SR568_'Off-bottom' trawling techniques for the sustainable exploitation of non-pressure stocks in Cornish inshore waters

Ken Arkley, Richard Caslake

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Off-bottom' trawling techniques for the sustainable exploitation of non-pressure stocks in Cornish inshore waters

Introduction

The decline in stocks of demersal species in general, and in the SW in particular, has resulted in fishermen looking for new fishing opportunities.

Discussions with fishermen, industry representatives and the Objective One Sustainable Fisheries Committee in Cornwall have highlighted the need to offer fishermen in Cornwall additional opportunities if the industry is to survive. It is evident that the only potential opportunities can come from under-exploited and/or non-pressure stocks.

Approach

There is potential to exploit a number of species using small-scale 'off-bottom' trawling techniques. Species such as John Dory, black bream, whiting, squid and cuttlefish have attracted particular interest with the potential for exploitation as target species in low volume/high quality fisheries. This would provide alternative opportunities for the small-boat inshore sector, taking away effort from pressure stock species in their existing traditional fisheries.

The report is in three parts summarised below

Review

This report reviews the ecology, biology, reproduction, recruitment, growth, maturity, stock dynamics and gear technology relating to the sustainable exploitation of john dory (*Zeus faber*), Black seabream (*Spondyliosoma cantharus*), Cuttlefish (*Sepia officinalis*), Squid (*Loligo forbesi & Loligo vulgaris*) and Whiting (*Merlangius merlangus*) off SW England. It also contains analysis of the data on these species (Section 2) contained in the Marine Biological Assocaition long term datasets from trawl catches off Plymouth

Fishing Gear Development and Testing

This report describes the construction (including net plans and rigging details) and flume tank testing of off bottom trawls suitable for use in Cornish inshore waters.

Fishing Gear Testing

This report describes the testing of off bottom trawls in Cornish inshore waters.

'Off-bottom' trawling techniques for the sustainable exploitation of non-pressure stocks in Cornish inshore waters

Literature Review

And

Data Summary

Report prepared by

Tthe Marine Biological Association of the United Kingdom, Plymouth for the Sea Fish Industry Authority

Section 1

'Off-bottom' trawling techniques for the sustainable exploitation of non-pressure stocks in Cornish inshore waters

Literature Review

Olivia Langmead

Georgina Budd

David Sims

Stephen Hawkins

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Whiting (*Merlangius merlangus*)

Ecology

Whiting belong to the family Gadidae (cods and haddocks) and are distributed in the Eastern North Atlantic from Iceland and the Southeastern Barents Sea to Portugal. Whiting is benthopelagic at depths from 10 to 200 m, but more common from 30 to 100 m. They live mainly on mud and gravel bottoms, but also on sand and rock (Bromley & Watson, 1994; Svetovidov, 1986). Given a choice of habitats in a laboratory experiment, whiting *Merlangius merlangus* preferentially spent most time over sand, then gravel and least time over a habitat with emergent structures. The introduction of a predator stimulus increased the preference for the sand habitat for large whiting, whereas small whiting had an increased preference for the habitat with emergent structures (Atkinson, et al., 2004).

The young are found in shallower waters, from 5 to 30 m depth. Juveniles migrate from nursery areas for the open sea after the first year of life. Juveniles up to 3 cm in length are associated with the common jellyfishes *Cyanea lamarcki and Chrysaora isosceles* (Wheeler, 1969). Spatial and seasonal patterns of whiting in the Celtic Sea in relation to their annual life cycle are not fully understood (Verdoit & Pelletier, 2000).

Whiting are active predators, feeding on shrimps, crabs, molluscs, small fish (e.g. Norway pout (*Trisopterus esmarki*), blue whiting (*Micromesistius poutassou*) and sprat (*Sprattus sprattus*), polychaetes and cephalopods (trophic level 2.8 and upwards) (Casey, et al., 1986; Daan, 1989; Dahl & Kirkegaard, 1986; Degnbol, 1992; Du Buit, 1991; Du Buit & Marlinat, 1985; Gordon, 1977b; Hislop, et al., 1991).

In turn a variety of species prey on whiting juveniles and adults. These include fish such as

- angler-fish, *Lophius piscatorius*, (Crozier, 1985)
- hake, *Merluccius merluccius,* (Du Buit, 1996)
- cod, *Gadus morhua*, (Armstrong, 1982)
- rays, e.g. *Raja microocellata*, (Ajayi, 1982)

mammals and invertebrates:

- dolphins, *Tursiops truncates,* (Santos, et al., 2001)
- grey seals, *Halichoerus grypus*, (Arnett & Whelan, 2001)
- jellyfish, cnidarians e.g. *Obelia* sp., (Purcell, 1985)

Biology

Reproduction

Whiting spawn at 20 to 150 m depth, from January to September in the area between the British Isles and the Bay of Biscay, and also in the North Sea (Bromley & Casey, 2003). In the western English Channel, spawning is between January and May, peaking in April. MAFF surveys in 1974 showed whiting eggs were particularly abundant off Start Point. They are batch spawners (McEvoy & McEvoy, 1992). Fecundity estimates range from 200,000 eggs in small females to over 1 million eggs in large individuals. Eggs are buoyant and pelagic (Cooper, 1983).

Recruitment

The eggs are pelagic, and larvae and juveniles are associated with jellyfish, and do not become demersal until they reach 5 to 10 cm length. In the English Channel this is usually in September (Pawson, 1995). Juvenile whiting appear to have an affinity for estuaries, both in the English Channel and other estuarine regions such as the Bristol Channel (Henderson & Holmes, 1989).

Growth

Growth is rapid; at one year of age, the size of fish ranges from 15 to 19 cm, at 2 years, from 22 to 5 cm, at 3 years, from 30 to 34 cm (Gordon, 1977a). Females grow faster than males and life expectancy is approximately 10 years. Maximum size is 70 cm, although most fish are less than 23.50 cm (Cohen, et al., 1990; Sager, et al., 1990). Maximum reported age is 20 years[1].

Maturity

First maturity is attained at 1 to 4 years of age, at a length of between 28 and 30 cm (Table 1). In a recent study from the Irish Sea, proportions of sexually mature individuals in 1-year-old males increased successively from almost zero in length classes below 15 cm to around 0.9 at 25 cm, whilst almost all 2-year-old males were mature from their smallest length of around 19 cm. Maturity in females was more strongly linked to age than to length. Most 1-year-old females were immature, the proportion of mature individuals not exceeding 0.3 in any length class. Most 2-year-old females were mature and immature fish were found in the smallest length classes only (20-25 cm). Almost all 3-year-olds of both sexes were mature in all length classes (Gerritsen, et al., 2003). Length at 50% maturity (L-50) averaged around 19 cm in males and 22 cm in females. Variability in L-50 was negatively cross-correlated with average sea surface temperature in the preceding year. There is no evidence for substantial changes in maturity of whiting since the 1950s, despite an order-of-magnitude reduction in biomass caused by high fishing mortality.

Table 1. Maturity studies for whiting (*Merlangius merlangus*). Age or size at which 50% of the population are sexually mature.

Length (cm)	Age range (y)	Sex of fish	Locality	Reference
30.0	1.0 - 2.0	unsexed	North Sea	(Myers, et al., 1995)
	2.0	unsexed	Irish Sea - ICES VIa	(Myers, et al., 1995)
28.0 - 30.0		female	E and W Channel	(Dorel, 1986)
	3.0 - 4.0	unsexed	Eastern North Atlantic	(Cohen, et al., 1990)

[1] Fishbase, www.fishbase.org

The sex ratio averages 38.5% males and 61.5% females in the Irish Sea, and 32.2% and 67.8% respectively in the North Sea (Pawson, 1995).

Stock dynamics

Whiting is a relatively common fish in European Atlantic waters. The total catch reported for this species to FAO for 1999 was 75 245 t. The countries with the largest catches were UK (25 561 t) and France (20 693 t).

It is not clear whether whiting stocks move between the eastern and western Channel; tagging experiments in the Channel have provided few data (Pawson, 1995). However, the prevalence of parasites has shown that southern North Sea whiting have a closer affinity with Channel stocks than northern North Sea whiting (Pawson, 1995). French small-scale fisheries exploit stocks in the eastern English Channel (Carpentier, 1998).

Stock resilience for this species can be considered medium, with a minimum population doubling time 1.4 - 4.4 years[1].

Gear

Whiting are caught mostly by bottom trawls and longlines; but handlines and occasionally, purse seines also are used. Effort has been put into reducing whiting bycatch in Irish sea *Nephrops* fisheries (Briggs, 1991a; Briggs, 1990, 1991b, 1992; Hillis & Carroll, 1988; Hillis, et al., 1991), and also reducing the amount of immature whiting caught by gear (Graham, et al., 2003; Groeneveld & Rijnsdorp, 1990; Robertson, 1984; Robertson & Shanks, 1994; Soldal & Engas, 1997).

<u>John dory (*Zeus faber*)</u>

Ecology

The john dory belongs to the family Zeidae (Dories). It has a worldwide distribution, and in the eastern Atlantic, is found from Norway to South Africa. John dory live in a variety of temperate marine environments from estuaries and lagoons to open ocean (Gibson & Ezzi, 1987). In a study of john dory in the waters of England and Wales, the species was most abundant in the waters to the south and west of the British Isles (Dunn, 2001). Its habitat is near bottom or in midwater, from close inshore down to 400m, but mainly at 50-150m (Quéro, 1986). A solitary fish, it rarely forms shoals larger than five individuals (Wheeler, 1969).

John dory is a very efficient predator and feeds almost entirely on schooling bony fishes, in northern waters herring, sand eels and young gadoids (Wheeler, 1969). It may also occasionally feed on cephalopods and crustaceans (Bianchi, 1992; Russell, 1983). Recruits and juveniles feed on zooplankton such as planktonic crustaceans (Gibson & Ezzi, 1987). However, one study has suggested that john dory switched from a diet of small prey species with more pronounced benthic behaviour to a diet of larger schooling pelagic species as the fish matured, suggesting parallel evolution to more pelagic foraging behaviour (Silva, 1999).

Biology

Reproduction

Spawning occurs from June-August, within the 100 m contour, in the Bay of Biscay and western part of the English Channel (Quéro, 1986; Wheeler, 1969). Eggs are large and pelagic.

Recruitment

Recruitment to the English Channel fishery takes place in summer and autumn at age one or more and a length of approximately 23 cm (Dunn, 2001). The eastern English Channel, southern North Sea and Irish Sea may be considered as seasonal nursery grounds for john dory.

Growth

John dory grow rapidly in their first year and more slowly thereafter. Immature fish measure about 4.3 mm at nine days and at a length of 7 mm have acquired the typical mouth shape and depth of body. By the first winter length is around 9-13 cm, at the second 24-27 cm, at the third 32-36 cm and at the fourth 40 cm. Males rarely grow longer than 45 cm. Females may live to their ninth winter, attaining an average length of 66 cm (Wheeler, 1969). Yoneda et al. (2002) determined the age and growth of john dory collected in the East China Sea from vertebral centra. Male fish had 1–13 ring marks, females 1–15. Using the observed total lengths (TLs) at age, the growth of male john dory can be expressed as $TL_t=446.7\ [1-\exp\{-0.128\ (t+1.465)\}]$ and that of females as $TL_t=580.2\ [1-\exp\{-0.112\ (t+0.772)\}]$. Females seemingly grew faster and lived longer than males, with most fish older than 10 years being female (Righini & Voliani, 1996).

The maximum reported size for john dory is 90.0 cm and the maximum reported age is 12 years (Karrer & Post, 1990). The maximum published weight is 8 kg (Muus & Nielsen, 1999).

Maturity

Maturity reached at between 3 and 4 years, at a length of between 26 to 37 cm for males and 34.5 and 37 cm for females (Table 2).

Table 2. Maturity studies for john dory (*Zeus faber*). Age or size at which 50% of the population are sexually mature.

Length (cm)	Age range (y)	Sex of fish	Locality	Reference
25.0 - 35.0	3.0 - 4.0	unsexed	Southern England	Muus & Nielsen (1999)
26.0		male	Celtic Sea and English Channel	Dunn (2001)
34.5		female	Celtic Sea and English Channel	Dunn (2001)
37.0		female	Gulf of Biscay	Dorel (1986)
37.0		female	E and W English Channel	Dorel (1986)

Stock dynamics

Growth and exploitation pattern of john dory in the English Channel have been described using length samples of commercial landings, discards, and research vessel samples collected between April 1994 and March 1996 (Dunn, 2001). Within the English Channel, the seasonal peak in landings during year quarters three and four coincided with the period of recruitment. A seasonal growth model (Von Bertalanffy, 1957) fitted to quarterly length data indicated that recruitment of young fish to the stock occurred at age >1.

Stock resilience for this species can be considered as low, with minimum population doubling time 4.5 - 14 years (Fishbase, see[1]) (K=0.15; tm=3-4; tmax=12).

1st quarter International Bottom Trawling Surveys 1970-1994 in the North Sea showed two periods of increased abundance, one in the mid-1970s and one around 1990. Both periods coincided with positive anomalies of winter temperature and salinity. These anomalies in turn are correlated with the southerly wind component over The Netherlands, suggesting increased inflow of Atlantic Water through the Strait of Dover. The conclusion is that the increased abundance does not reflect a long-term trend, but is the effect of temporary increases in southerly winds over the southern North Sea, resulting in increased transport of southern fish species into the North Sea, and favourable temperature conditions during winter (Corten & Kamp, 1996).

