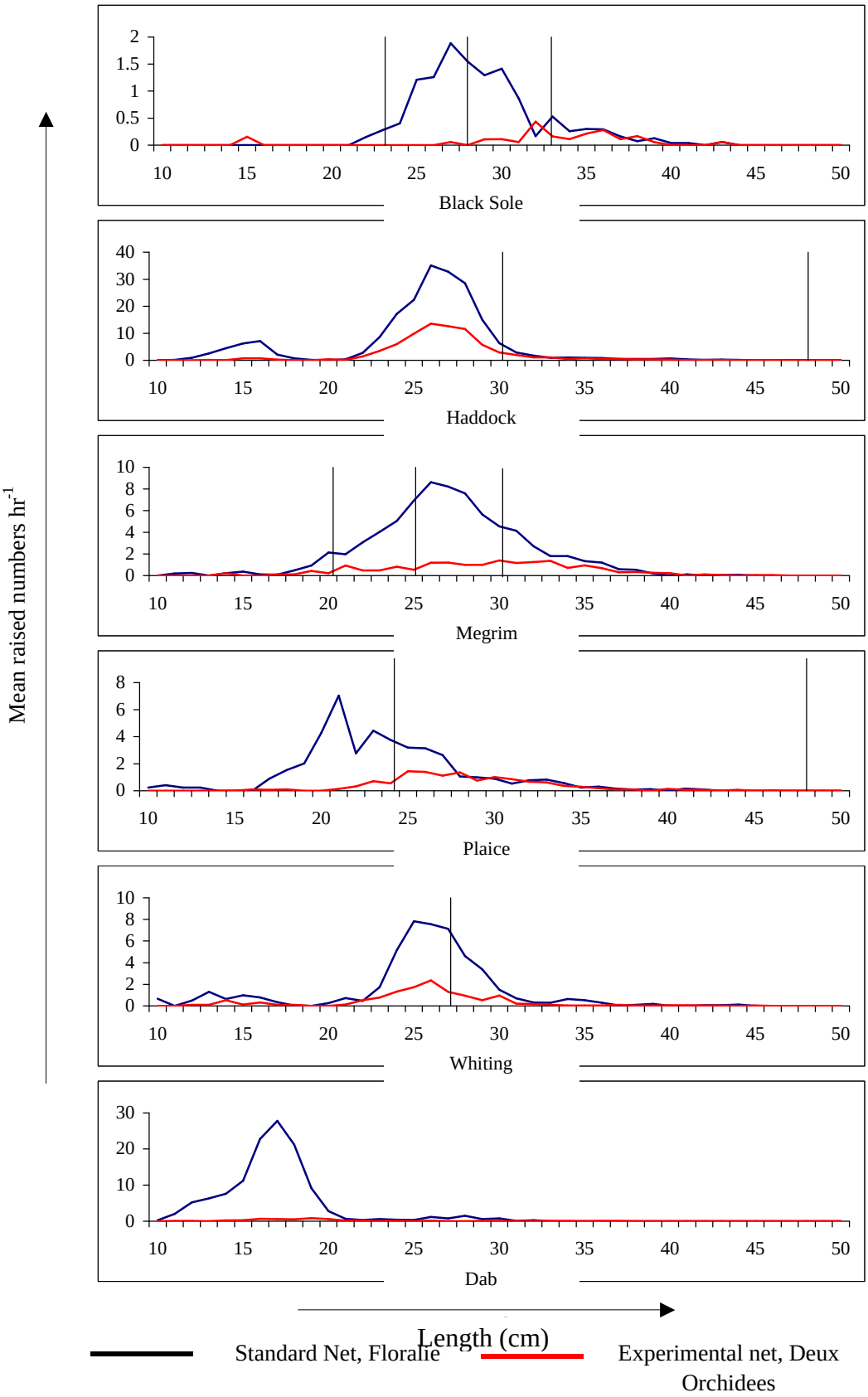


Figure E.9; Length profile for pairing 3; Year 2; - experimental net, Deux Orchidees, 100mm cod-end; standard net (Floralie, 80mm cod-end).

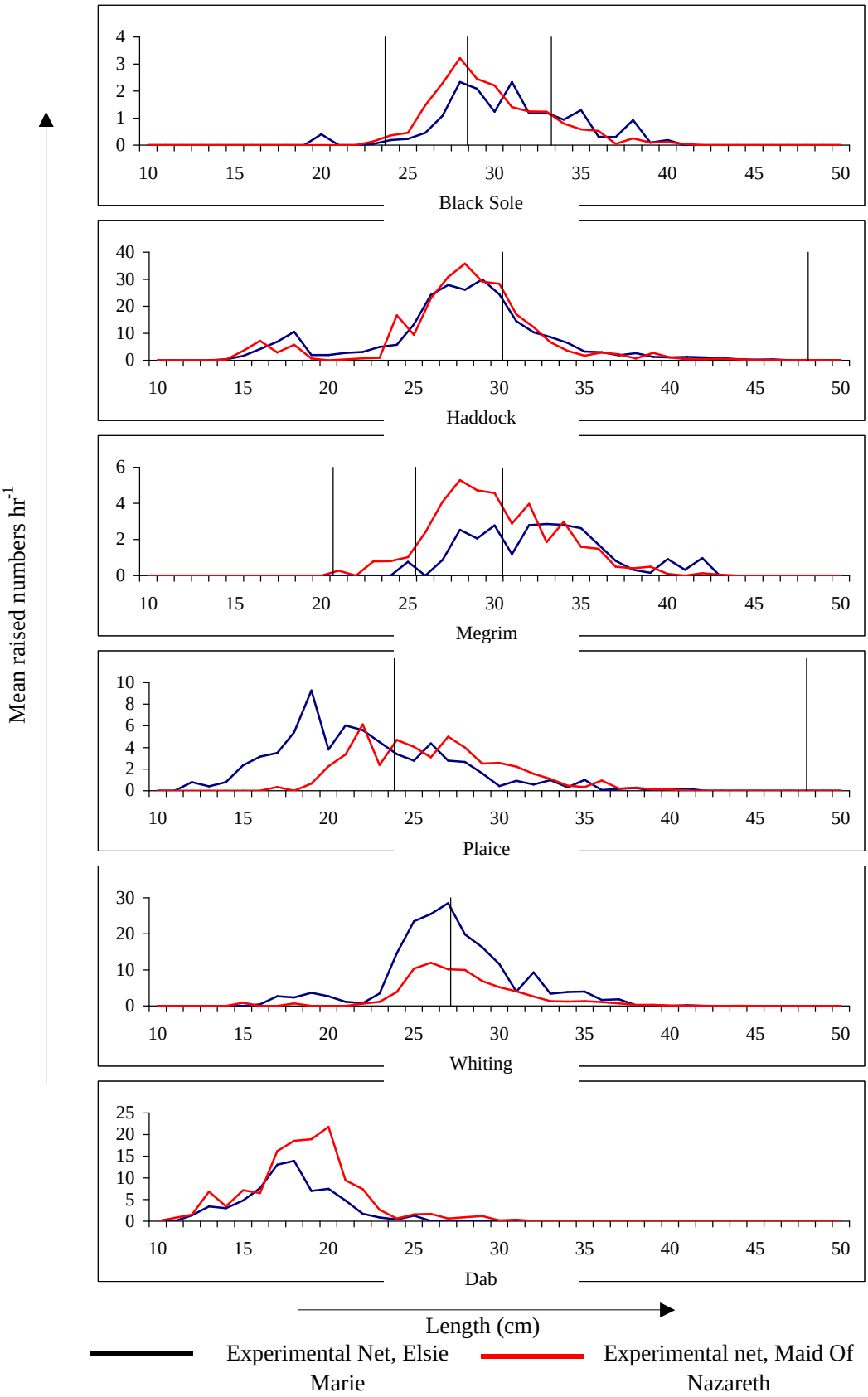


Figure E.10; Length profile for pairing 4; Year 2, Elsie Marie experimental net- 80mm square mesh panel), Maid of Nazareth experimental net-80mm square mesh panel.

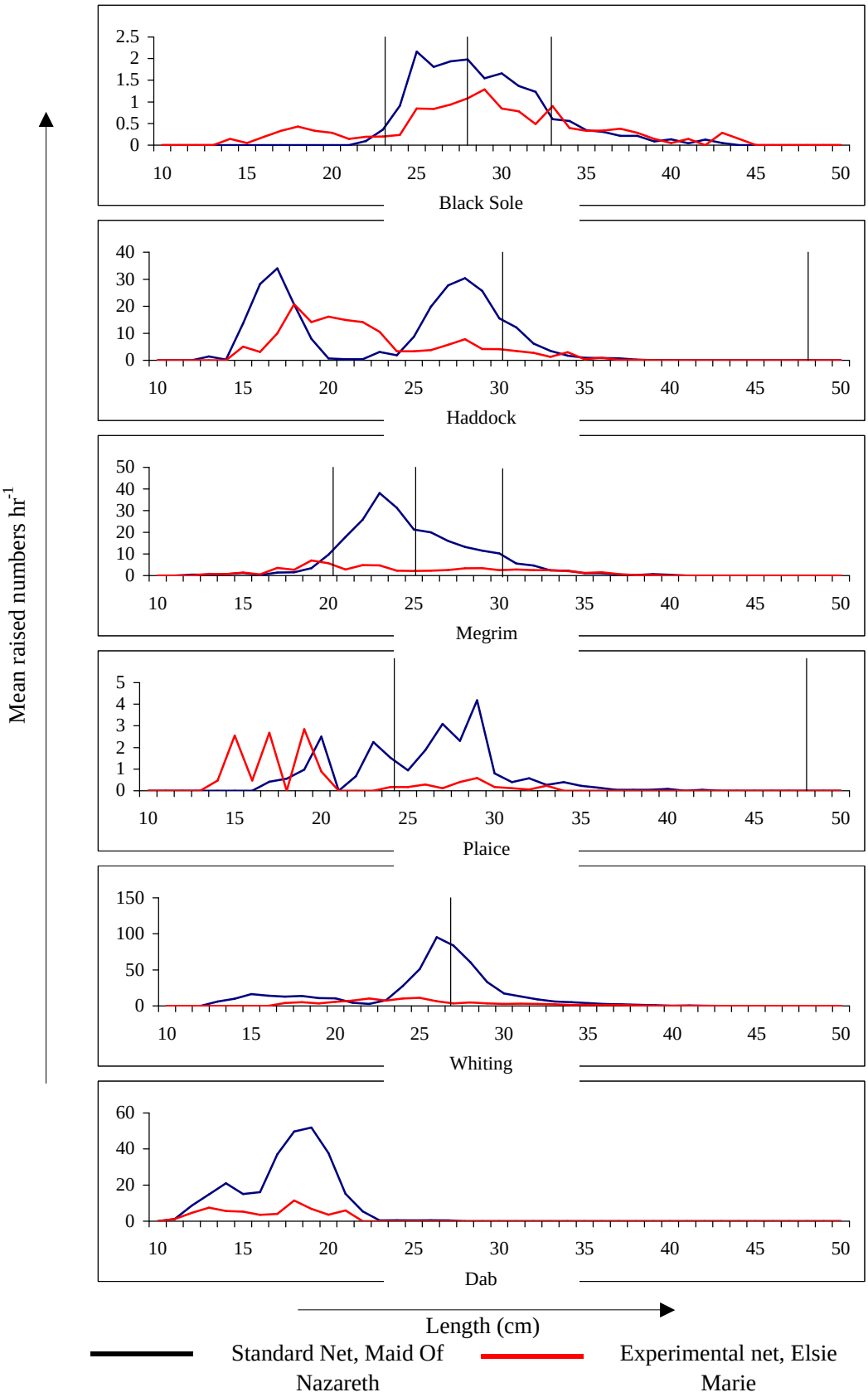


Figure E.11; Length profile for pairing 5; Year 2; Experimental net, Elsie Marie- 80mm square mesh panel; Standard net, Maid of Nazareth -80mm cod-end.