Catch data

Although not very abundant, the john dory is widely known and its flesh has a high market value (Omnes, 2003). Within the England and Wales fishery, landings of john dory have increased since 1980, with landings in years 1985 -1986, 1991 and 1997 being especially low (e.g. 25.5, 34.9, 55.0 & 48.3 tonnes respectively in ICES Division VIIe) and those between 1994-1995 being particularly high (e.g. 162.3 and 139.9 tonnes respectively in ICES Division VIIe), relative to the trend (Dunn, 2001); Table 1.) John dory has been consistently landed from the western English Channel (VIIe), but since 1993 landings from the Western Approaches and Celtic Sea (VIIg, h, j & K) have increased. Landings of john dory are lesser in the eastern Channel (VIId), North Sea (sub-area IV), Irish Sea (VIIa), and areas to the west and north of Ireland (VI, VIIb-c).

Gear

John dory is an important by-catch species in the mixed species fisheries of southern England and Wales, caught with demersal trawl gear (Dunn, 2001). However, the status of john dory as a by-catch species limits the effectiveness of directed stock conservation options such as limited entry or minimum mesh size. Minimum landing size or restrictive Total Allowable Catches (TACs) may cause increased discarding rather than reduced fishing mortality. It is likely that a reduction in revenue for inshore fishing fleets would result if efforts were made to reduce the capture of juvenile fish in inshore waters, as larger adult fish appear to congregate on grounds further offshore.

Black seabream (*Spondyliosoma cantharus*)

Ecology

Black seabream belong to the family Sparidae (Porgies). This species has a distribution in northeastern Atlantic shelf waters from Scandinavia and the Orkney Islands south to the Mediterranean sea (Pawson, 1995), including the Strait of Gibraltar, Madeira, Canary Islands, and Cape Verde (Smith & Heemstra, 1995). It is benthopelagic with a depth range of 5 to 300 m. It can be found over seagrass beds (Jackson, et al., 2002), rocky and sandy bottoms (Bauchot & Hureau, 1986). It is gregarious, sometimes forming large schools (Bauchot & Hureau, 1986). Black seabream are omnivorous, feeding on seaweeds and small invertebrates including plumose anemones, crustaceans, polychaetes, amphipods and hydrozoans (Bauchot & Hureau, 1986; Goncalves & Erzini, 1998; Mattacola, 1976; Pita, et al., 2002).

Biology

Reproduction

Black seabream spawn demersally. The male makes a depression in a gravel substrate and subsequently guards the fertilised eggs (Pawson, 1995). Accordingly, spawning areas cannot be identified by planktonic egg surveys. The presence of ripe and running bream in commercial catches suggests that spawning begins in the southwestern channel in April and takes place around the Channel Islands and off the Isle of Wight in May (Pawson, 1995). The latest spawning was recorded in the Baie de Seine during September and October. Most spawning areas are less than 50 m deep (Pawson, 1995). In southwest Portugal, spawning takes place from February to April, peaking in March (Goncalves & Erzini, 2000). Absolute fecundity ranges from 37,506 to 112,074 eggs, with a mean of

61,396 (Goncalves & Erzini, 2000) or 850 eggs per g in the 30.5 cm to 31.0 cm length class (Dulcic, et al., 1998).

Recruitment

Juvenile black seabream are found inshore around the Channel Islands, Port en Bessin, Isle of Wight and in the Solent, which suggests that they do not move far from the spawning grounds. Juveniles remain in these inshore areas for two to three years before recruiting to the adult stock at a length of approximately 20 cm (Pawson, 1995).

Growth

There is little information on growth of black bream from UK waters. Work from eastern middle Adriatic that fitted the von Bertalanffy growth equation on the basis of mean length-at-age data resulting in parameter values of L(infinity) = 47.7 cm, K = 0.178 and t(0) = -0.27. Weight growth constants are: W-infinity = 2269.2 g, K = 0.149 and t(0) = -0.74. Weight increased allometrically for both sexes together with b = 3.12 and in females alone with b = 3.14, while it increased isometrically in males with b = 2.99 (Dulcic & Kraljevic, 1996).

The black sea bream is a long-lived species. The sex ratio can be skewed in favour of females (3.12:1 in the Adriatic and 2.18:0 off the Canary Islands (Dulcic & Kraljevic, 1996; Pajuelo & Lorenzo, 1999)). Sex reversal has been mainly observed in age classes 7 and 8 (Dulcic & Kraljevic, 1996). Maximum reported size of black bream is 60.0 cm (male/unsexed) (Bauchot & Hureau, 1986).

Maturity

Black bream all mature as males at a length of around 20 cm and remain male until a length of approximately 30 cm. However, once bream exceed 30 cm, they may change into females, and all bream over 40 cm in length are females (Pawson, 1995).

Stock dynamics

The size structure of bream may have important consequences for the sustained reproductive capacity of a bream stock; the modal size of bream decreased from 37-38 cm in 1977 to 28-30 cm in 1979 as the bream fishery expanded (Soletchnik, 1983).

Bream migrations have been characterised by inferring seasonal movements from fishery data and analysing the distribution of maturing, ripe and spent fish. During the winter months, pre-spawning adult concentrations are found in the waters from 50-100 m depth west of a line from Alderney to Start Point. Evidence for this is from catch data provided by the French pair- and otter-trawl fisheries and incidental catches by English purse-seiners fishing off Land's End (Pawson, 1995).

During April and May, adult fish are caught in shallow (under 50 m) water around the Channel Islands, where they are no longer accessible to the deeper water pair-trawl fishery (Soletchnik, 1981). In subsequent months, bream migrate along the English and French coasts, and they probably enter the southern North Sea during July. It has been suggested that the migrations of bream, like bass, follow the eastward movement of the 9 °C isotherm as the Channel warms in spring (Pawson, 1995).

Once bream have entered the eastern Channel, groups of them are regularly encountered in particular localities during the summer. These support commercial fisheries off Boulogne (July to December), Dieppe (July to November), Port en Bessin (July to October) and the Isle of Wight and Sussex Coast (May to November) (Perodou & Nedelec, 1980; Perodou & Nedelec, 1982). Recreational fisheries also target bream off Sussex and south Devon, west Wales and around the Channel Islands. Bream feed in these inshore sites after spawning and begin to leave the eastern Channel in November and December. The winter concentrations in the western Channel appear in January as the fish move offshore into deeper water (Pawson, 1995)

In terms of resilience, black seabream can be classified as medium, with a minimum population doubling time 1.4 - 4.4 years (see Fishbase[1]).

Gear

There is very little information available about gear, selectivity and the food technology aspects of the black sea bream fishery.

Cuttlefish (*Sepia officinalis*)

Ecology

The common cuttlefish, *Sepia officinalis,* is found in eastern Atlantic shelf waters, from southern Norway and northern England, south to approximately Cap Blanc (Boletzky, 1983). It is the only species of *Sepia* abundant in the English Channel (Dunn, 1991). Sepiids are largely benthic or benthopelagic in habitat, and found mostly where the bottom is of rock, sand, pebbles or mud associated with seagrass. (Nixon & Young, 2003). *Sepia officinalis* is buoyant and swims in mid-water in darkness and buries itself in gravel during the day (Denton & Gilpin-Brown, 1961).

The food of *Sepia officinalis* includes crustaceans, bony fishes, molluscs, and less often polychaetes and nemerteans (Nixon, 1987). Predators of common cuttlefish include sharks, sparids and other demersal fishes and cuttlefishes.

Biology

Reproduction

Sexual dimorphism is apparent; females are smaller than males (Naef, 1923) and different body patterns are exhibited by the sexes during courtship (Tinbergen, 1939). Mature adults move inshore to spawning grounds where the water is around 30-40 m in depth (Mangold-Wirz, 1963). A cycle of shorter and longer generations occurs amongst females as large mature females migrate into shallow water in spring, whereas smaller ones move inshore later to spawn, in spring and early summer (Mangold, 1966). Eggs are laid in grape-like clusters to seaweeds, debris, shells and other substrates from early February until the end of May, but in the English Channel, the peak of spawning occurs from mid-April to mid-May. Major spawning areas on the English Channel coast are found in the Baie du Mont St Michel and Lyme Bay (Pawson, 1995).

Recruitment

First year cuttlefish remain inshore close to the site of hatching during the summer months. Observations and tagging experiments suggest that juveniles leave shallow coastal nurseries in October when they have attained a mantle length of around 6 cm, and migrate to areas of the western Channel where the depth exceeds 70 m and the mean water temperature remains above 9°C (Pawson, 1995). Juveniles hatched in early summer from the spring brood usually participate in the autumn spawning of the following year, while those from the autumn brood spawn in spring in their second year of life. Thus, the two cycles alternate. Males predominate in the adult phase because of massive post-spawning mortality among large females.

Growth

At hatching the mantle of *Sepia officinalis* is 6-9 mm in length. In laboratory-reared animals a mantle length of 150 mm is attained in around 200 days at 15 °C; the growth curve is typically sigmoid (Nixon & Young, 2003). Growth rate is greater in males and they attain a larger size than females (Mangold-Wirz, 1963). Males of 30 cm mantle length (ML) have been recorded; these were at least of two years of age. Females of 25 cm ML are known. Mattacola et al. (1984) caught an especially large female of 30 cm ML in the English Channel. However, large fluctuations in cohort growth rates do occur (Dunn, 1999). The resulting implications of this are that published growth parameters cannot be used for describing separate stocks (Pawson, 1995), and that calculated weights-at-age from one year cannot be used to infer numbers at-age from catches taken in another year (Dunn, 1999).

Maturity

Maturation occurs at different sizes: some males of 6 – 8 cm mantle length are mature but others are not, and females do not generally reach maturity until 11 – 25 cm ML. Thus males may have a longer period of reproductive activity than females (Nixon & Young, 2003).

Stock dynamics

Dunn (1999) describes aspects of the stock dynamics of the common cuttlefish in the English Channel. The exploitation pattern was shown to be a function of the region fished, the catching gear employed, and the growth and migrations of the cuttlefish population. Commercial landings data showed that spawning cuttlefish initially arrived on the inshore grounds in the western Channel, but slightly later and in greater numbers on the inshore grounds of the middle and eastern Channel.

Cuttlefish have a clear general annual migration pattern, consistently occurring in broadly the same areas in different years (Wang, et al., 2003). The strength of the Atlantic currents into the west part of the English Channel and the south part of the Celtic Sea may be the dominant influence on the timing of cuttlefish migration to these areas. Local abundance shows a positive correlation with SST, although it is difficult to determine if this reflects any causal link. Cuttlefish expand their distribution further north in the spawning season in warm years and shift south in cool years. The centre of high abundance in offshore deep water shifts north in warm winters and south in cool winters (Denis, 2000).

Gear

The common cuttlefish is typically caught in offshore beam trawls, and inshore otter trawls and nets (Dunn, 1999). Exploitation of juveniles occurs owing to the semelparous life cycle of the species and otter trawls are particularly guilty of growth overfishing of young cuttlefish (< 12 months old). Further control of 'effective' mesh sizes could help reduce growth overfishing (Dunn, 1999), and has been attempted in some fisheries (Pereira, 1993). More widespread use of cuttlefish traps has been encouraged, as they only catch spawning cuttlefish (Pinczon du Sel & Daguzan, 1997) and have little interaction with other gears but caveats include the mortality of attached eggs and an economic risk associated with investment in gear to exploit a species with potentially large annual variations in abundance (Dunn, 1999). Artisanal fisheries utilize a great variety of highly selective gear, such as spears, pots and traps, often combined with the use of light.

Food technology

There has been work on the effects of different storage methods on the meat quality (Anon, 1976; James & Iyer, 1998; Joseph & Perigreen, 1988; Prafulla, et al., 2000; Tanimoto, et al., 2000; Zacharia, 1986).

Non-edible wastes from cuttlefish processing have been used for aquacultural and agricultural feeds (Abdelmouleh, 1996, 2002; Ali, 1995).

Squid (*Loligo forbesi* & *Loligo vulgaris*)

Ecology

The loliginid squid, *Loligo forbesi* inhabits subtropical and temperate waters over a broad geographical range in the eastern Atlantic (Sims, et al., 2001). It is found in continental shelf waters in temperate regions and deeper in subtropical waters in temperate areas, generally between 60° and 20° N excluding the Baltic Sea (Roper, et al., 1984). *Loligo vulgaris* is common along the coasts of the north-eastern Atlantic Ocean and the Mediterranean Sea (Nixon & Young, 2003), but is much less common than *Loligo forbesi* in the English Channel being mainly found in winter, when it may be the only species of *Loligo* taken (Holme, 1974).

Squid are important constituents of marine food chains and are taken in the diet of fish, sea birds and marine mammals, and they predate on fish (sandeels, whiting and pout) and crustaceans (Pierce, et al., 1993).

Typically, loliginids exhibit diurnal, vertical movements aggregating near the bottom in daytime and dispersing in the water column in darkness. *Loligo forbesi* conducts seasonal migrations off southwestern England and has an annual life cycle (Sims, et al., 2001). The squid hatch in the western English Channel and migrate eastwards appearing in demersal otter trawls off Plymouth around May (Holme, 1974). Following several months of rapid growth in the English Channel and southern North Sea, including summer spawning, *Loligo forbesi* move back to the western approaches to spawn and die during the following December and January (Holme, 1974). Sims et al. (2001) found that *Loligo forbesi* migrate eastwards in the English Channel earlier when water in the preceding months is warmer, and that higher temperatures and early arrival correspond with warm (positive) phases of the North Atlantic oscillation (NAO). Sea bottom temperature was also closely linked to the extent of the squid movement.

Loligo forbesi differs from *Loligo vulgaris* in distribution, breeding season, length of life and number of spawning periods in a lifetime of an individual. The life-history of *Loligo vulgaris* has been described for the Atlantic coast of Europe (Tinbergen & Verwey, 1945) and the biology of *Loligo forbesi* in the Plymouth area of the western English Channel (Holme, 1974).

Biology

Reproduction

The spawn of *Loligo* is laid in clumps of finger-like masses of jelly attached to objects so that the spawn hangs clear of the sea bed. Off Plymouth the spawning period for *Loligo forbesi* tends to be from early December to the end of January, and throughout this period the majority of squid of both sexes are in spawning condition (Holme, 1974). Death occurs shortly after spawning. There is some doubt as to whether *Loligo vulgaris* spawns in this part of the Channel (Holme, 1974). *Loligo vulgaris* is also reported to spawn off the Dutch coast in summer (Tinbergen & Verwey, 1945).

Recruitment

Loligo forbesi spawned in December should hatch by the beginning of February. In order for this brood to appear in trawls by the end of May, a growth rate in the order of 25 mm per month is likely (Holme, 1974).

Growth

Mean growth rates, between the months of June and November, for males was 37 mm per month and for females 27 mm per month (Holme, 1974).

Maturity

Loligo forbesi is an annual species, growing to maturity and dying within twelve months of being spawned (Holme, 1974).

Stock dynamics and gear

Squid are caught in UK waters mainly as a by-catch when trawling or seining for white fish. Since squid tend to swim off the bottom, the best catches are obtained with midwater trawls or high headline (opening) bottom trawls. High opening bottom trawls are the primary gear type used in Atlantic *Loligo* and *Illex* fisheries (Rathjen, 1991). Some comparative trials between conventional high opening bottom trawls and pelagic off-bottom trawls have been conducted. Bowman & Mayo (1977) found that catches of squid with pelagic off-bottom trawls was higher (average 1715 kg squid per hour) than with high opening bottom trawls (1204 kg squid per hour). In spite of these results, most commercial trawling for squid is conducted with bottom tending trawls (Rathjen, 1991). The most prolific catching areas are south west Scotland, the Moray Firth, Rockall and Faroe. The squid fishery fluctuates from year to year, since in such a short-lived species it is so much dependent on the success or failure of a particular breeding season. The squid fishery tends to be seasonal, coincident with the movement from deep water to inshore grounds (Stroud, undated).

Food technology

The main market for *Loligo* species landed in the UK is as whole squid for export. Only a small amount is sold on the home market together with some imported canned delicatessen products, thus there is little incentive towards development of new squid products in the UK but outlets possibly worth pursuing include frozen packs of strips or rings of squid enrobed in batter, and paella or other seafood dishes containing pieces of squid meat (Stroud, undated).

Squid are not normally gutted at sea they are simply washed and packed in ice. They are more susceptible to damage than gutted white fish if not handled carefully; crushing, scuffing or tearing of the skin, and burst ink sacs are indicative of rough handling. Squid are left ungutted because many markets, particularly overseas, prefer them whole; the ink and the tentacles are often used along with the flesh of the mantle when preparing squid for eating. Stowage in boxes is generally better than bulk stowage because there is less risk of crushing and bursting the ink sac. There should be at least one part of ice to three parts of squid by weight (Stroud, undated).

Ungutted squid in ice keep in first class condition for up to 8 days; after that time the flesh begins to redden, musty odours develop, and the squid become inedible in 13-14 days. Ungutted squid stowed in chilled sea water keep in first class condition for 6 days, and become inedible after 9 days (Stroud, undated).

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Section 2

'Off-bottom' trawling techniques for the sustainable exploitation of non-pressure stocks in Cornish inshore waters

Data Summary

Georgina Budd

Olivia Langmead

David Sims

Stephen Hawkins

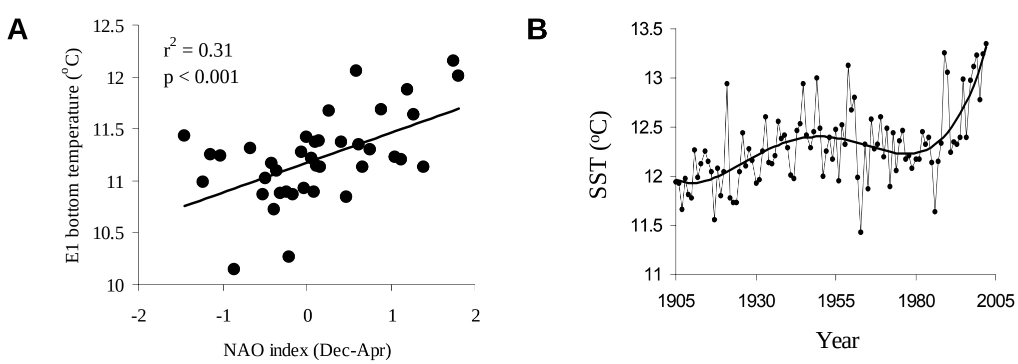
Fishery independent data

The Marine Biological Association (MBA) has collected and archived long-term records on a range of physical and biological variables, such as sea temperature and demersal species assemblages, from the region of the English Channel and Western Approaches over the course of the 20th Century.

Climatic and sea temperature trends

A major atmospheric climate influence on northeast Atlantic waters is the North Atlantic Oscillation (NAO). The NAO index quantifies the alternation of the atmospheric mass between the North Atlantic region of subtropical high pressures centred on the Azores and the subpolar low pressures centred on Iceland, changes which determine the speed and direction of the surface westerlies across the Atlantic (Hurrell 1995; Fromentin & Planque 1997). In years with a high, positive NAO index an accentuated pressure difference between the Azores and Iceland occurs, with resultant strong wind circulation producing high temperatures in western Europe and low temperatures on the Canadian east coast (Fromentin & Planque 1997). During positive phases of the NAO, warmer water occurs off Plymouth whereas colder water predominates during negative phases (Sims *et al.* 2001). This suggests that fluctuations in the NAO determine to a large extent the thermal regime in the western English Channel. The NAO index shows long-term fluctuations although during the last decade positive (warm) phases have generally predominated.

Sea-bottom temperature shows a positive correlation with the NAO index (see figure A below) indicating that thermal habitat occupied by demersal fish in the western English Channel is influenced by large-scale climatic changes occurring across the whole North Atlantic. Over the past century the western English Channel has been subject to major climatic shifts (Russell *et al.* 1971; Southward 1980; Southward *et al.* 1995), with mean annual sea surface temperatures fluctuating within a range of 1.8°C over the past century (see figure B below). These trends are consistent with larger-scale patterns in temperatures in the Northern Hemisphere over the past century (Mann 2002), namely warming in the 1950s and in the 1990s to the present day, following relatively cooler periods in the early 1900s and 1970s (Genner *et al.* 2004).



Figures: (A) The relationship between bottom temperature and NAO index and (B) the trends in SST in the western English Channel over the last century.

Demersal fish datasets

Description

The Standard Haul dataset consists of catch data of 84 fish species gathered through intermittent sampling of the demersal fish assemblage in inshore waters off Plymouth between 1913 and 2003. The 'Sarsia' dataset contains catch data of demersal species, gathered from trawls conducted in the English Channel and Western Approaches between 1953 and 1972. The 'Sarsia' dataset is of a finer temporal scale than the Standard Haul dataset.

Standard Haul

A total of 784 standard hauls have been conducted in the inshore waters off Plymouth between 1913 and 2003. Hauls were on average of 52 minutes duration over the period, and catches were sorted and the number of individuals of each species per haul recorded. In most cases species-level identification was performed, but in some years and with some species groups, identification was only undertaken to genus or family-level. They were undertaken at 30 to 50 m depth over a spatial scale of 42 x 19 km (50^{o}10′ - 50^{o}20′ N, 04^{o}00′ - 04^{o}35′ W). Six vessels were used for sampling, ranging in overall length from 18.3 to 39.0 m. Trawls were comparable in dimensions: headline length range, 16.2-19.8 m; groundrope length range, 19.8-27.4 m; main net stretched mesh diameter, 75-100 mm. All vessels used a fine-mesh cod end or a cover, and similar trawling speeds. The same net and vessel was used from 1976 to the present day. The mean number of hauls per year was 30.7 (± 16.2 S.D.). Although not complete over the 90-year period, the dataset is an internally consistent assessment of the demersal fish community of inshore waters off Plymouth.

'Sarsia'

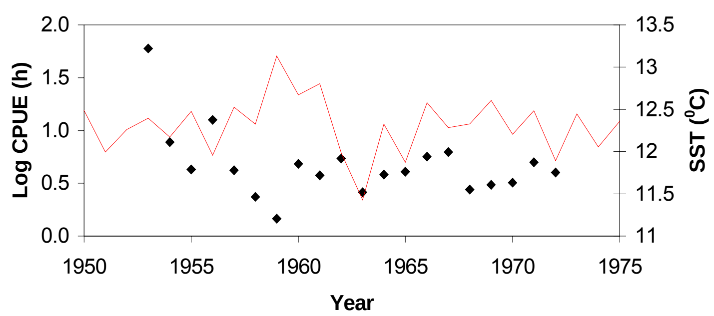
Within the 90-year period (1913-2003) over which Plymouth's demersal fish assemblages have been monitored through the Standard Haul, there exists a second, distinct and very comprehensive 20-year sampling period of bottom trawls conducted on the RV Sarsia. A total of 1,781 trawls of average 2 h duration were undertaken in the English Channel and Western Approaches between November 1953 and December 1972. This period included the end of a warm phase and the onset of cold conditions (Southward, 1980), thus data from this period represent a good subset with which to examine the relationships between inter-annual and seasonal species abundance trends and fluctuating sea surface temperatures. 'RV Sarsia' used an Otter trawl with Vigneron-Dahl gear (headline length = 18.9 m; footrope length = 27.4 m; bridle length = 54.9 m). The cod-end had a mesh of 6.35 cm measured diagonally inside a stretched mesh. Four trawling stations off Plymouth were sampled (*n*, number of trawls): Looe Grounds (Lat. 50^{o}16'N, Long. 04^{o}24'W), *n* = 735; Middle Grounds, L4 (50^{o}15.5'N 04^{o}13'W), *n* = 325; Eddystone (inner) Channel Grounds (50^{o}08.5'N 04^{o}15'W), *n* = 111; Eddystone (outer) Channel Grounds (50^{o}02'N 04^{o}20'W), *n* = 386. The number of trawls carried out in each year varied, having a range of 28 to 160 (mean, 83.7 trawls ± 32.7 S.D.; median, 76.5).

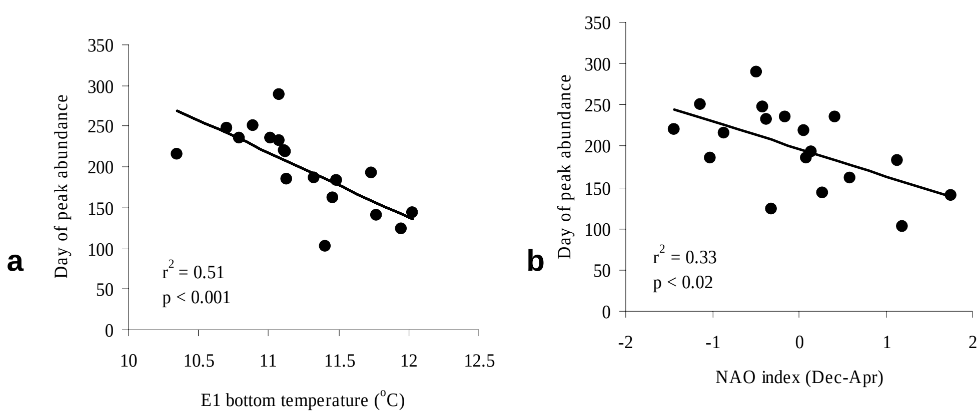
Summaries of MBA datasets

Squid (*Loligo forbesi* & *Loligo vulgaris*)

A total of 40,622 Loligo were caught on 'Sarsia' trawls between November 1953 and December 1972. The average annual catch per unit effort (Log CPUE) of *Loligo* spp., in terms of numbers caught per hour spent fishing, on all trawls conducted is plotted against year in the time-series (Figure 1). Annual *Loligo* abundance was high at the beginning of the time-series, and exhibited a steady, fluctuating decrease with lowest catches in 1959. In 1960, abundance returned to moderate levels, around which it fluctuated until the end of the time-series. The average annual sea surface temperature (SST °C) is also plotted in Figure 1 from 1950 through to 1975. Using this high temporal resolution MBA dataset ('Sarsia', 1953-1972), Sims et al. (2001) illustrated that the timing of migration in the veined squid (*Loligo forbesi*) was temperature dependent with squid arriving earlier on the trawling grounds in warmer years (Fig. 1(i) a). The thermal changes illiciting this response were mediated by climatic fluctuations associated with the North Atlantic Oscillation (Fig. 1(i) b). This climate index summarises the extent of surface westerlies across the North Atlantic. In years with high NAO index values and strong surface westerlies, sea temperature in the western Channel was warmer (Fig. 1 (i) c). Temperature increases over the 5 months prior to and during the month of peak squid abundance did not differ between early and late years, indicating squid responded to climate-linked temperature changes independently of time of year (Fig. 1 (i) d).