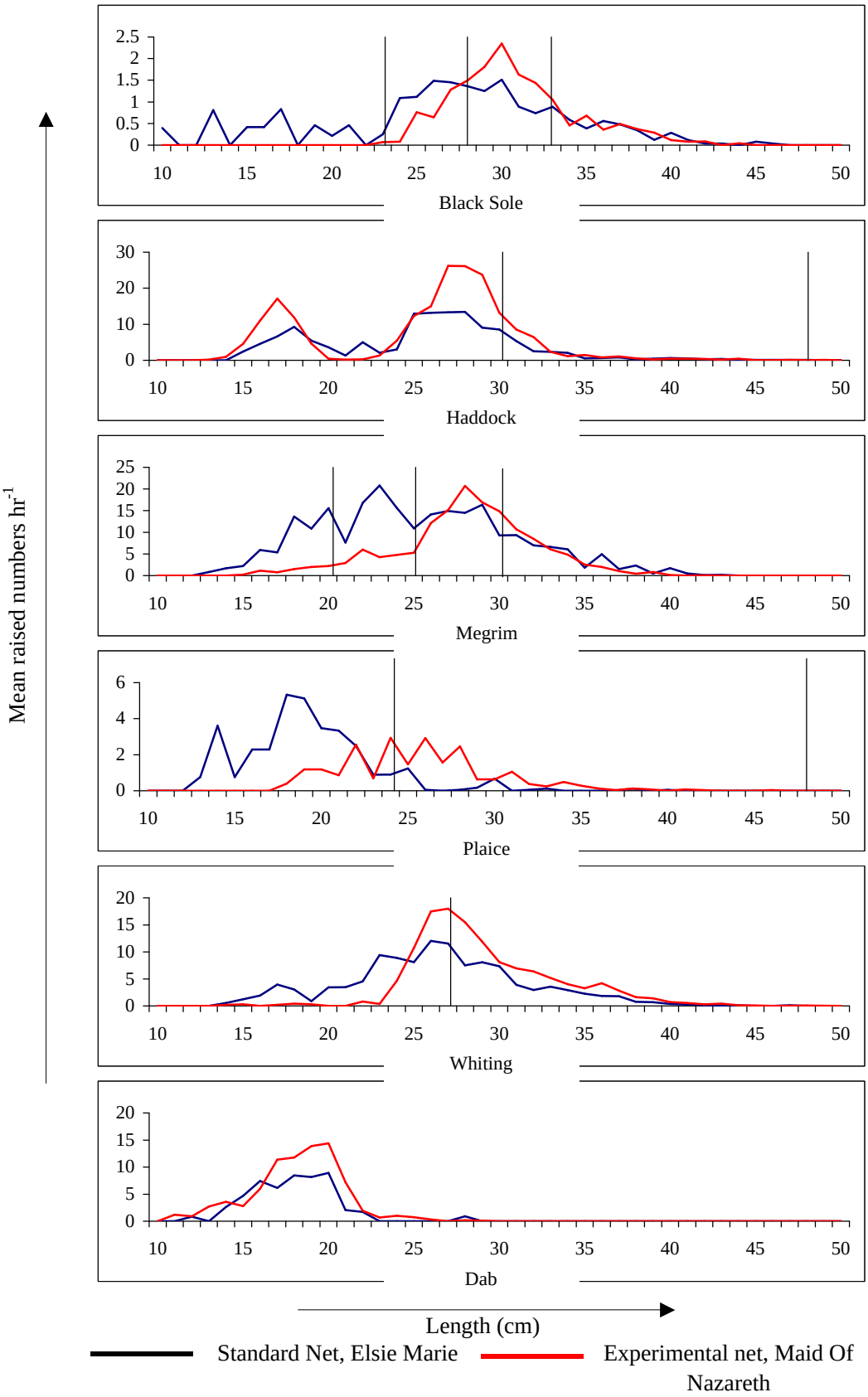


Figure E.12; Length profile for pairing 6; Year 2; - experimental net, Maid of Nazareth - 80mm square mesh panel; standard net, Floralie, 80mm cod-end.

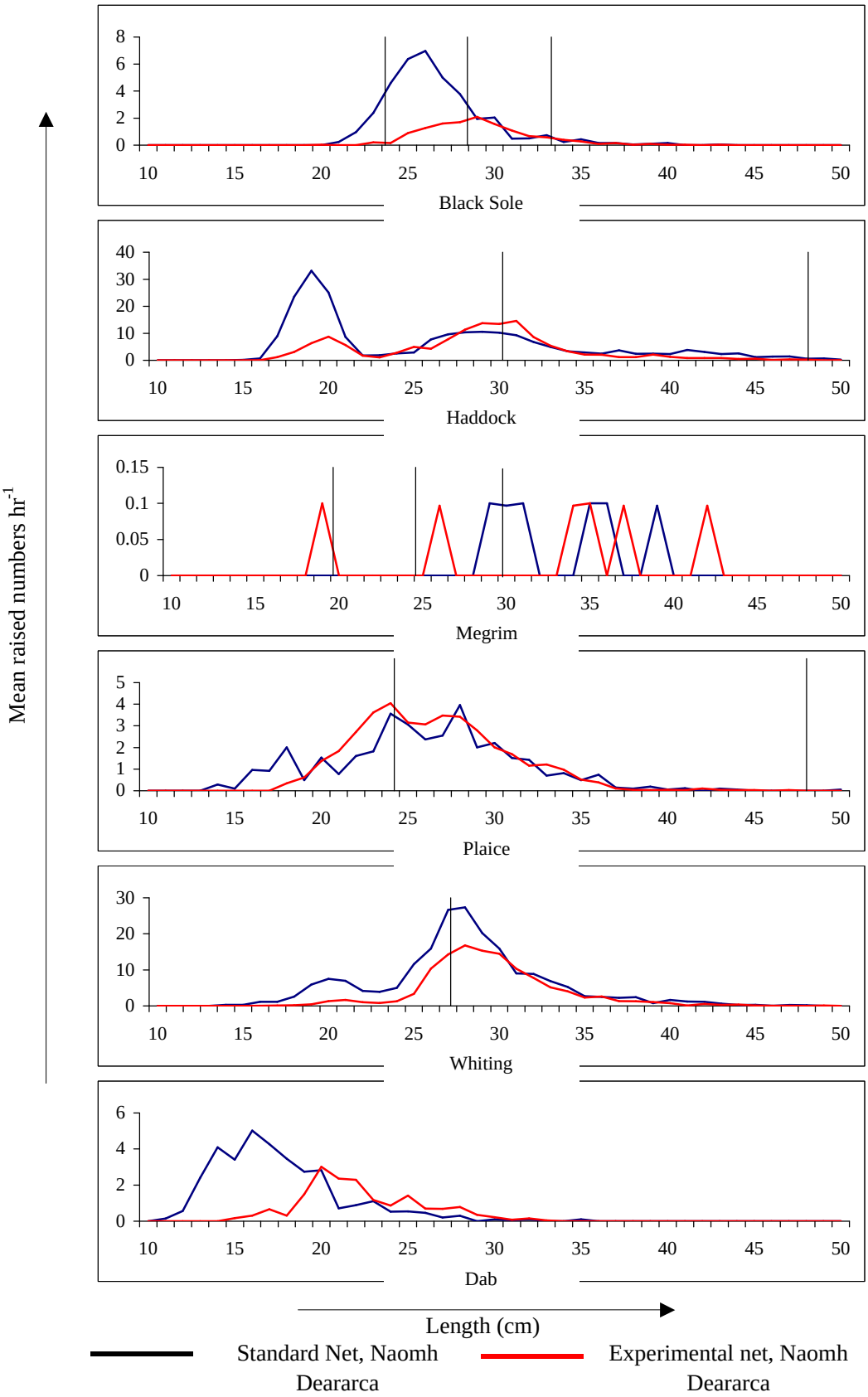


Figure E.13; Length profile for pairing 7; Naomh Dearca, year 2; experimental net 100mm cod-end, standard net, 80mm cod-end.

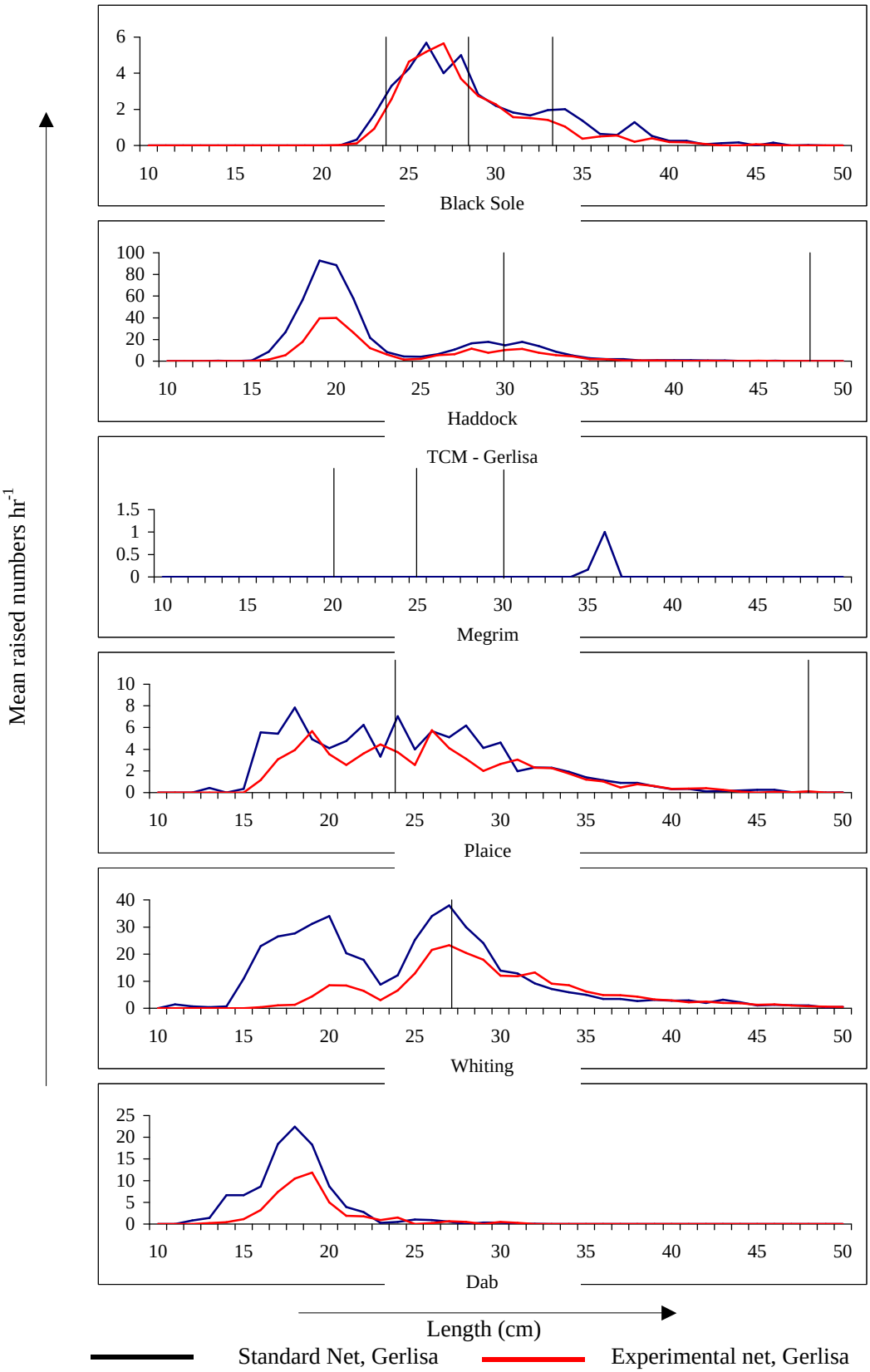


Figure E.14; Length profile for pairing 8; Gerlisa, year 2; experimental net 100mm cod-end, standard net, 80mm cod-end

Appendix F: Proportion Retained.

Each point on these graphs represents the proportion of the total raised catch per hour retained in experimental net where:

$$\text{Proportion of fish in experimental cod-end} = \frac{\text{Number of fish in experimental net}}{\text{Total number of fish in both nets.}}$$

To try and display trends in proportion retained a line is plotted by taking a moving average over five length classes.