Figure 1. Average annual Log CPUE (hour) of squid (*Loligo* spp.) (R.V. *Sarsia*) 1953-1972 (black points) and average annual sea surface temperature (SST^{0}C) (red line)





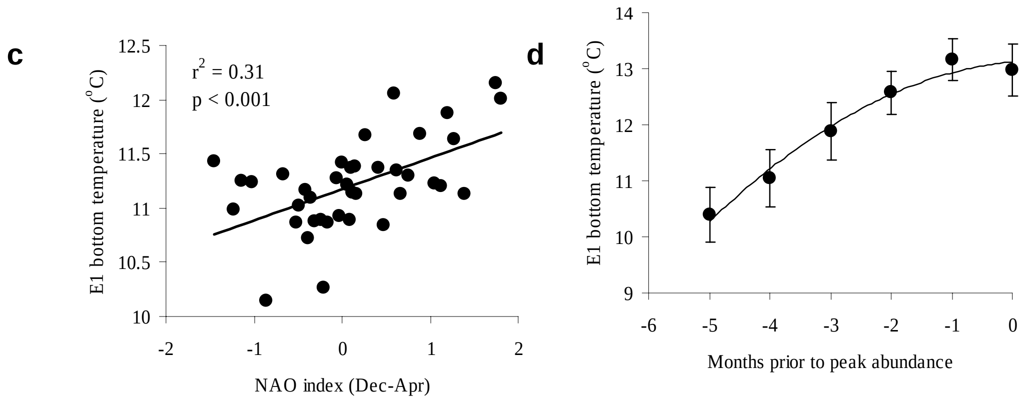
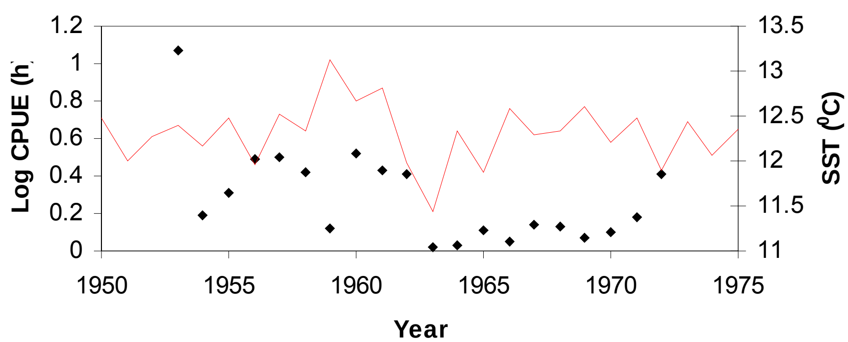


Fig 1 (i). Relationships of (a) sea bottom temperature at ICES station E1 and (b) NAO index to day of peak abundance of veined squid off Plymouth over a 20-year period (1953-1972). (c) The relationship between bottom temperature and NAO over a 40-year period (1947-1986). Day of peak abundance, day 1 = 1 April. (d) Mean monthly E1 bottom temperature during the five months prior to, and in the month of peak abundance. Bars denote 95% confidence limits.

Cuttlefish (*Sepia officinalis*)

A total of 20,285 *Sepia officinalis* were caught on 'Sarsia' trawls between November 1953 and December 1972. The average annual catch per unit effort (Log CPUE) of *Sepia*, in terms of numbers caught per hour spent fishing, on all trawls conducted is plotted against year in the time-series (Figure 2). Annual Sepia abundance was high in 1953, but fell to a fairly low level in 1954. Abundance then increased to 1957, followed by a decrease to 1959. Abundance was fairly high in 1960, but underwent a slight decrease over 1961 and 1962 before falling to a low level in 1963. Abundance fluctuated about this low level until 1970, after which it increased again until the end of the time-series. The average annual sea surface temperature (SST °C) is also plotted in Figure 2 from 1950 through to 1975. When annual average temperature was high, *Sepia* abundance was also generally higher.

Figure 2. Average annual Log CPUE (hour) of cuttlefish (*Sepia* spp.) 1953-1972 (R.V. *Sarsia*) (black points) and average annual sea surface temperature (SST^{0}C) (red line)



John Dory (*Zeus faber*)

A total of 3,129 john dory were caught on 'Sarsia' trawls between November 1953 and December 1972. The average annual catch per unit effort (Log CPUE) of John dory, in terms of numbers caught per hour spent fishing, on all trawls conducted is plotted against year in the time-series in Figure 3(i). Annual john dory abundance was high at the beginning of the time-series. Thereafter, abundance steadily decreased, to reach its lowest point in the time-series in 1964. Post-1964, abundance began to increase and continued to increase until 1972 when average catch per hour was highest. A total of 4,594 John dory were caught in 784 Standard Hauls over the 100 year period between June 1913 and September 2003. Figure 3(ii) illustrates the Standard Haul average annual catch per unit effort (Log CPUE). John dory abundance was relatively high at the start of the time series, but fluctuated greatly between the years 1950-1986. The highest average annual catchs occurred in the early 1970's. Moderate catches of John dory have been recorded sine 2000. The average annual sea surface temperature (SST °C) is also superimposed in figures 3 (i) and 3 (ii). There is no obvious relationship between John dory abundance and average annual sea surface temperature.

Figure 3(i) Average annual Log CPUE (hour) of John Dory (*Zeus faber*) 1953-1972 (R.V. *Sarsia*) (black points) and average annual sea surface temperature (SST^{0}C) (red line)

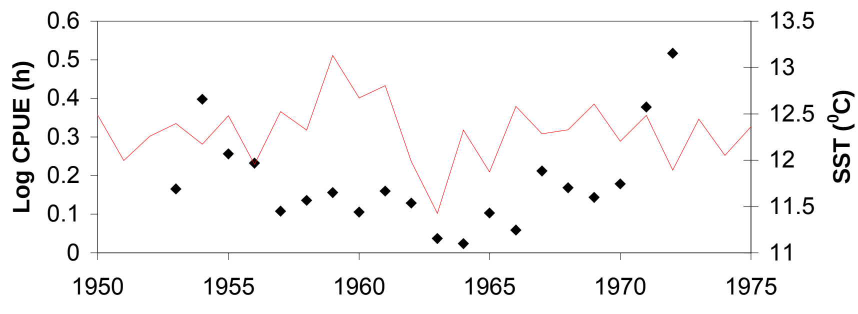
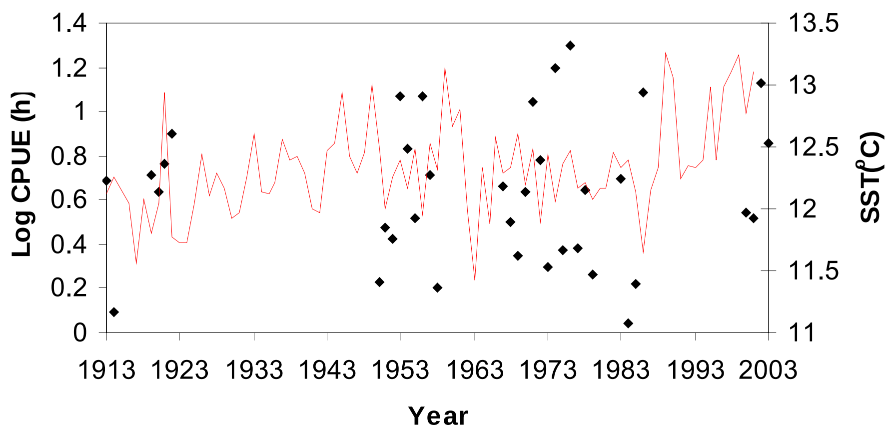


Figure 3 (ii) Average annual Log CPUE (hour) of John dory (*Zeus faber*) and average annual sea surface temperature (SST^{0}C) 1913-2003 (MBA Standard Haul data)



Bream (*Pagellus bogaraveo & Spondyliosoma cantharus*)

A total of 12,746 bream, a mixture of both red and black bream, were caught on 'Sarsia' trawls between November 1953 and December 1972. The average annual catch per unit effort (Log CPUE) of bream in terms of numbers caught per hour spent fishing, on all trawls conducted is plotted against year in the time-series in Figure 4 (i). Annual bream abundance was very low at the beginning of the time-series, but increased to a peak in the mid-1950's. Bream catches subsequently decreased to virtually zero in 1958, and remained so up until 1960. In 1961, a greater number of bream were caught, however, post-1961 bream abundance gradually declined and remained low throughout the 1960's. A peak catch was recorded in 1972. Figure 4 (ii) illustrates catches of the black bream *Spondyliosoma cantharus* from the Standard Haul. A total of 130 black bream have been caught in 784 trawls between 1913 and 2003. Generally, catches are very low, but small peaks are evident in 1950 and the early 1970's. Average annual catches increased dramatically post–2000. The average annual sea surface temperature (SST °C) is also superimposed in figures 4 (i) and 4 (ii). S. cantharus have significantly increased in occurrence in trawls over the period 1913 to 2003 (Fig 4 (iii)). It appears 12oC is an annual threshold level above which black sea bream are more abundant.

Figure 4 (i) Average annual Log CPUE (hour) of sea breams (*Pagellus bogaraveo & Spondyliosoma cantharus*) 1953-1972 (R.V. *Sarsia*) and average annual sea surface temperature (SST^0C)

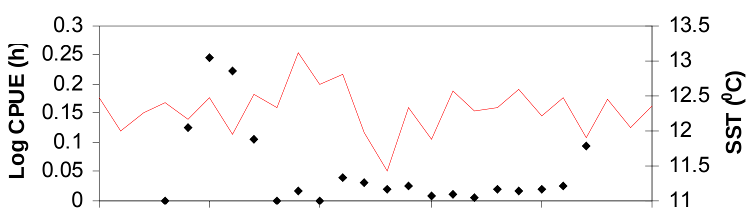
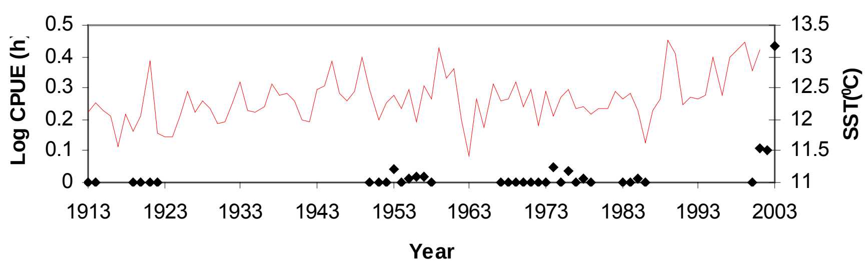


Figure 4 (ii) Average annual Log CPUE (hour) of black bream (*Spondyliosoma cantharus*) and average annual sea surface temperature (SST^0C) 1913-2003 (MBA Standard Haul data)



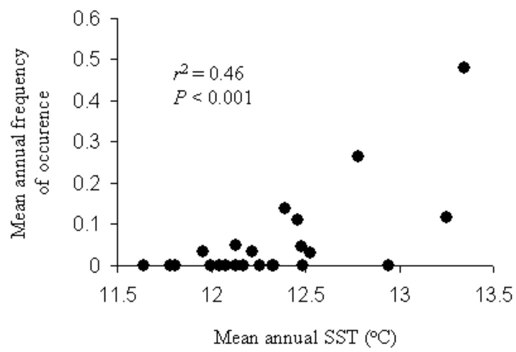


Fig. 4(iii). The mean annual frequency of occurrence of *S. cantharus* off Plymouth has increased with increasing sea temperature between 1913 and 2003.

Whiting (*Merlangius merlangus*)

A total of 138,870 whiting were caught on 'Sarsia' trawls between November 1953 and December 1972. The average annual catch per unit effort (Log CPUE) of whiting in terms of numbers caught per hour spent fishing, on all trawls conducted is plotted against year in the time-series in Figure 5 (i). Annual whiting abundance was very low at the beginning of the 'Sarsia' time-series, but a general pattern of increased abundance is apparent with the exception of abrupt decreases in catches in the early and late 1960's respectively. Peak whiting abundance occurred in 1965 in the 'Sarsia' dataset. Figure 5 (ii) illustrates catches of whiting from the Standard Haul. A total of 24,857 whiting have been caught in 784 trawls between 1913 and 2003. Although average annual catches fluctuate inter-annually, it is apparent that abundance of whiting has increased throughout the time series. The average annual sea surface temperature (SST °C) is also superimposed in figures 5 (i) and 5 (ii). Principal components analysis of the standard haul data shows that whiting have increased in abundance with increasing sea temperature between 1913 and 2003 (correlation of log-transformed mean annual CPUE with smoothed SST, $r = 0.45$) (Genner et al. 2004).