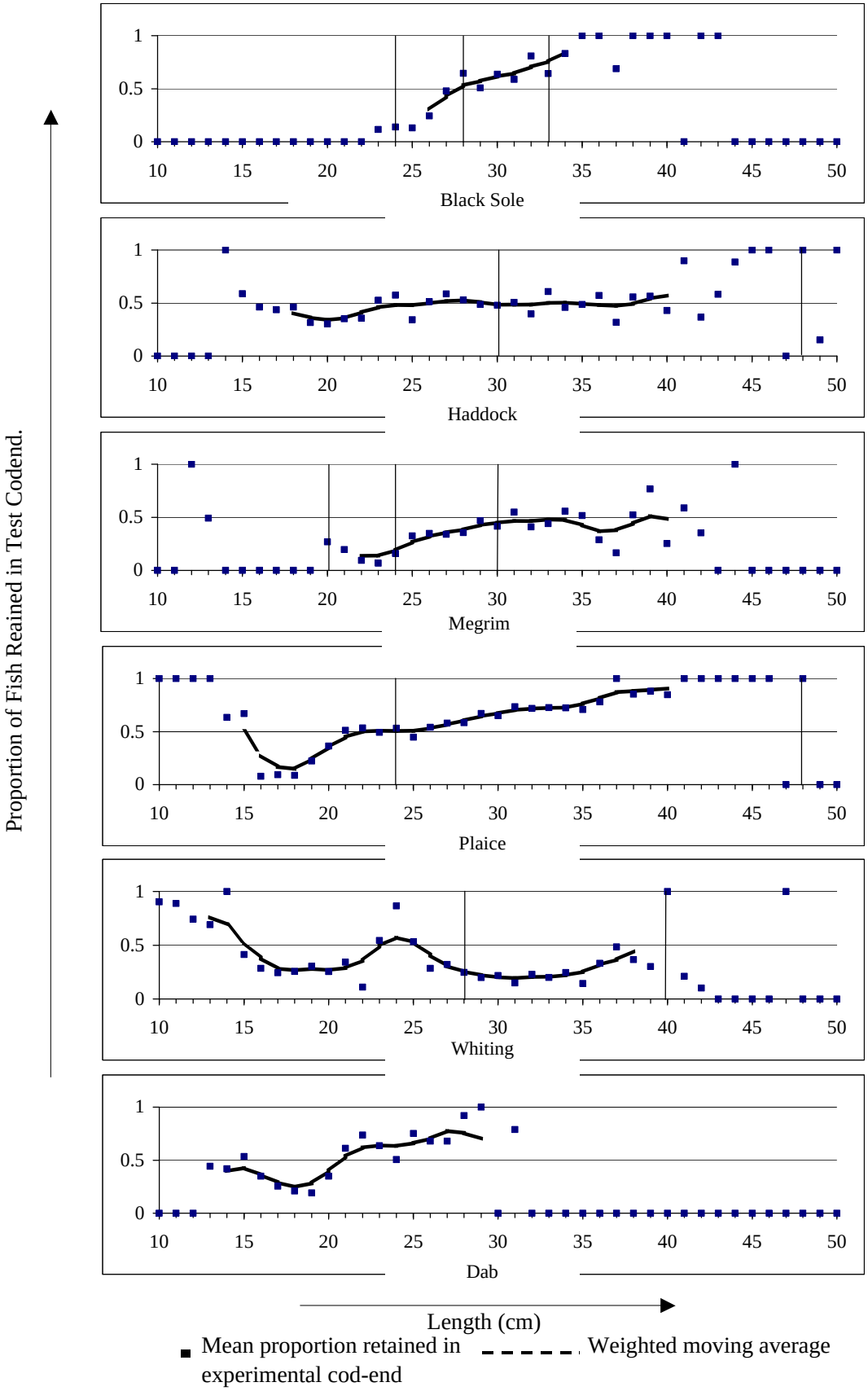


Figure F.1; Proportion of catch retained in test cod-end for pairing 11; Maid of Nazareth, year 1;experimental net =80mm square mesh panel.

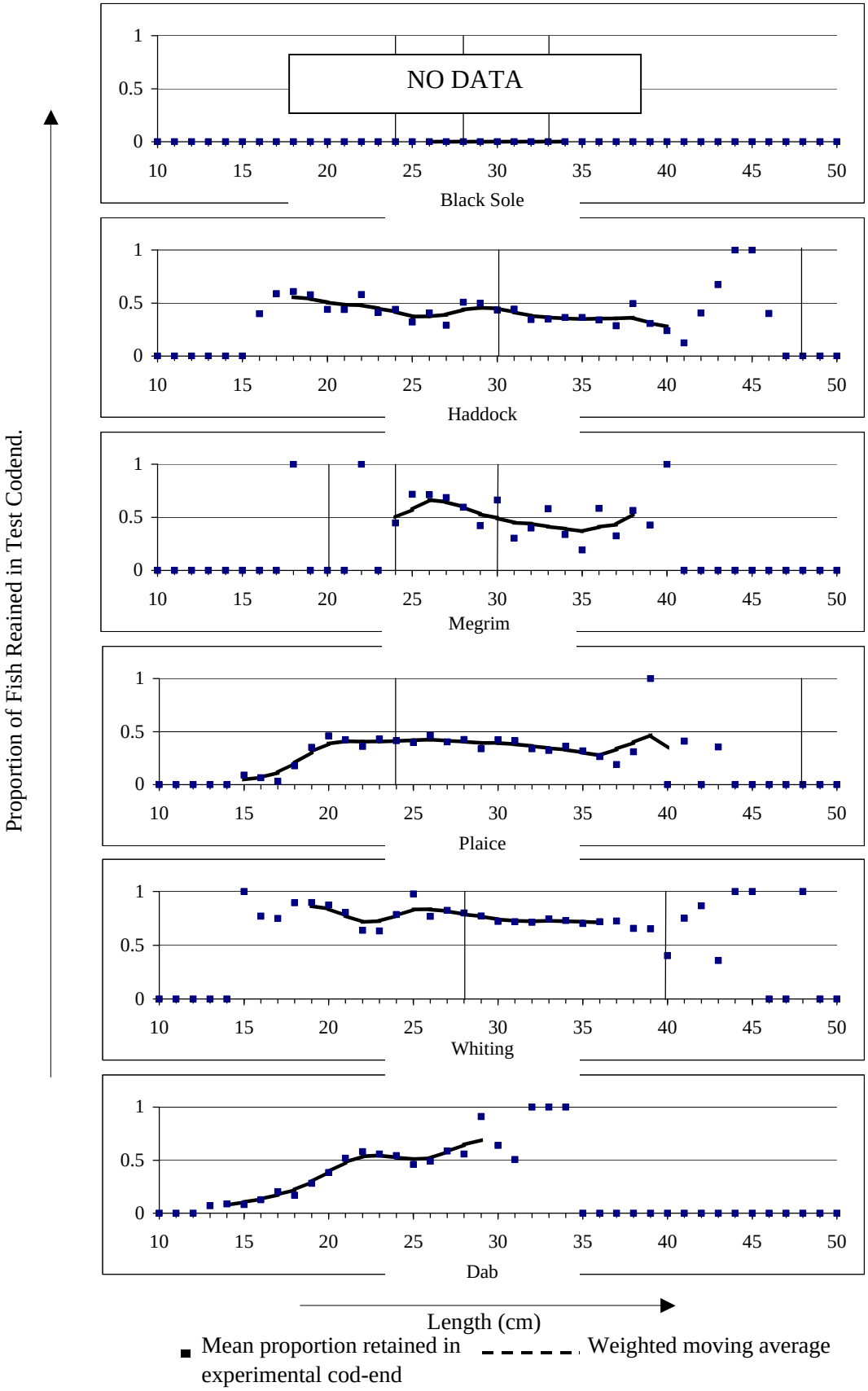


Figure F.2; Proportion retained in test cod-end for pairing 12; Floralie, year 1; experimental net =90mm square mesh panel (No data for black sole).

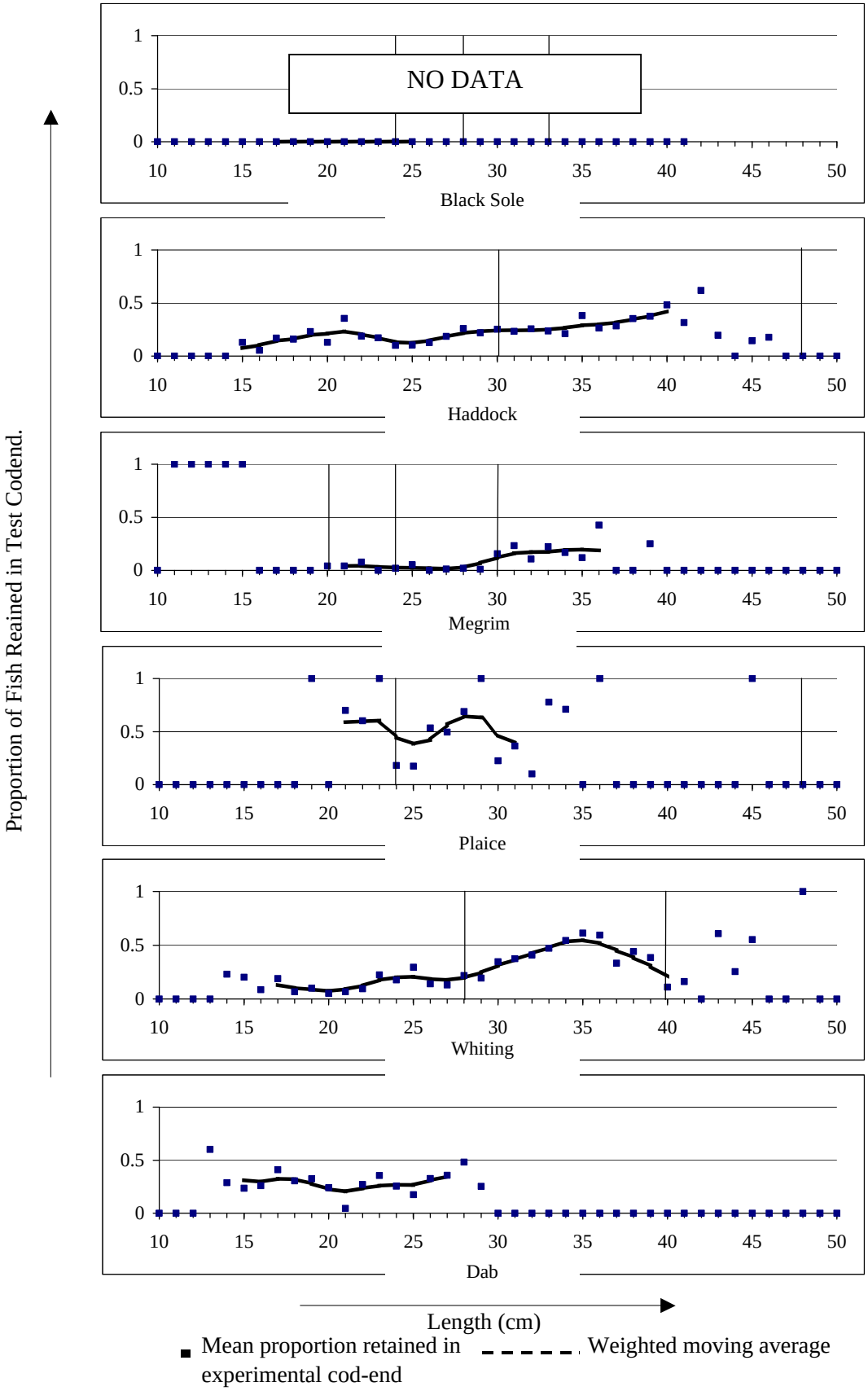


Figure F.3; Proportion retained in test cod-end for pairing 13; Gerlisa, year 1; experimental net =100mm cod-end.

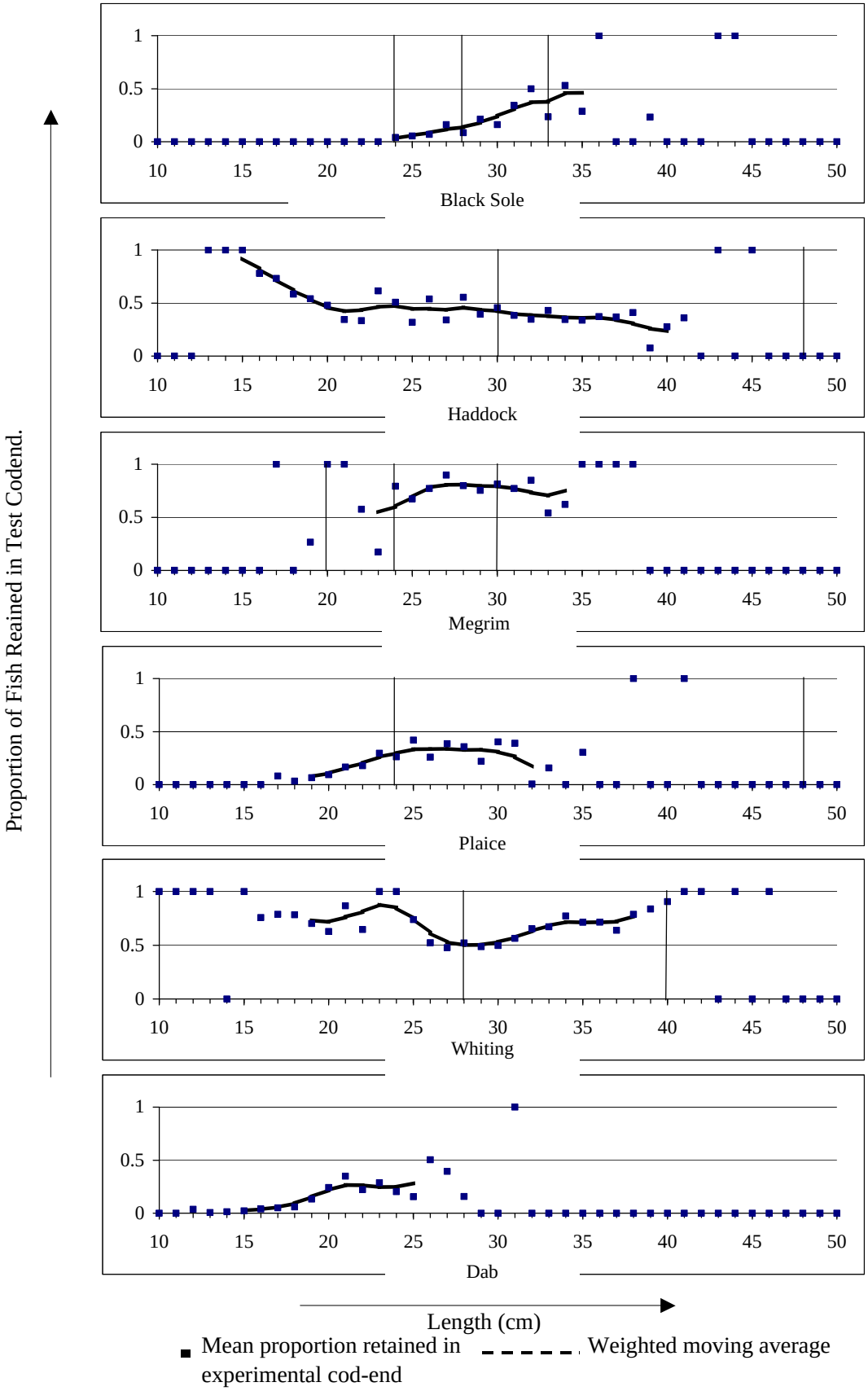


Figure F.4; Proportion retained in test cod-end for pairing 14; Elsie Marie, year 1; experimental net = Separator trawl.

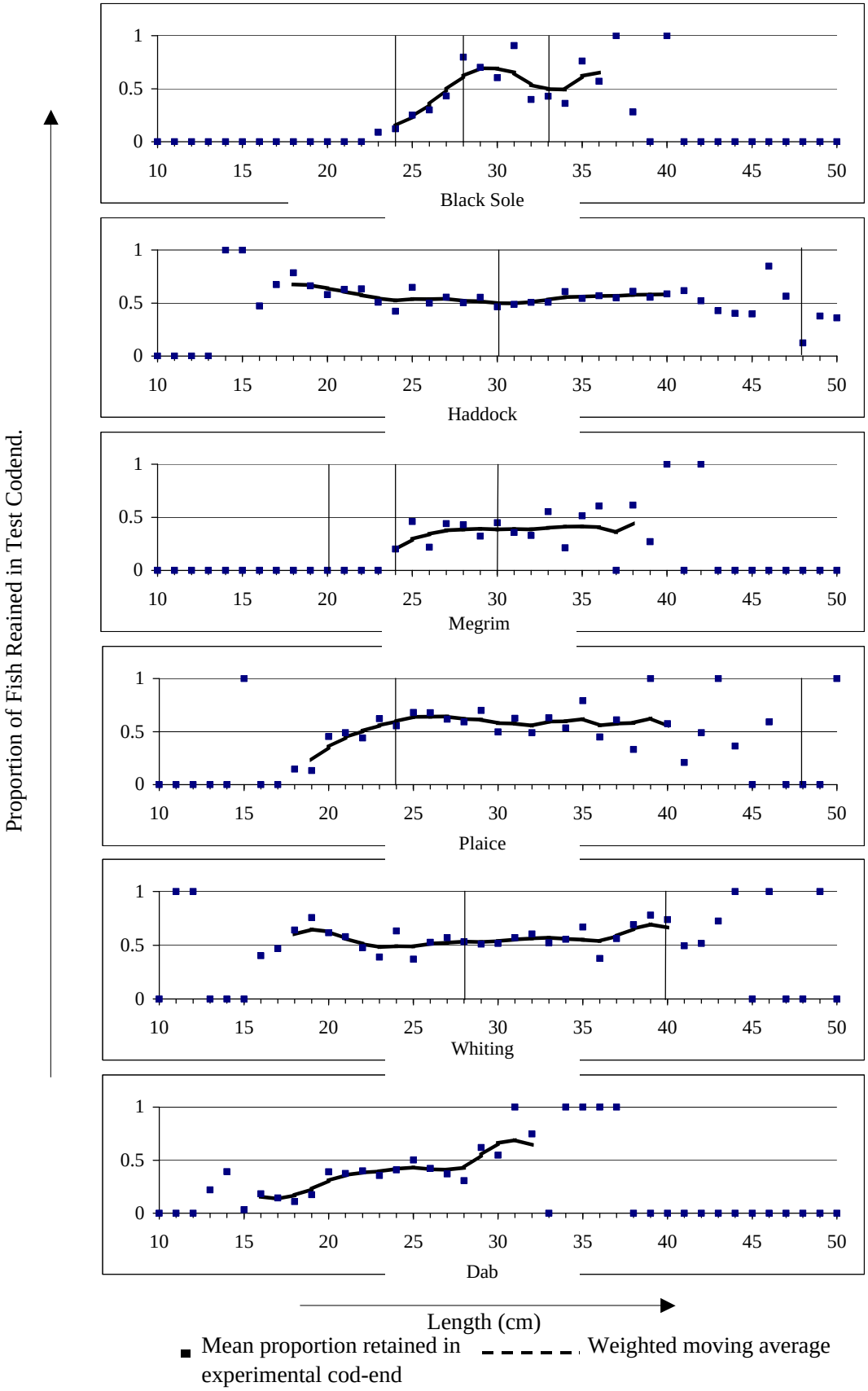


Figure F.5; Proportion retained in test cod-end for pairing 15; Naomh Deararca, year 1; experimental net =160mm coversheet.

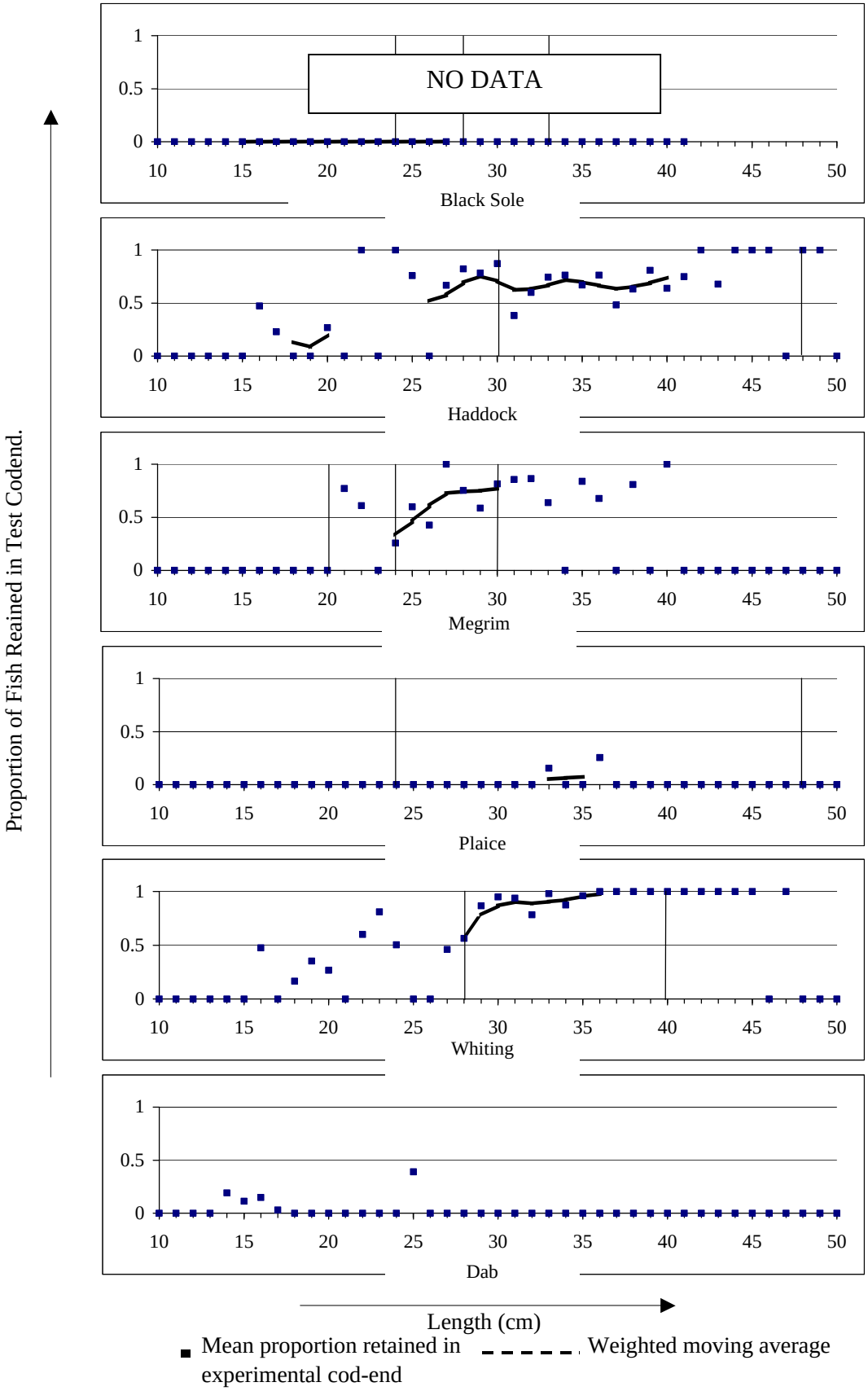


Figure F.6; Proportion retained in test cod-end for pairing 16; Deux Orchidees, year 1; experimental net =100mm cod-end.

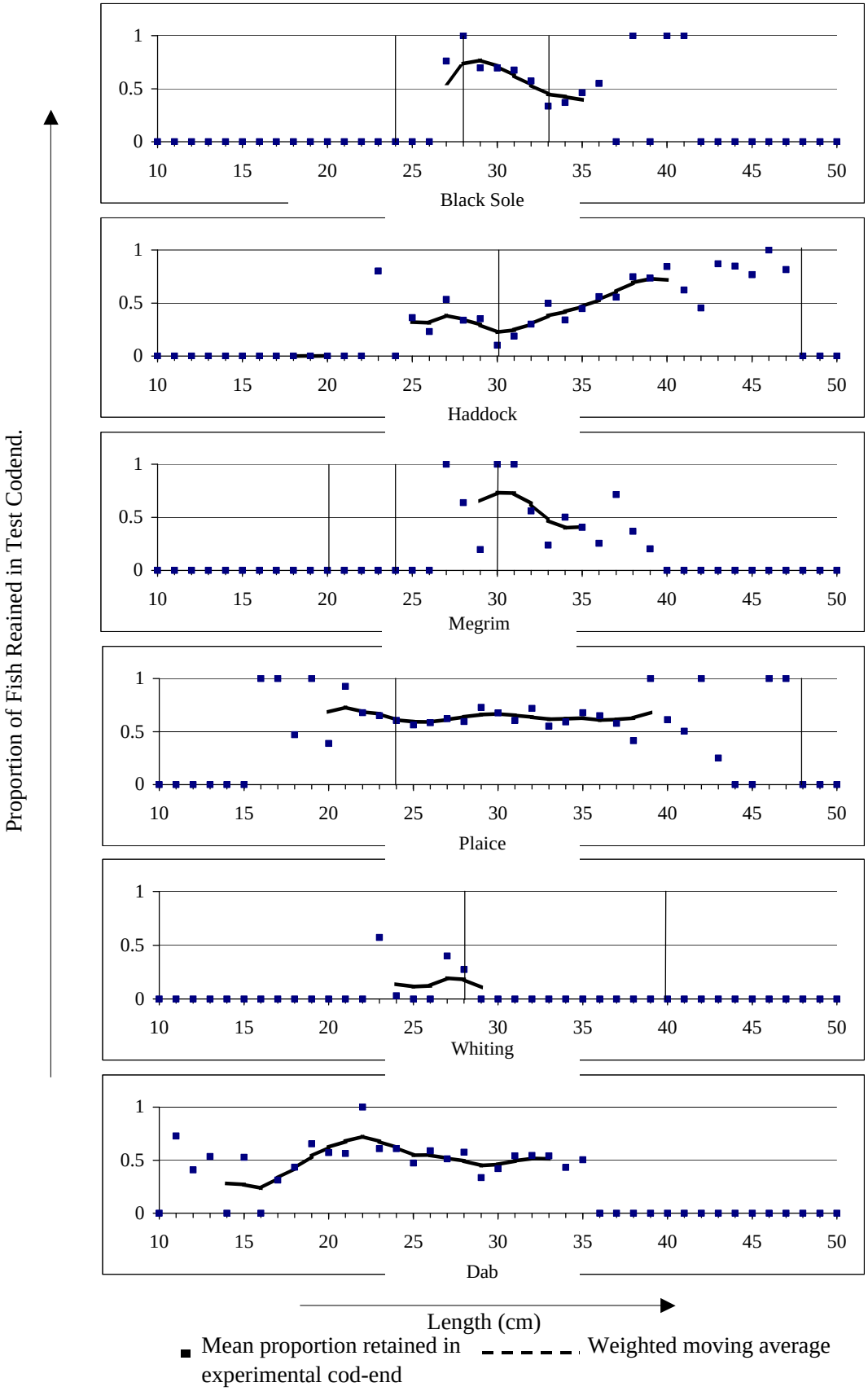


Figure F.7; Proportion retained in Floralie's cod-end for pairing 1; Year 2; Deux Orchidees, experimental net (100mm cod-end), Floralie, experimental net (100mm cod-end).