Figure 5 (i) Average annual Log CPUE (hour) of whiting (*Merlangius merlangus*) 1953-1972 (R.V. *Sarsia*) and average sea surface temperature (SST^{0}C)

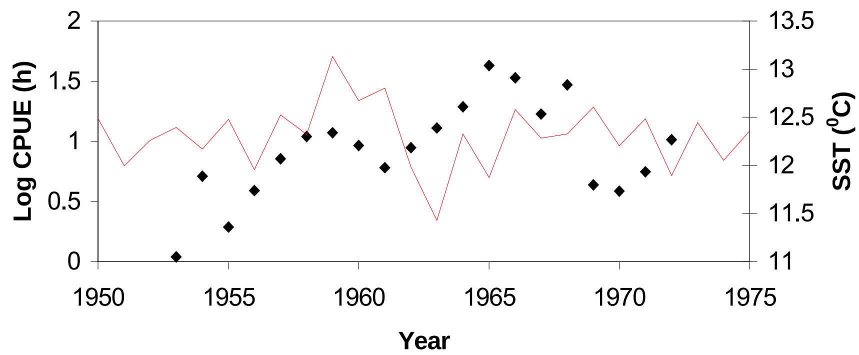
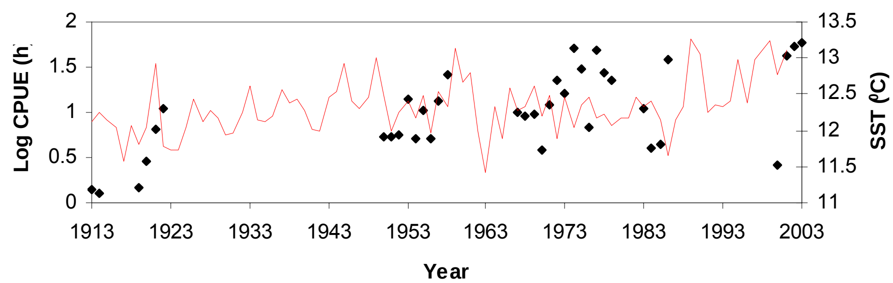


Figure 5 (ii) Average annual Log CPUE (hour) of whiting (*Merlangius merlangus*) and average annual sea surface temperature (SST^{0}C) 1913-2003 (MBA Standard Haul data)



Data Summary References

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Sea surface temperature off Plymouth – obtained from the UK Meteorological Office Hadley Centre / British Atmospheric Data Centre (http://www.badc.nerc.ac.uk)

Project to demonstrate the potential of ‘off-bottom’ trawling techniques for the sustainable exploitation of non-pressure stocks in Cornish inshore waters.

Fishing Gear Development and Testing

Trawl Design and Selection of Rigging Configurations

SEAFISH Gear technologists, in consultation with the project's Fishing Gear Working Group (FGWG), opted for a relatively simple trawl design that would provide scope for achieving versatility with respect to trawl, (wingend) spread and vertical opening (headline height). This adaptability was seen as important due to the nature of the fisheries/target species selected and the constraints imposed by the power of the vessels involved.

The net designed for this project was based on a relatively conventional, 4-panel, 3-bridle *'Butterfly'* trawl design. Very simple, basic cutting rates and hanging rates were used throughout and all roping was done length-for-length. In order to try and optimise trawl size for the low power category of vessels being used (150hp), it was necessary to utilise relatively large mesh sizes and low twine diameters in the design. To maintain strength and durability, it was proposed to construct the trawl(s) using high performance polyethylene (HPPE) twines such as Dyneema. The net(s) would be made in 1.0mm and/or 1.5mm twines in mesh sizes of 400mm, 200mm and 100mm (full mesh).

The net design, rigging and construction were kept as simple as possible for ease of maintenance, repair and alteration.

Scale Models

The development of the gear for this project benefited from the construction of scale models, (1:10) and subsequent flume tank testing at the SEAFISH Fisheries Development Centre (FDC) in Hull.

Initially two models were made to the SEAFISH design described in the following figures. A *'mesh-for-mesh'* version provides a relatively accurate representation of the final full-scale version from the point of view of shape and general characteristics. However, due to modelling constraints associated with twine diameters of the modelling materials, this model was not representative of the twine surface area and hence resultant drag of the full-scale version.

To overcome this problem a second model was constructed to a design that would be more representative of the full-scale version. This was achieved by building the second net using half the number of meshes but at double the mesh sizes used in the first model. This provided a more than adequate model *'tool'* to predict the performance of the full-scale trawl and to identify the most appropriate rigging configurations for the net given the requirements of the overall gear.

Considering the target species selected for this project and the inshore conditions in local Cornish waters, it was decided that adaptability was not just required from the net design, but also from the rigging configurations, i.e. bridle arrangements, lengths, trawl door size, weight, position relative to the net, etc.

The principle aim was to produce a configuration whereby this gear could be operated and controlled virtually anywhere within the water column. This could not be achieved easily by the use of only one rigging arrangement. A series of flume tank tests was arranged during a workshop at the FDC involving the FGWG. An extensive range of options and rigging arrangements were explored and tested. The results of these tests and details of the main configurations examined are included in this report.

Findings

The net demonstrated excellent versatility when used in a wide range of varied configurations. It was adaptable to all arrangements examined with minimal adjustments to maintain good overall shape. The net has the scope to achieve very good spread and/or vertical opening as required.

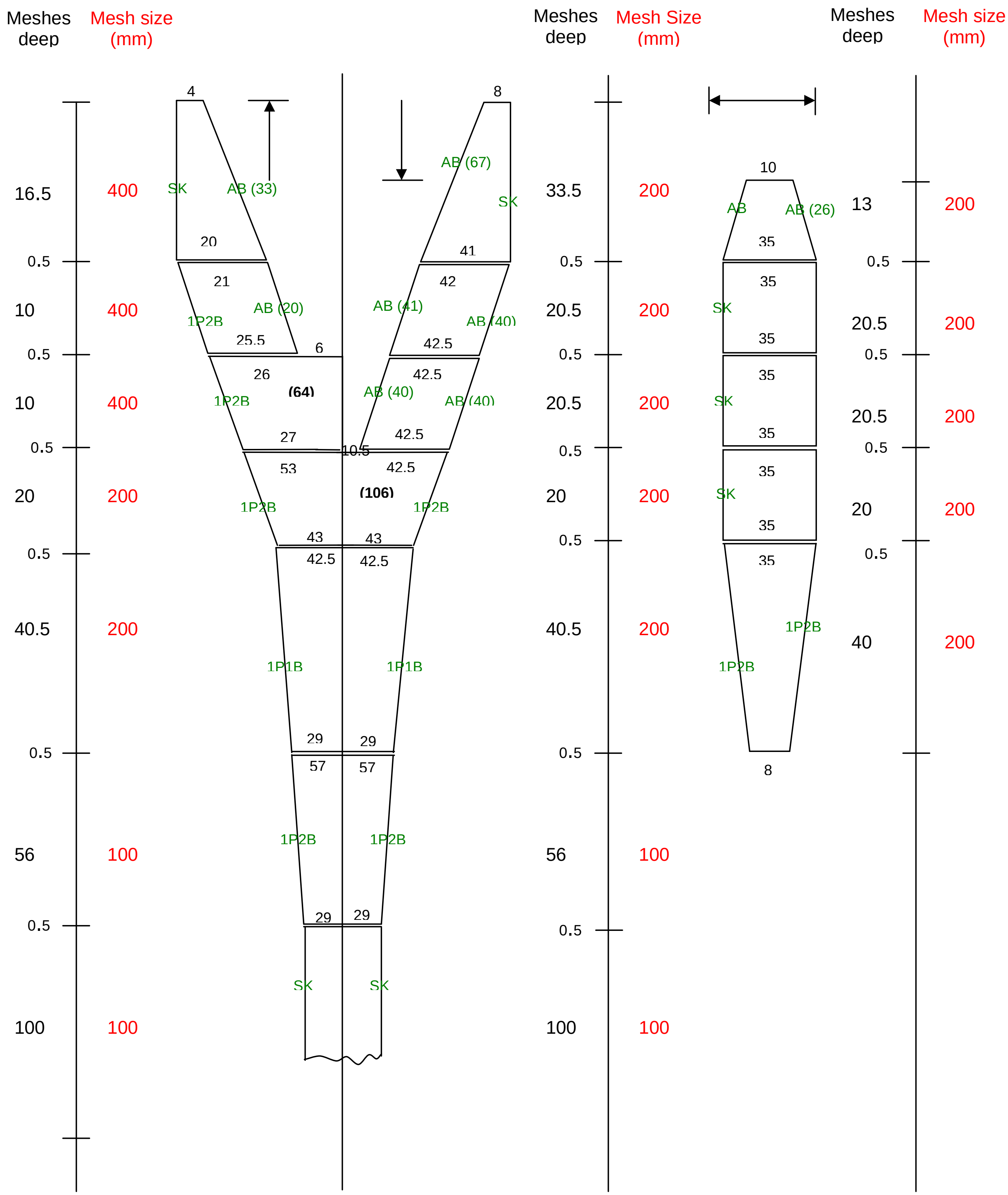
As a result of the workshop, one or two preferred options were identified. However, it was established that in order to have the versatility required to target the selected species effectively at different times of the year and under varying conditions, the net might have to be rigged using a number of different configurations:

- French style 'fork'-rig with the net in contact with the seabed through the use of a lightweight ground gear – suspended footrope arrangement.
  Note: this arrangement to be investigated further at model scale prior to finalising as full-scale option.
- French style 'fork'-rig with the net *'flying'* – essentially the same rig as above with the ground gear removed.
- 4-door 'off-bottom' rig with doors rigged close to the net.
- Midwater rig using pelagic style doors – ideally this would require modifications to the net itself i.e. replacing lower wing and bunt sections with duplicate top wing and square section.
  Note: this arrangement to be investigated further at model scale prior to finalising as full-scale option.

  The details of these proposed and the preferred options are described in the rest of the report.

Seafish 4-Panel 'Butterfly' Trawl

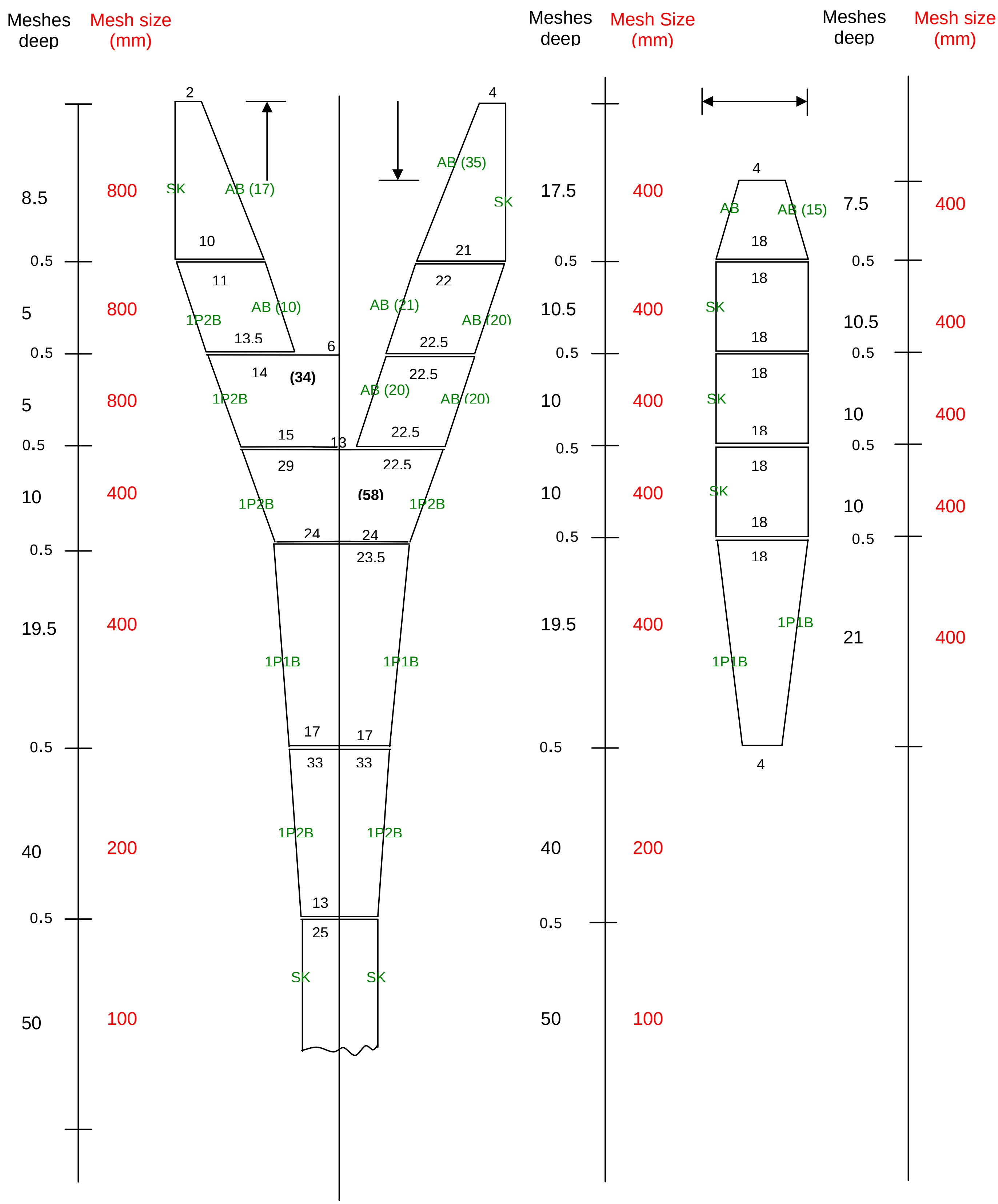
(176 x 200mm)
(Not to scale)