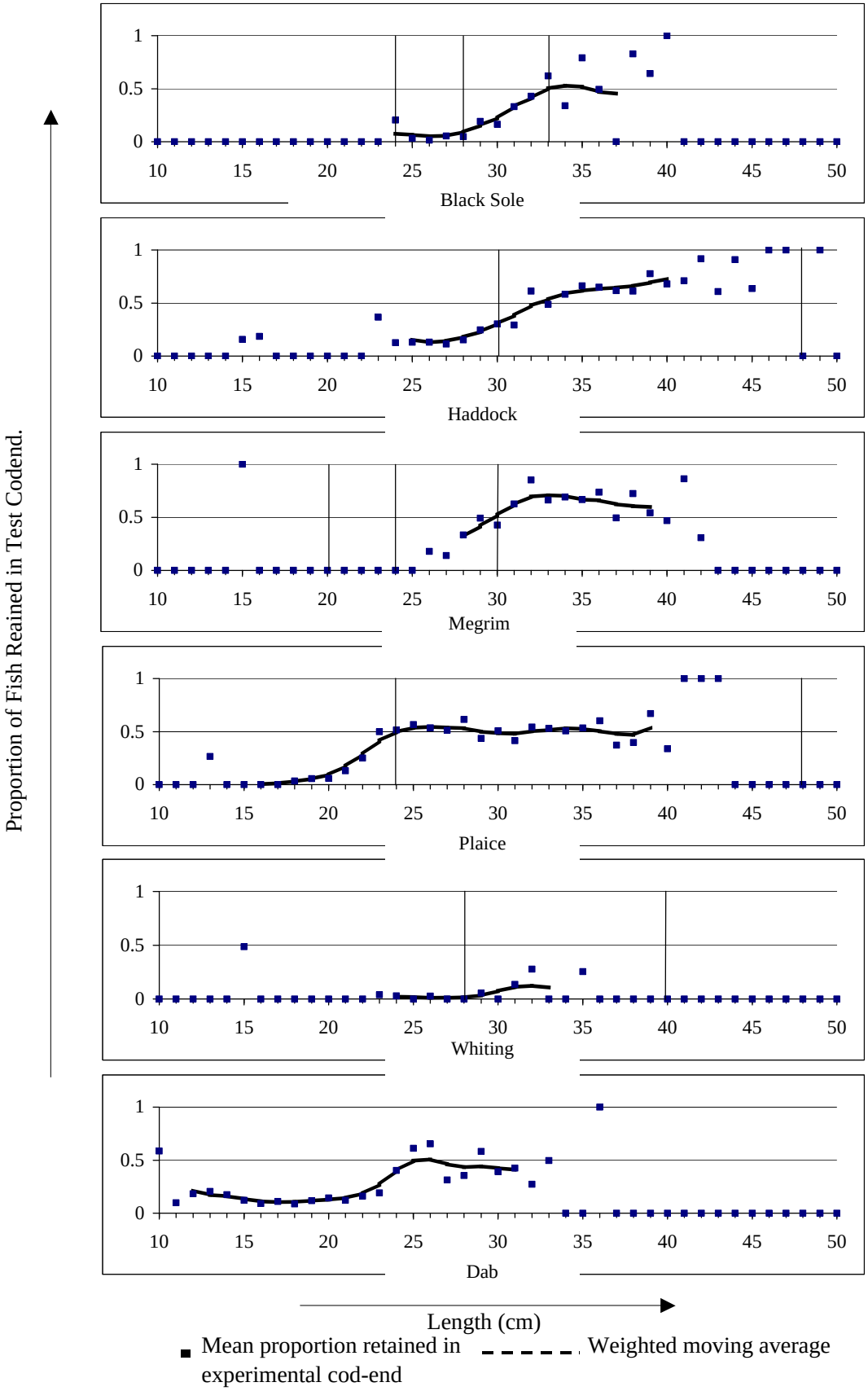


Figure F.8; Proportion retained in test cod-end for pairing 2; Year 2; experimental net, Floralie, (100mm cod-end), standard net, Deux Orchidees (80mm cod-end).

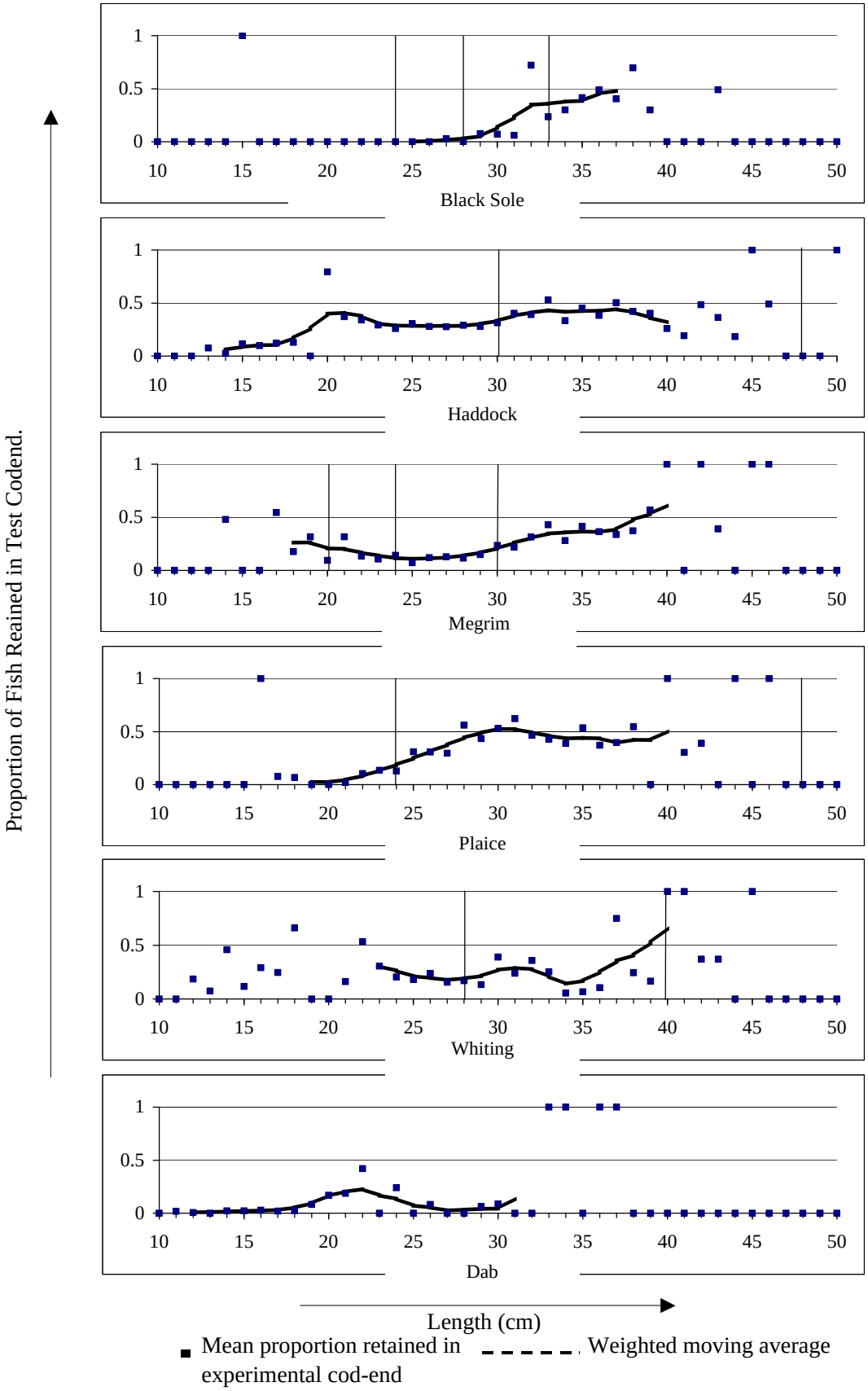


Figure F.9; Proportion retained in test cod-end for pairing 3; Year 2; experimental net: Deux Orchidees, 100mm cod-end; standard net: Floralie, 80mm cod-end.

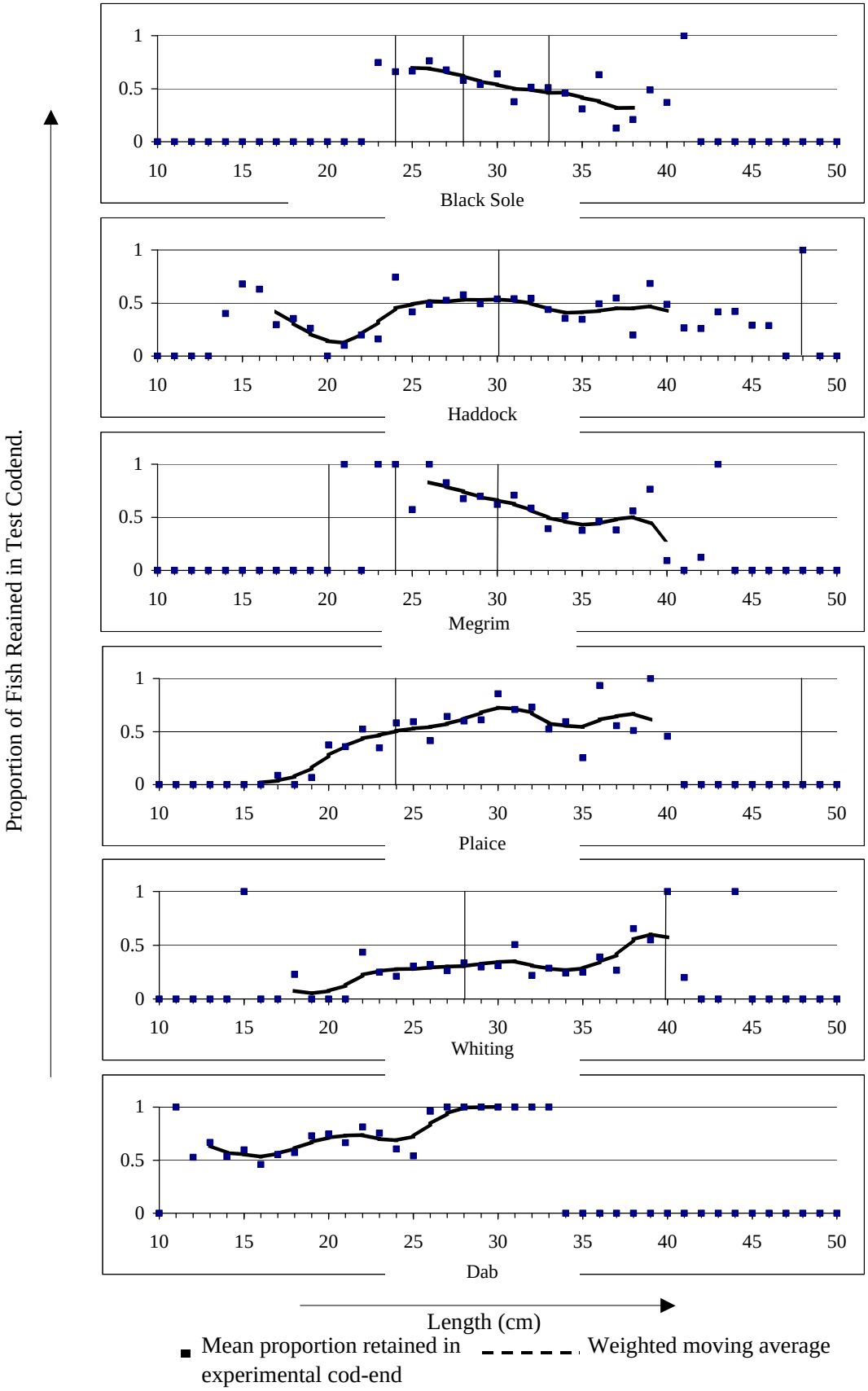


Figure F.10; Proportion retained in Elsie Marie cod-end for pairing 4; Year 2, Elsie Marie, experimental net (80mm square mesh panel) and Maid of Nazareth experimental net (80mm square mesh panel).