Seafish 4-Panel 'Butterfly' Trawl

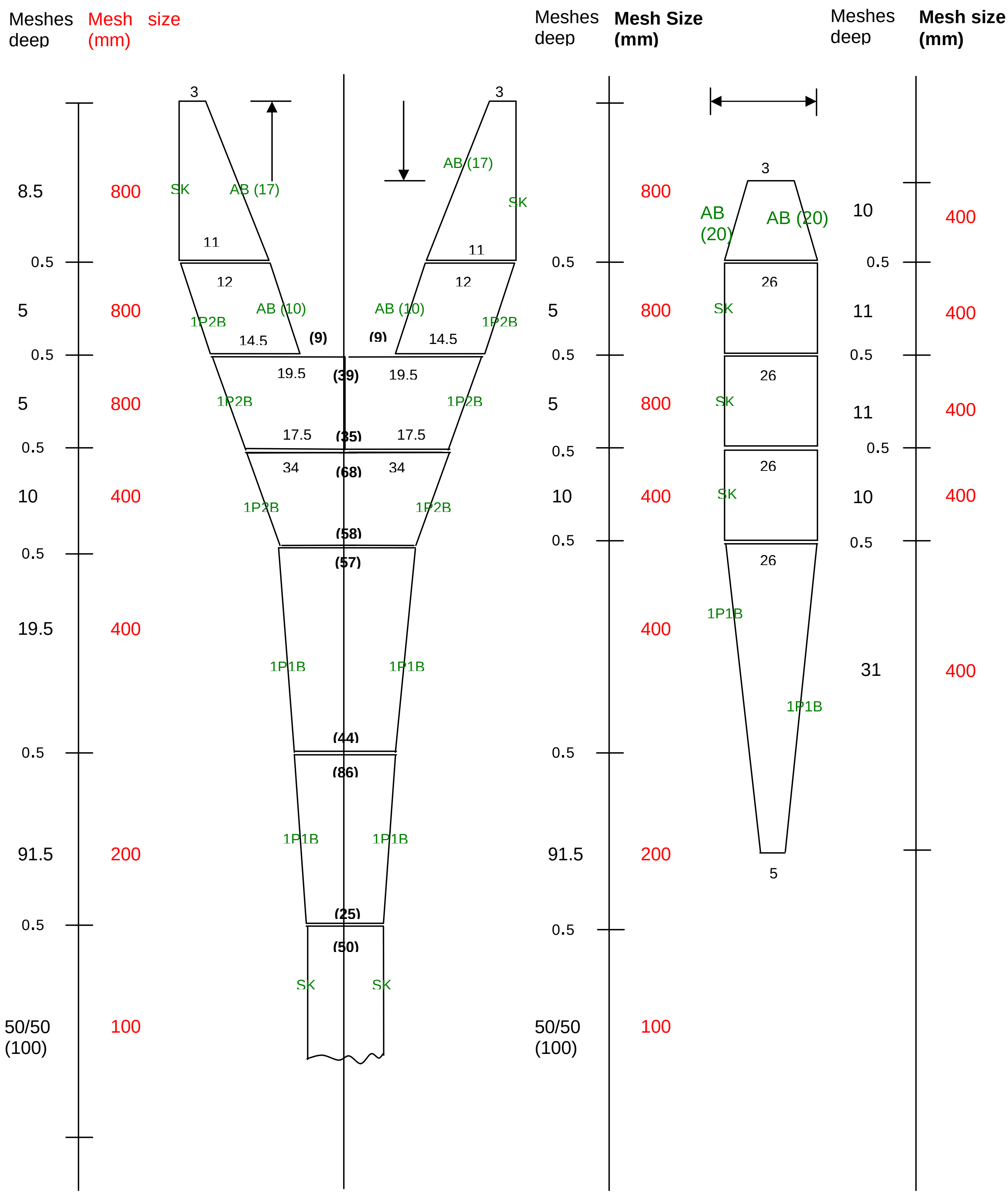
(152 x 400mm simulated low diameter Dyneema twine model version)

(Not to scale)



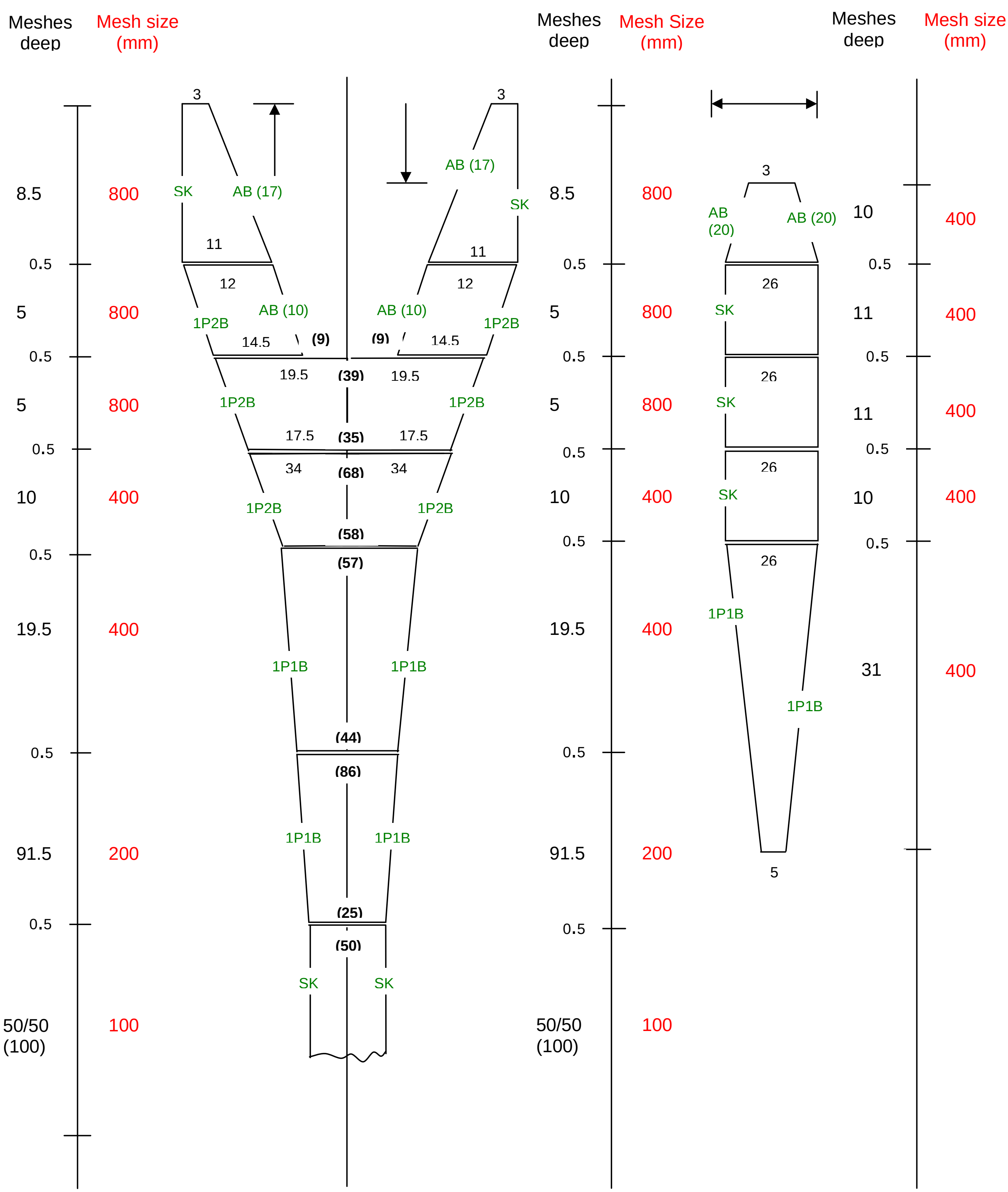
Seafish 4-Panel 'Butterfly' Trawl

(Pelagic version – 104 x 800mm)
(Not to scale)



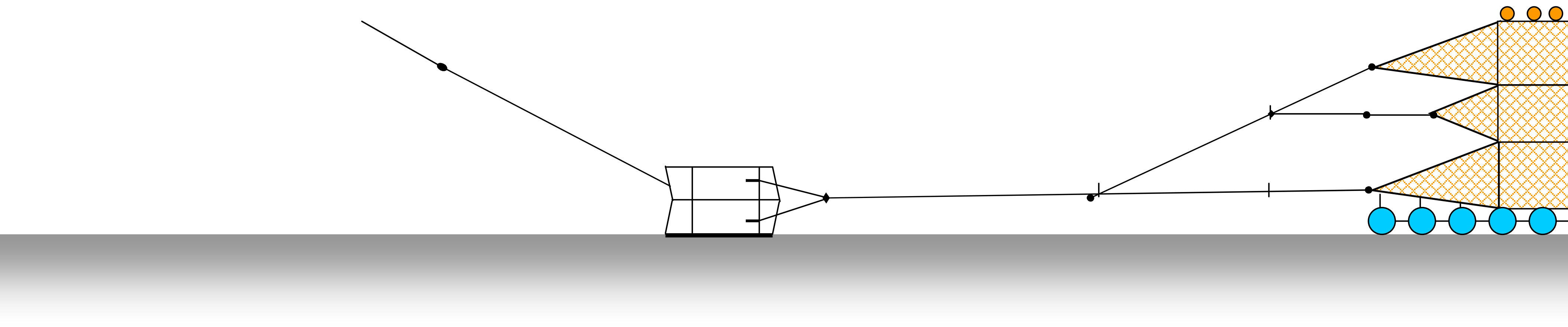
Seafish 4-Panel 'Butterfly' Trawl

(Pelagic version – 104 x 800mm)
(Not to scale)



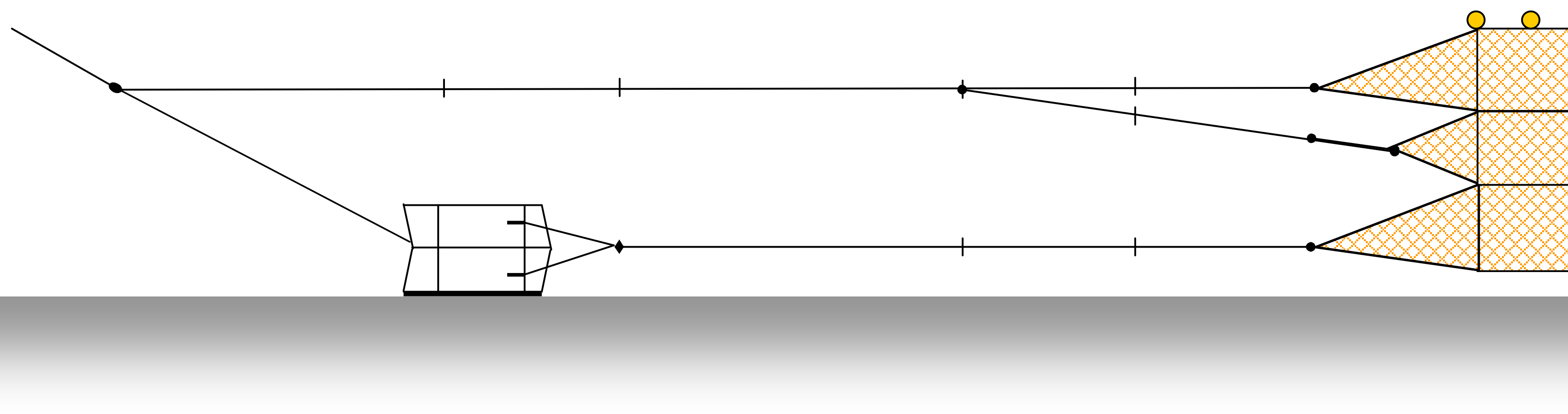
Seafish 4-Panel 'Butterfly' Trawl – Alternative rigging arrangements using 3-bridle rig.

Demersal Rig



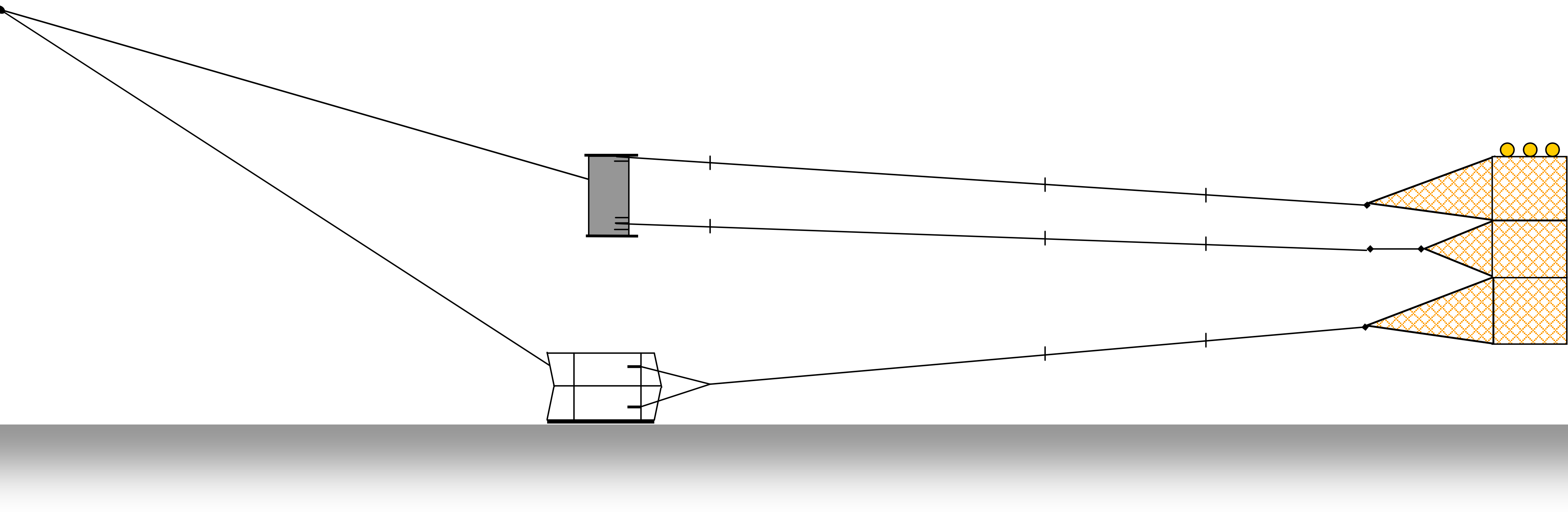
Seafish 4-Panel 'Butterfly' Trawl – Alternative rigging arrangements using 3-bridle rig.