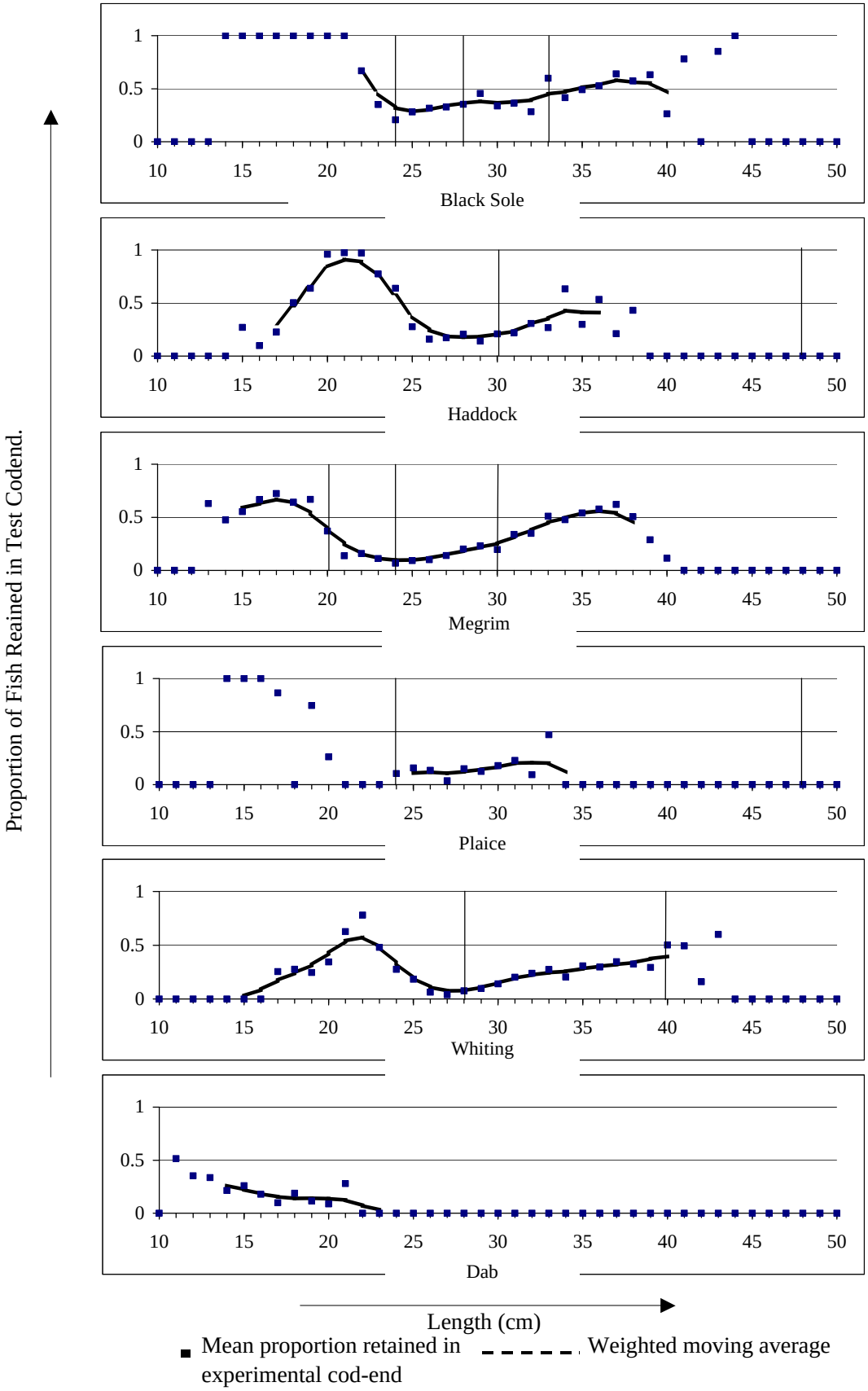


Figure F.11; Proportion retained in test cod-end for pairing 5; Year 2; experimental net (Elsie Marie, 80mm square mesh panel), standard net (Maid of Nazareth, 80mm cod-end).

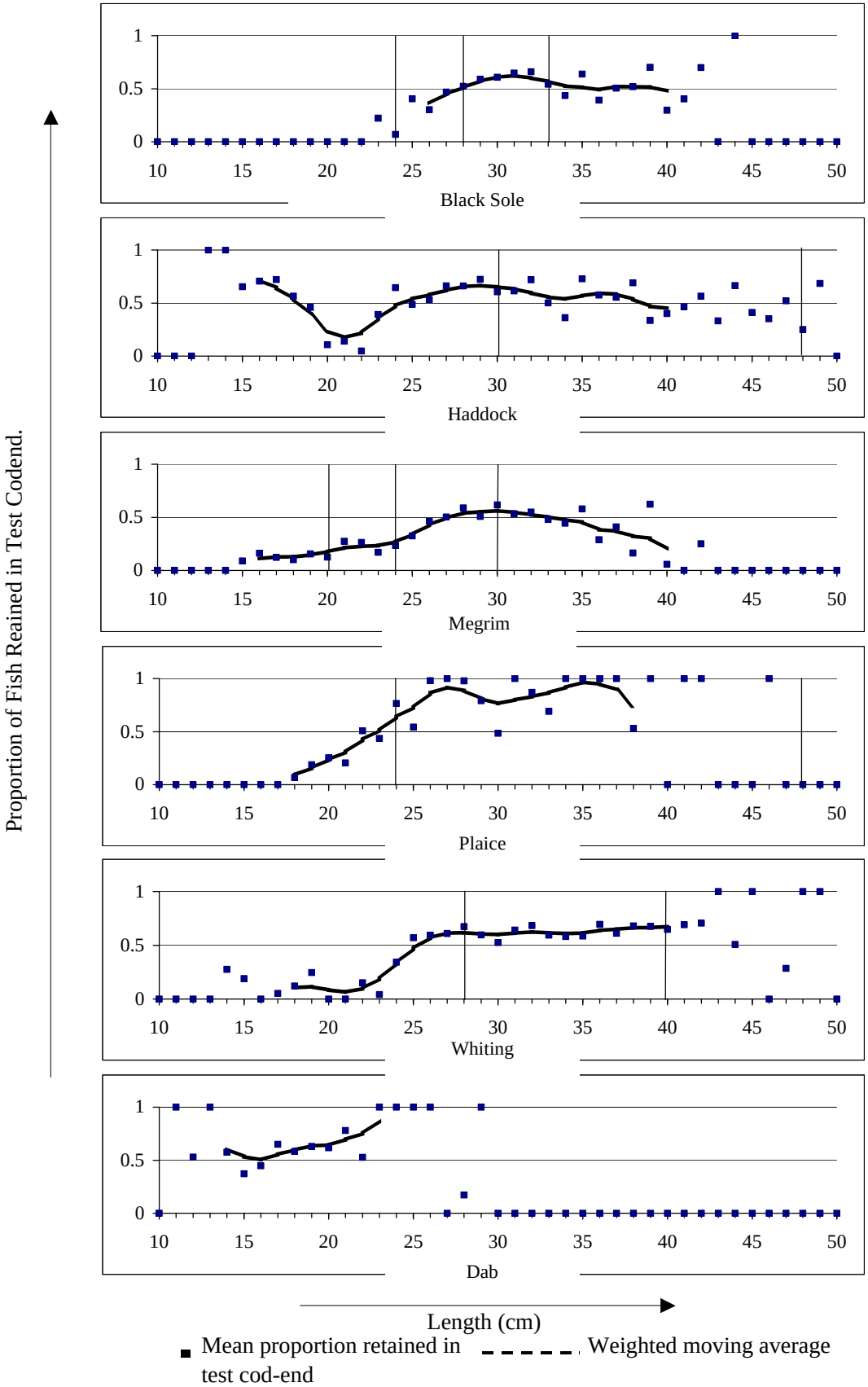


Figure F.12; Proportion retained in test cod-end for pairing 6; Year 2; -experimental net (Maid of Nazareth, 80mm square mesh panel), standard net (Floralie, 80mm cod-end).

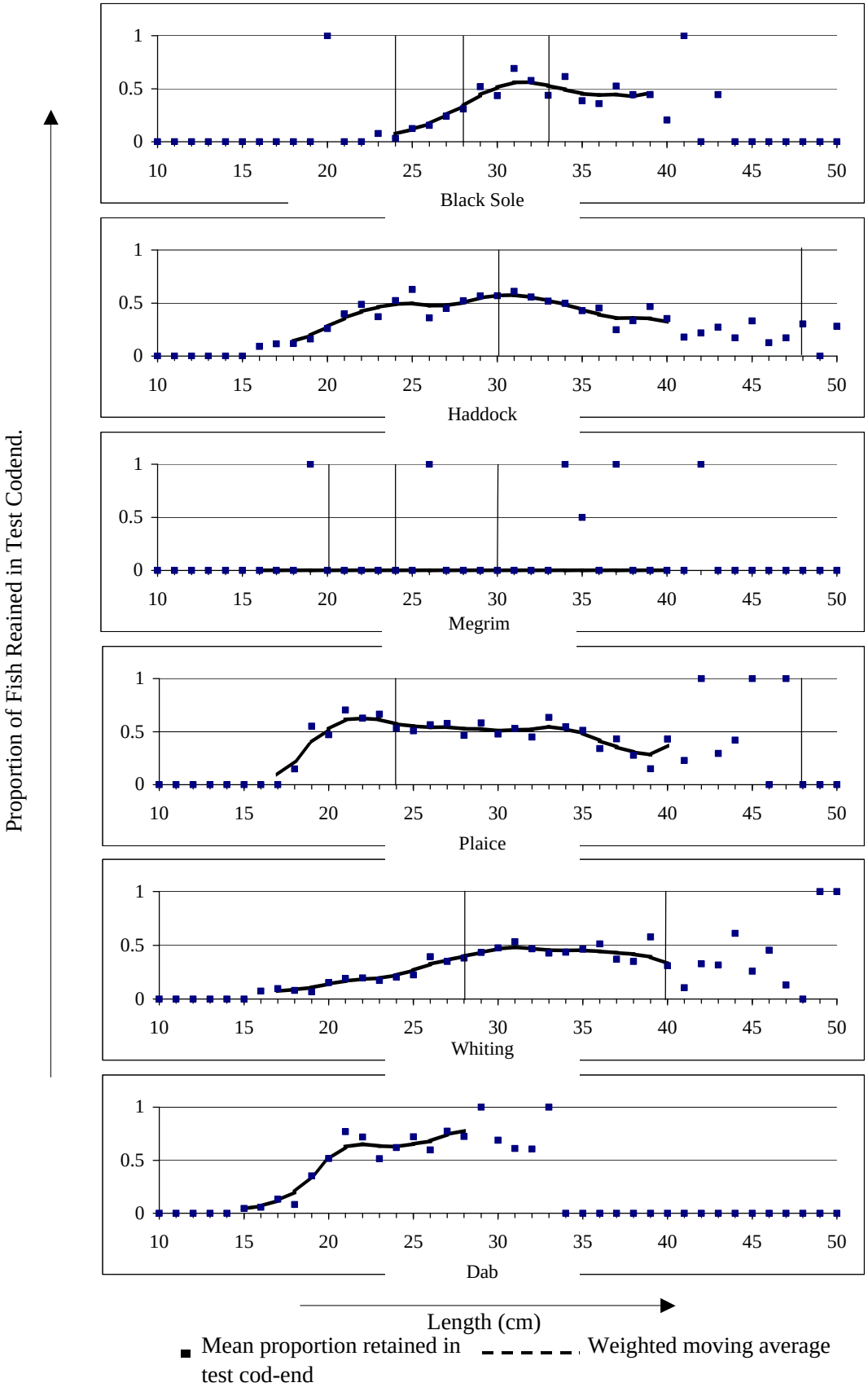


Figure F.13; Proportion retained in test cod-end for pairing 7; Naomh Deararca, year 2; experimental net (100mm cod-end.

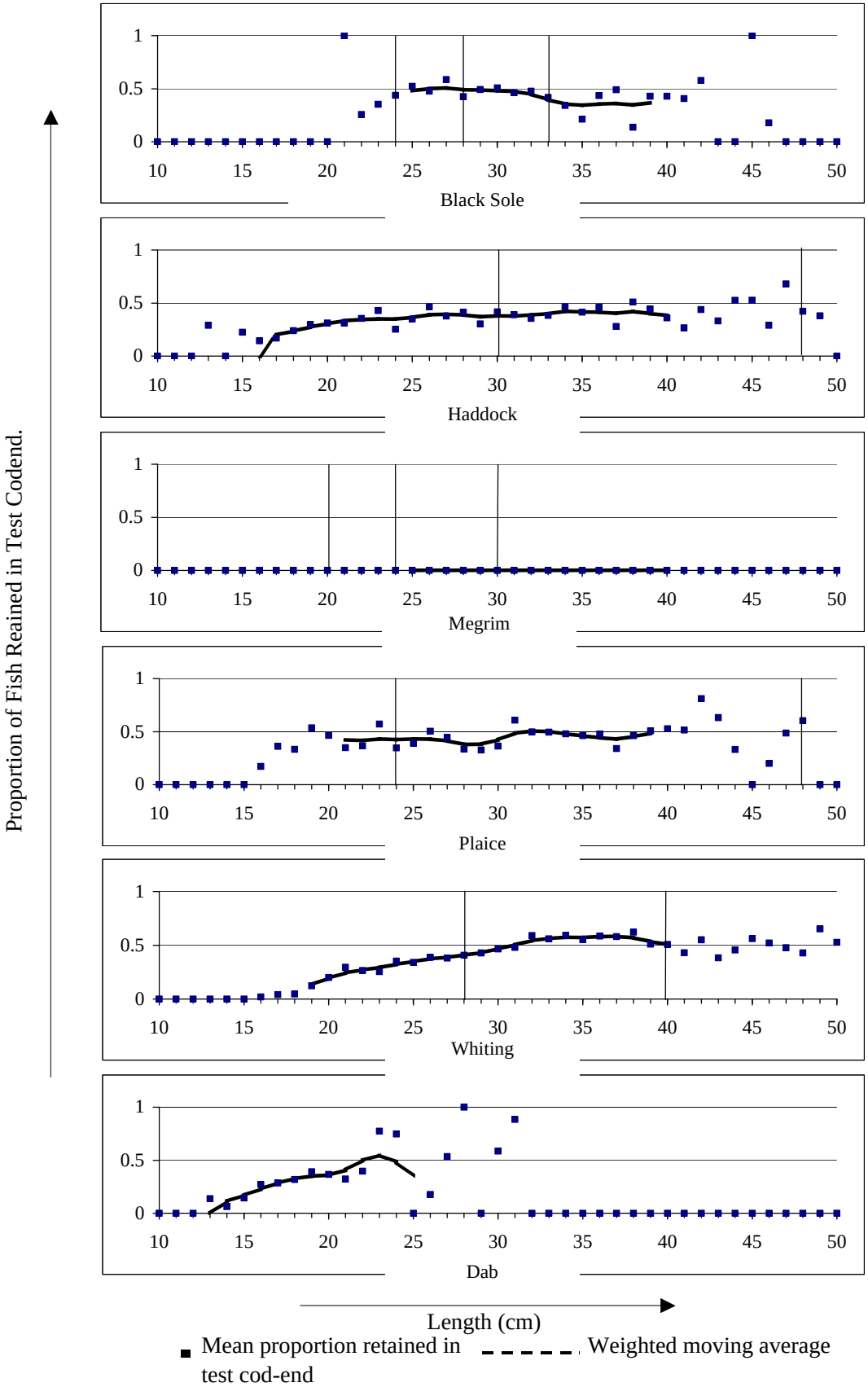


Figure F.14; Proportion retained in test cod-end for pairing 8; Gerlisa, year 2, experimental net =100mm cod-end.

Appendix G: Principal Component Analysis

Principal component analysis biplots for all species measured in parallel tows. Each species on each boat is represented by a labelled arrow; the angle between arrows represent how closely the pattern of catches of these species were correlated, the closer to 0 degrees the angle between arrows the more strongly positive the correlation and the closer to 180 degrees the more negatively correlated the catches.

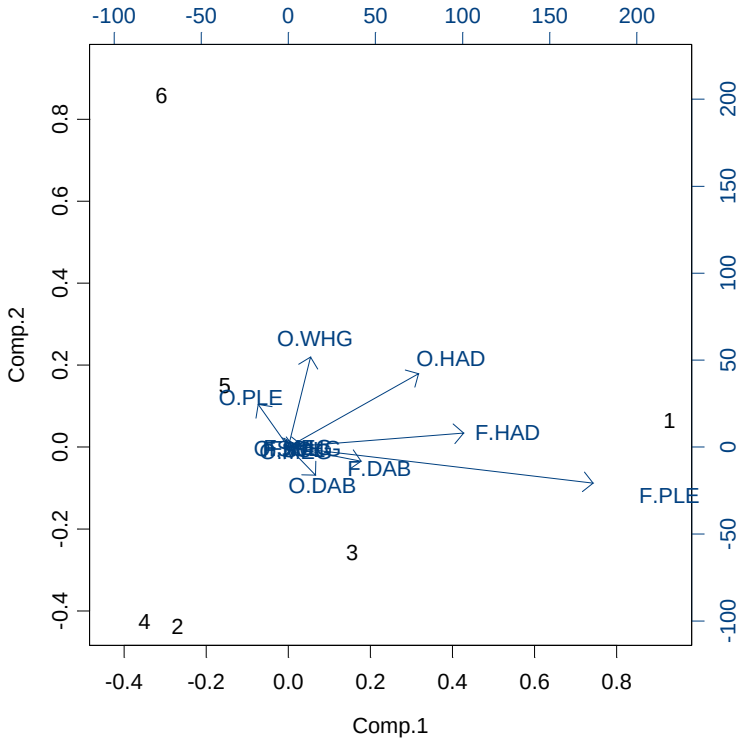


Figure G.1; Pairing 1, Year 2; O-Deux Orchidees (experimental net; 100mm cod-end), F-Floralie (experimental net; 100mm cod-end). Principal components 1 and 2 account for 93% of the variance.

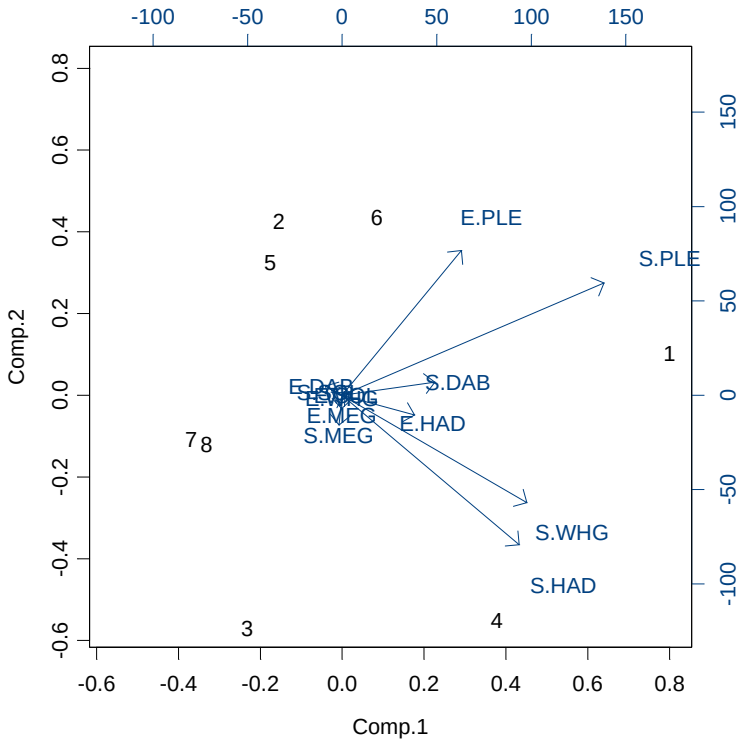


Figure G.2; Pairing 2 Year 2; - E-experimental net (Floralie, 100mm cod-end), S-standard net (Deux Orchidees, 80mm cod-end). Principal components 1 and 2 account for 83% of the variance.

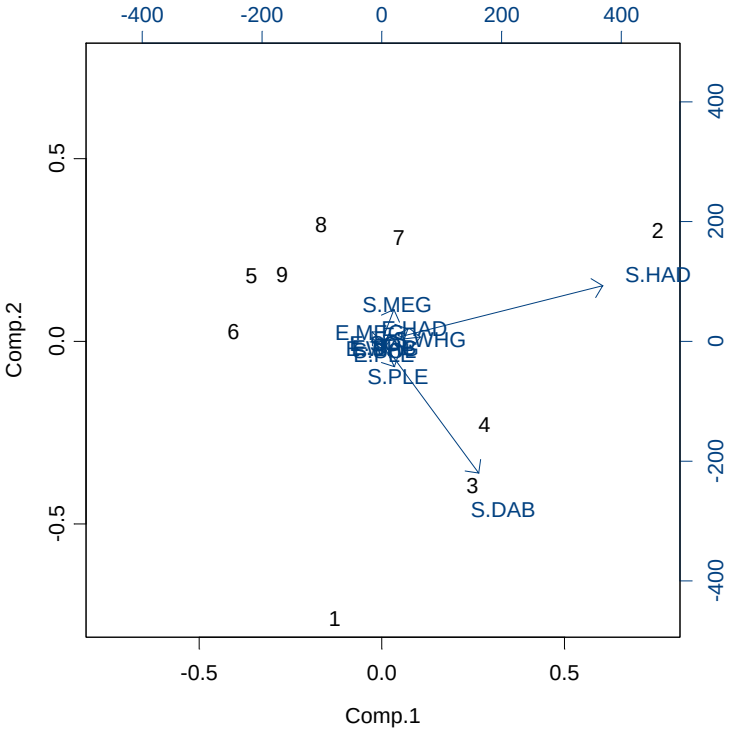


Figure G.3; Pairing 3, Year 2; - E-experimental net (Deux Orchidees, 100mm cod-end), S-standard net (Floralie, 80mm cod-end). Principal components 1 and 2 account for 96% of the variance.

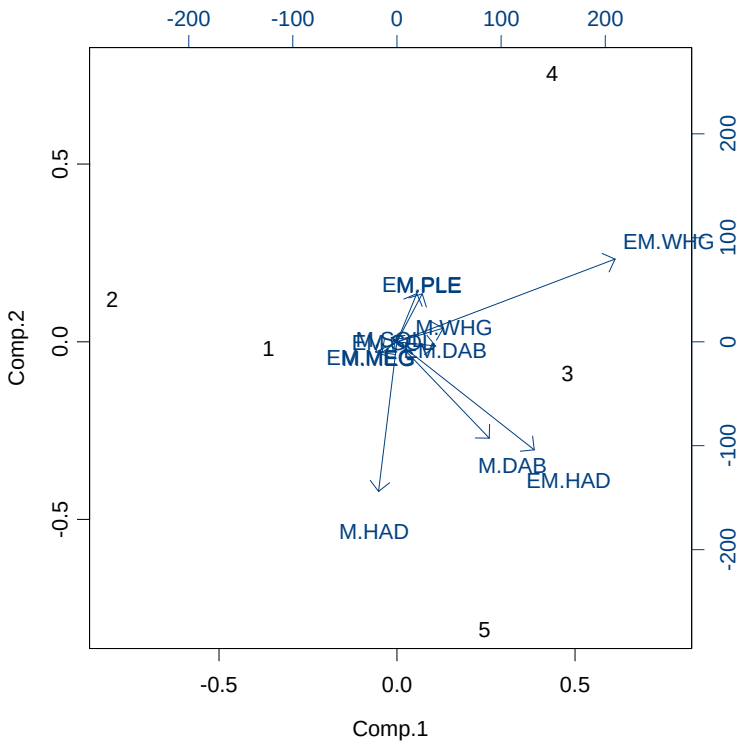


Figure G.4; Pairing 4, Year 2, E-Elsie Marie (experimental net; 80mm square mesh panel), M-Maid of Nazareth (experimental net; 80mm square mesh panel). Principal components 1 and 2 account for 96% of the variance.