French style 'Fork'-Rig



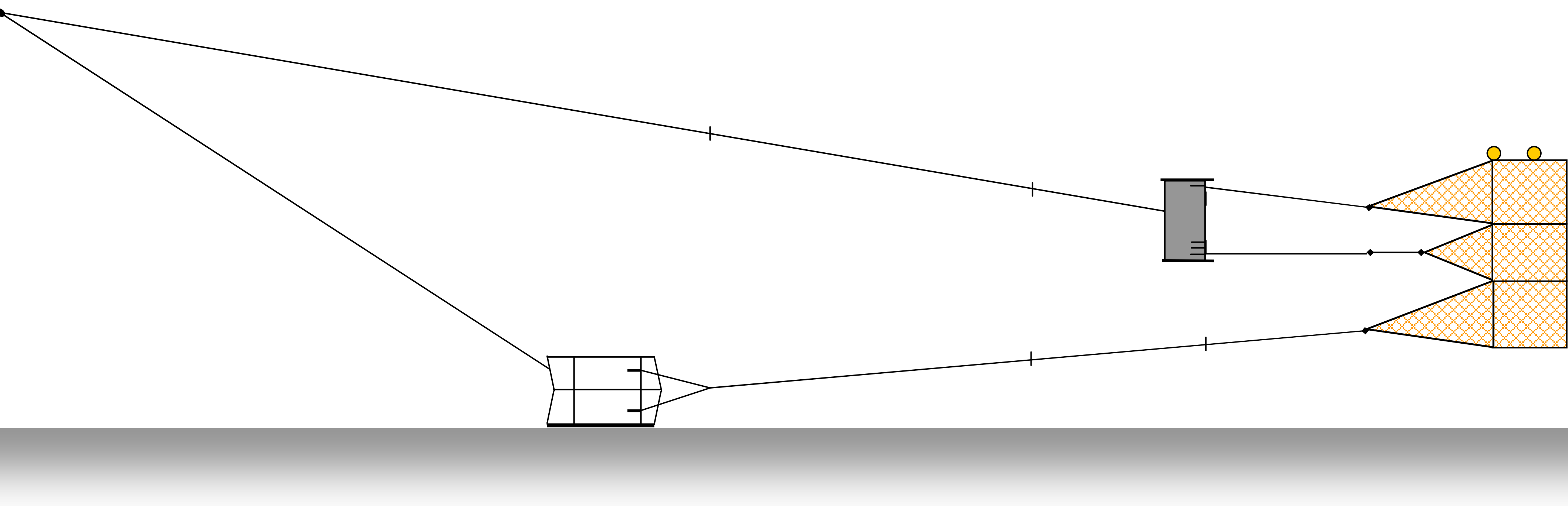
Seafish 4-Panel 'Butterfly' Trawl – Alternative rigging arrangements using 3-bridle rig

4-Door Semi-Pelagic Rig



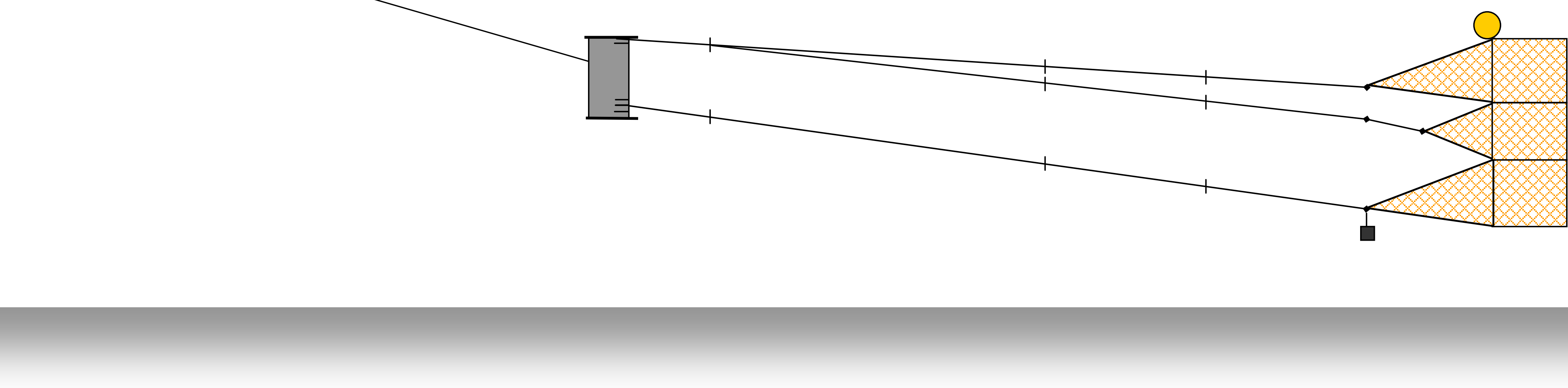
Seafish 4-Panel 'Butterfly' Trawl – Alternative rigging arrangements using 3-bridle rig

4-Door Semi-Pelagic Rig



Seafish 4-Panel 'Butterfly' Trawl – Alternative rigging arrangements using 3-bridle rig

Pelagic Rig



Off-Bottom Trawl Gear – FT Model Tests – Scale: 1:10

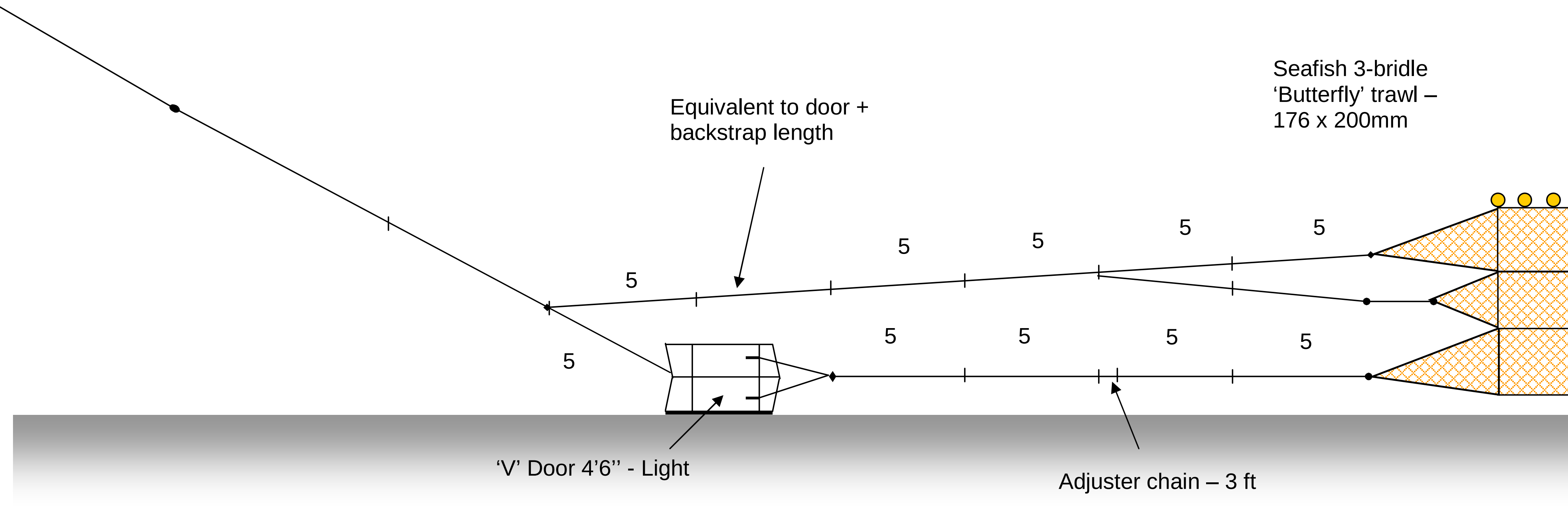
Tank Tests – Rig 1

Net: Seafish 3–bridle 'Butterfly' trawl – 176 x 200mm, mesh–for–mesh version. Headline: ~ 84 Ft, Fishingline: ~ 110 Ft.

Rig	Warp:Depth	Speed (k)	Warp Loads (Kg)		Door Spread (Ft)	Wing-end Spread (Ft)	Headline Ht (Ft)	Off-bottom Ht (Ft)	Comments
			Port	Stbd					
Refer to Fig.:*Tank Tests Rig 1* Fork set at 5 fthm. up warp. 20ftm. Sweep between net and 4' 6'' lightweight 'V'-door. Middle bridle at 10fthm. from net – 3' tight in top and middle bridles compared to bottom (3' ext.)	3:1	3.0k	610	630	87.5	37.5	13.25	4.5	Good shape to net – no strain lines of concern. Tensions even. Doors light on bottom indicating that slightly larger and heavier doors would be more suited to this rig and set-up.
	3:1	2.5	420	440	85.0	35.0	15.0	4.5	
	3.75:1	2.5	450	460	85.0	35.0	14.75	6.75	

Tank Tests – Rig 1

- Wire lengths in fathoms
- Floatation equivalent to 22 x 8''floats



Off-Bottom Trawl Gear – FT Model Tests – Scale: 1:10

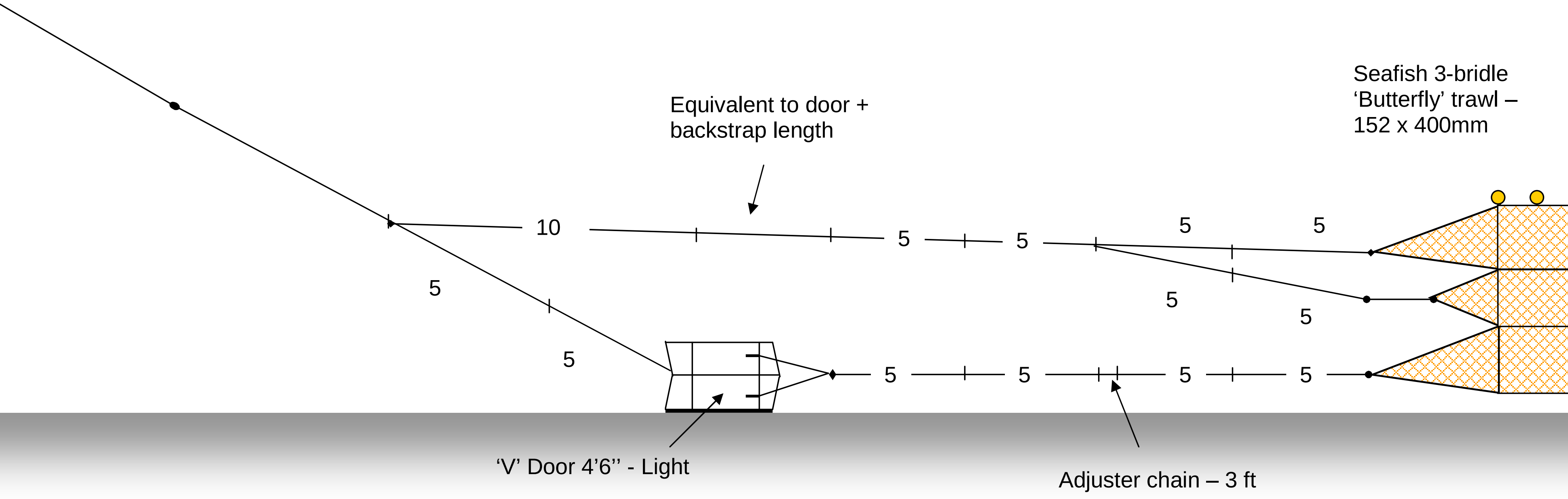
Tank Tests – Rig 2/3

Net: Seafish 3–bridle 'Butterfly' trawl – 152 x 400mm, Simulated low diameter twine version.   Headline: ~ 86 Ft, Fishingline: ~ 111 Ft.

Rig	Warp:Depth	Speed (k)	Warp Loads (Kg)		Door Spread (Ft)	Wing-end Spread (Ft)	Headline Ht (Ft)	Off-bottom Ht (Ft)	Comments
			Port	Stbd					
Refer to Fig.:*Tank Tests Rig 1* . As for *Rig 1* Fork set at 5 fthm. up warp. 20ftm. Sweep between net and 4'6'' lightweight 'V'-door. Middle bridle at 10 fthm. from net – 3' tight in top and middle bridles compared to bottom (3' ext.)	3:1	3.0k	410	430	100.0	45.0	16.5	4.5	Less drag. Doors in better contact. More height achieved for same settings compared to mesh-for-mesh (106 x 200mm) version.
Rig 3 – Refer to Fig.:*Tank Tests Rig 3* - 10 fthm. fork	3:1	3.0			102.0	47.0	17.5	9.5	Top panel starting to distort, (drop back) as strain comes off headline.