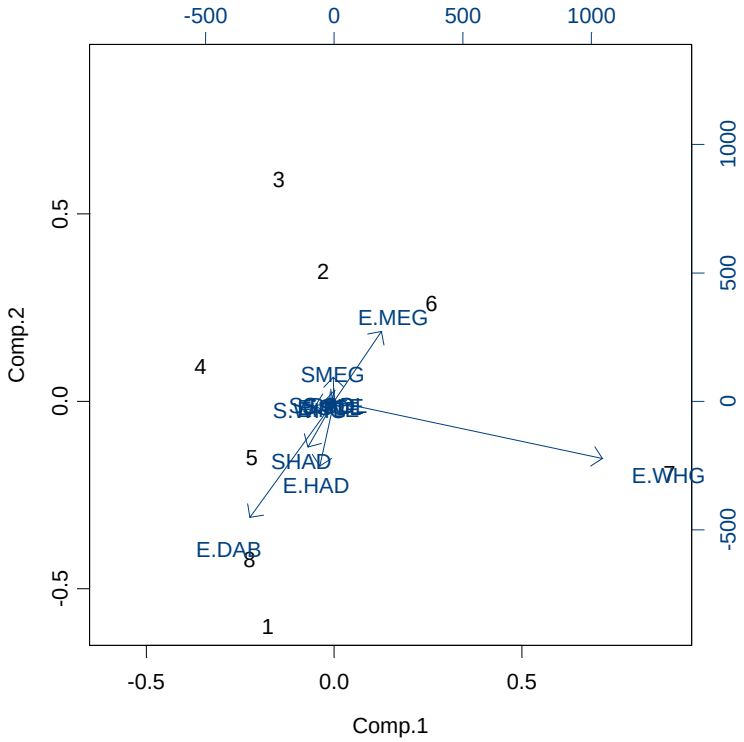


Figure G.5; Pairing 5, Year 2; - E-experimental net (Elsie Marie, 80mm square mesh panel), S-standard net (Maid of Nazareth, 80mm cod-end). Principal components 1 and 2 account for 91% of the variance.

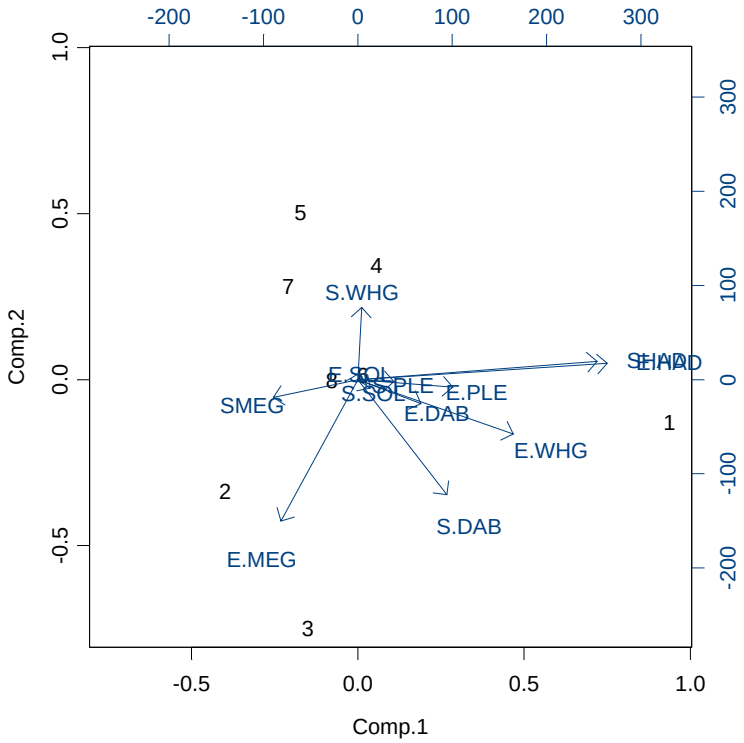


Figure G.6; Pairing 6, Year 2; - exp-experimental net (Maid of Nazareth, 80mm square mesh panel), std-standard net (Floralie, 80mm cod-end). Principal components 1 and 2 account for 87% of the variance.

Appendix H: Calculated Value.

Calculated value of landings for all species measured for all valid tows. The numbers at length caught was converted to overall mass caught; this was then multiplied by the value of that mass of fish.

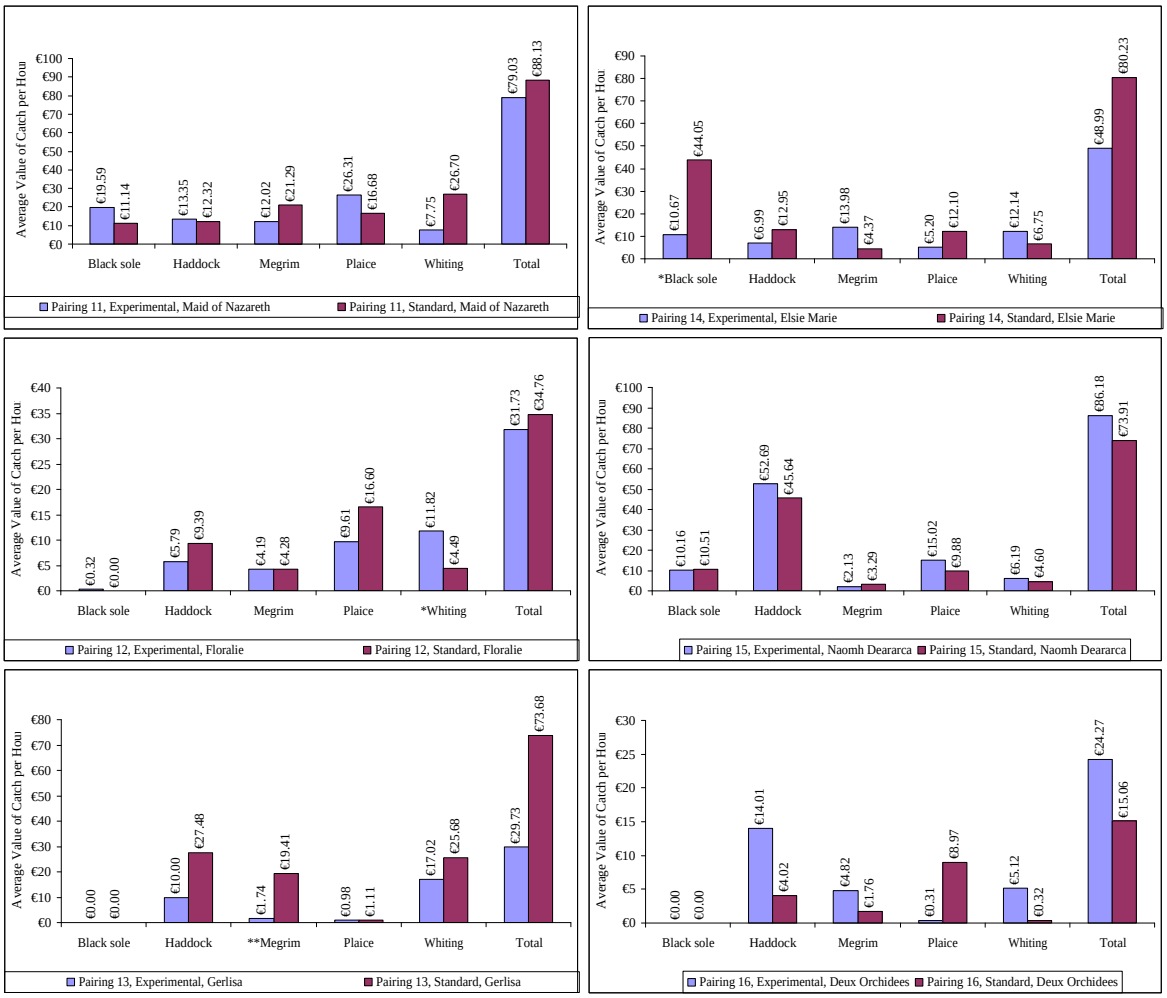


Figure H.1: Value of Hauls, Euro per hour. Significant differences in numbers of fish landed denoted by *, **, & ***.

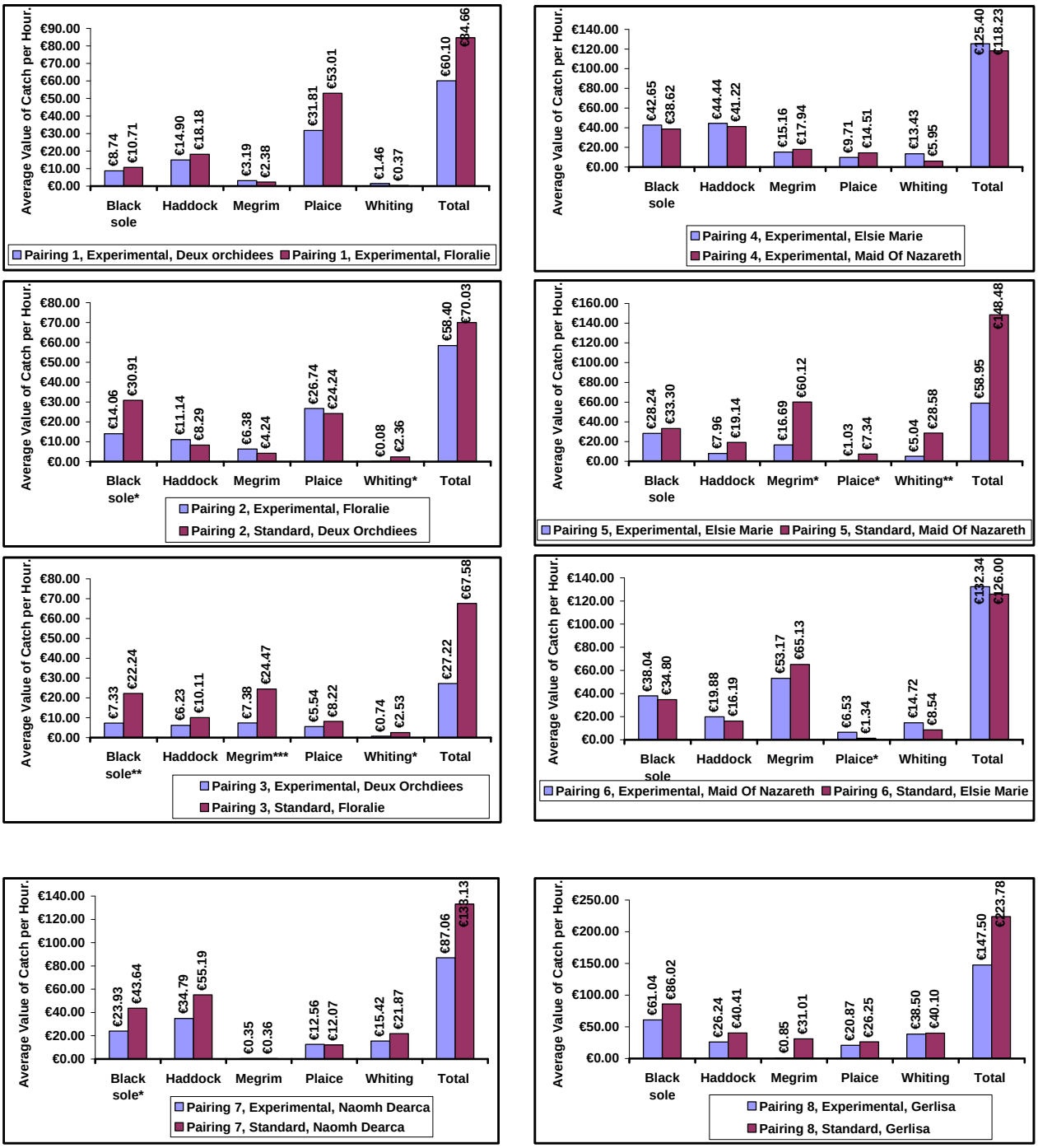


Figure H.2: Value of Hauls, Euro per hour. Significant differences in numbers of fish landed denoted by *, **, & ***.