Tank Tests – Rig 3

- Wire lengths in fathoms
- Floatation equivalent to 23 x 8''floats



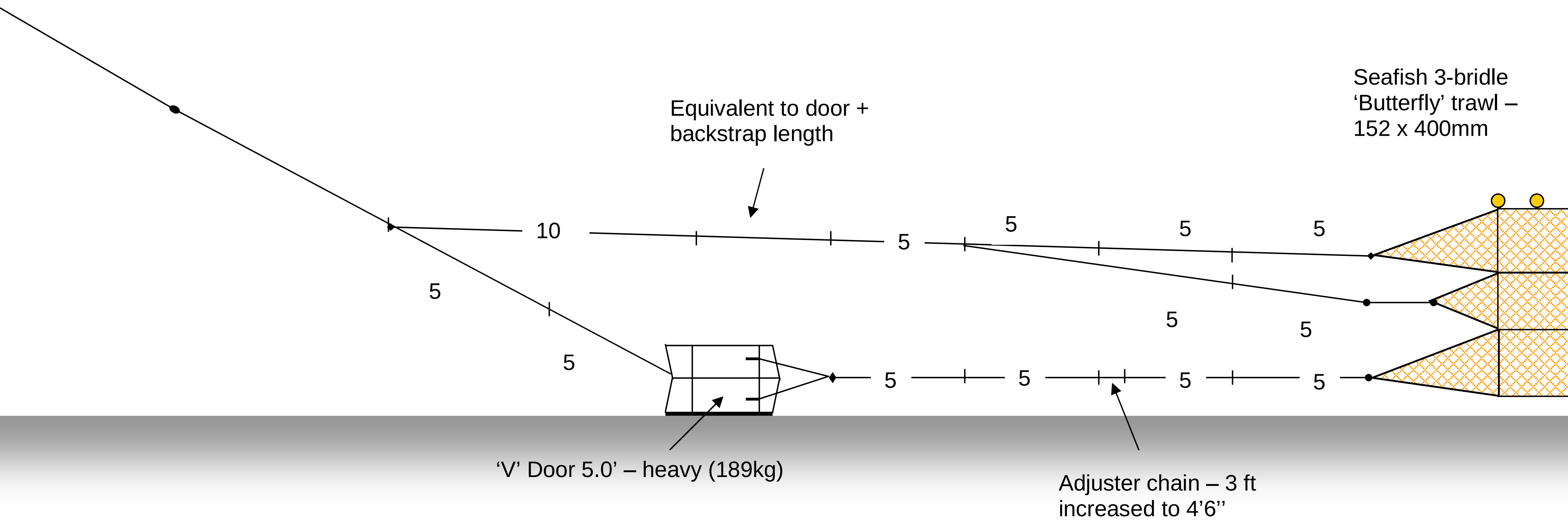
Off-Bottom Trawl Gear – FT Model Tests – Scale: 1:10
Tank Tests – Rig 4

Net: Seafish 3–bridle 'Butterfly' trawl – 152 x 400mm, Simulated low diameter twine version.   Headline: ~ 86 Ft, Fishingline: ~ 111 Ft.

Rig	Warp:Depth	Speed (k)	Warp Loads (Kg)		Door Spread (Ft)	Wing-end Spread (Ft)	Headline Ht (Ft)	Off-bottom Ht (Ft)	Comments
			Port	Stbd					
Refer to Fig.:*Tank Tests Rig 4* Fork set at 10 fthm. up warp. 20ftm. Sweep between net and 4'6'' lightweight 'V'-door. Middle bridle at 15fthm. from net – 3' tight in top and middle bridles compared to bottom (3' ext.)	3:1	3.0k	430	400	100.0	36.0	18.25	7.25	3' tight in top and middle wires. Doors in good contact at 3k. Good overall shape to net, some slackness in top selvedge of side panel – could take more strain on top wire (suggest 18''). Belly sheet cuts away sharply giving good ground clearance.
Additional 18'' in bottom extension (total 4' 6'') Changed to 5' 'V' door (189 kg)	3:1	3.0	420	420	110.0	35.0	18.25	5.0	More strain on headline producing more even tensions, some slack remaining in top selvedge but no distortion. Very little change to overall shape. Net closer to bottom. Excellent mouth opening and spreads relative to size of net. Larger, heavier door more suited to rig.

Tank Tests – Rig 4

- Wire lengths in fathoms
- Floatation equivalent to 23 x 8''floats



Off-Bottom Trawl Gear – FT Model Tests – Scale: 1:10

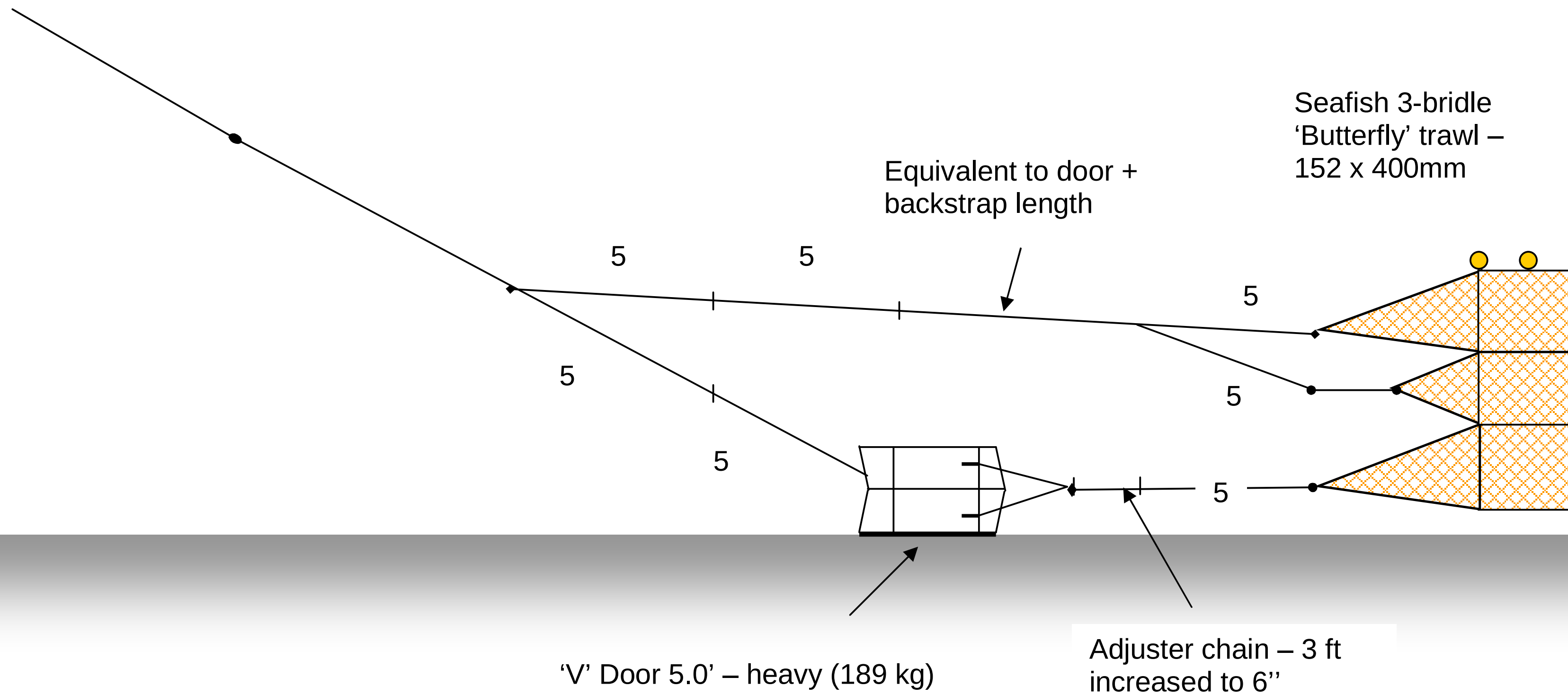
Tank Tests – Rig 5

Net: Seafish 3–bridle 'Butterfly' trawl – 152 x 400mm, Simulated low diameter twine version. Headline: ~ 86 Ft, Fishingline: ~ 111 Ft.

Rig	Warp:Depth	Speed (k)	Warp Loads (Kg)		Door Spread (Ft)	Wing-end Spread (Ft)	Headline Ht (Ft)	Off-bottom Ht (Ft)	Comments
			Port	Stbd					
Refer to Fig.:*Tank Tests Rig 5* Fork set at 10 fthm. up warp. 5ftm. Sweep between net and 5 heavy 'V'-door. Middle bridle at 5fthm. from net – 3' tight in top and middle bridles compared to bottom (3' ext.)	3:1	3.0k	450	460	80.0	56.0	16.75	7.0	Doors nose-down, light bottom contact at 3k. Good overall shape to net, relatively even strains –. Belly sheet cuts away sharply giving good ground clearance (7'+). Very good spreads in excess of half the headline length. Middle bridle could be extended to 10 or 15 fthm. or even to junction of fork i.e. 20fthm.
Additional 3' in bottom extension (total 6')	3:1	3.0	440	500	90.0	60.0	17.0	6.5	Doors down level with better ground contact. Good tensions in top and middle wires. Lower wire slacked back slightly but with no noticeable distortion to net.
									Rig could still benefit from heavier doors especially with short bridles between net and doors.

Tank Tests – Rig 5

- Wire lengths in fathoms
- Floatation equivalent to 23 x 8''floats



Off-Bottom Trawl Gear – FT Model Tests – Scale: 1:10

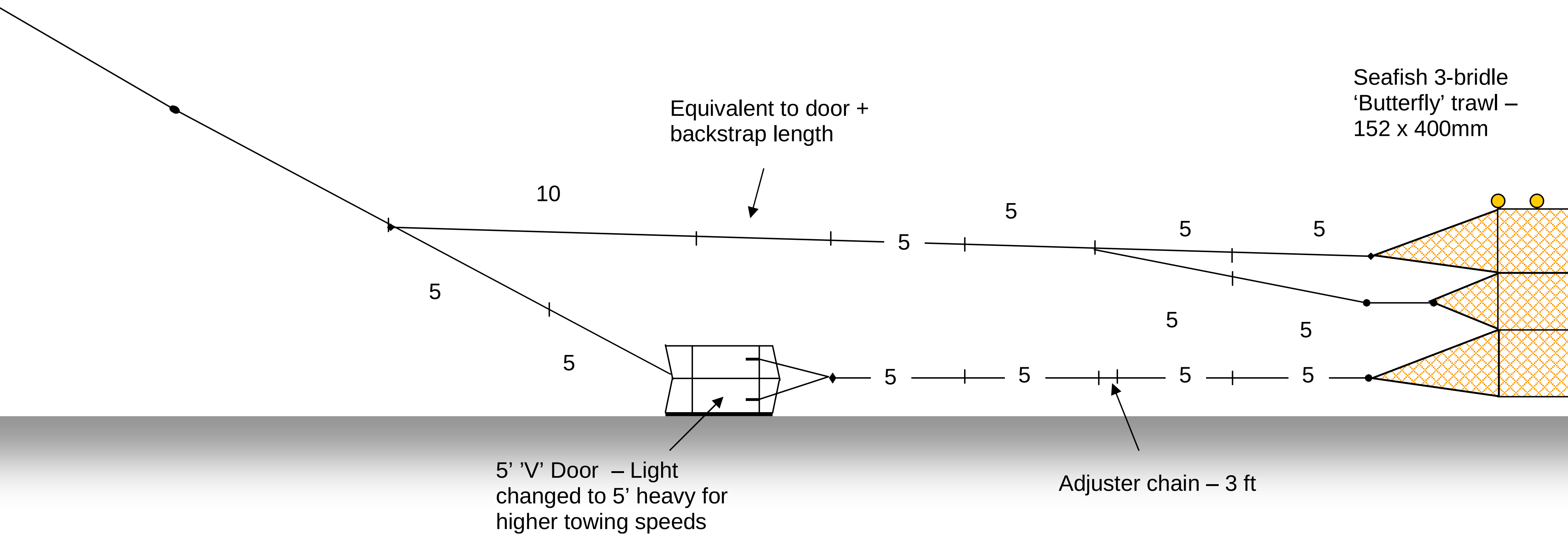
SW Skippers Gear Workshop – Rig 1

Net: Seafish 3–bridle 'Butterfly' trawl – 152 x 400mm, Simulated low diameter twine version. Headline: ~ 86 Ft, Fishingline: ~ 111 Ft.

Rig	Warp:Depth	Speed (k)	Warp Loads (Kg)		Door Spread (Ft)	Wing-end Spread (Ft)	Headline Ht (Ft)	Off-bottom Ht (Ft)	Comments
			Port	Stbd					
Refer to Fig.:*Workshop Rig 1* Fork set at 10 fthm. up warp. 10ftm. Sweep between net and 5 'V'-door. Middle bridle at 10fthm. from net – 3' tight in top and middle bridles compared to bottom (3' ext.)	3:1	3.0	~400	~400	110.0	46.0	19.5	6.5	Doors light on bottom, (nose-down) and lifting off bottom completely at 3k on short wire (warp:depth 2.5:1).
	3.75:1	3.0	~400	~400	115.0	48.0	19.5	4.5	
	2.5:1	3.0	~400	~400	95.0	48.0	20.5	8.75	
Doors replaced with heavier model of 'V'door – 189kg	3:1	3.0	~450	~450	110.0	53.0	19.25	6.75	Doors down level with better ground contact. Rig could still benefit from heavier doors especially with short bridles between net and doors.
	3:1	4.0	~750	~750	112.0	55.0	16.0	8.5	
	3.75:1	4.0	~700	~700	120.0	58.0	14.5	6.5	

Workshop – Rig 1

- Wire lengths in fathoms
- Floatation equivalent to 23 x 8’’floats



Off-Bottom Trawl Gear – FT Model Tests – Scale: 1:10

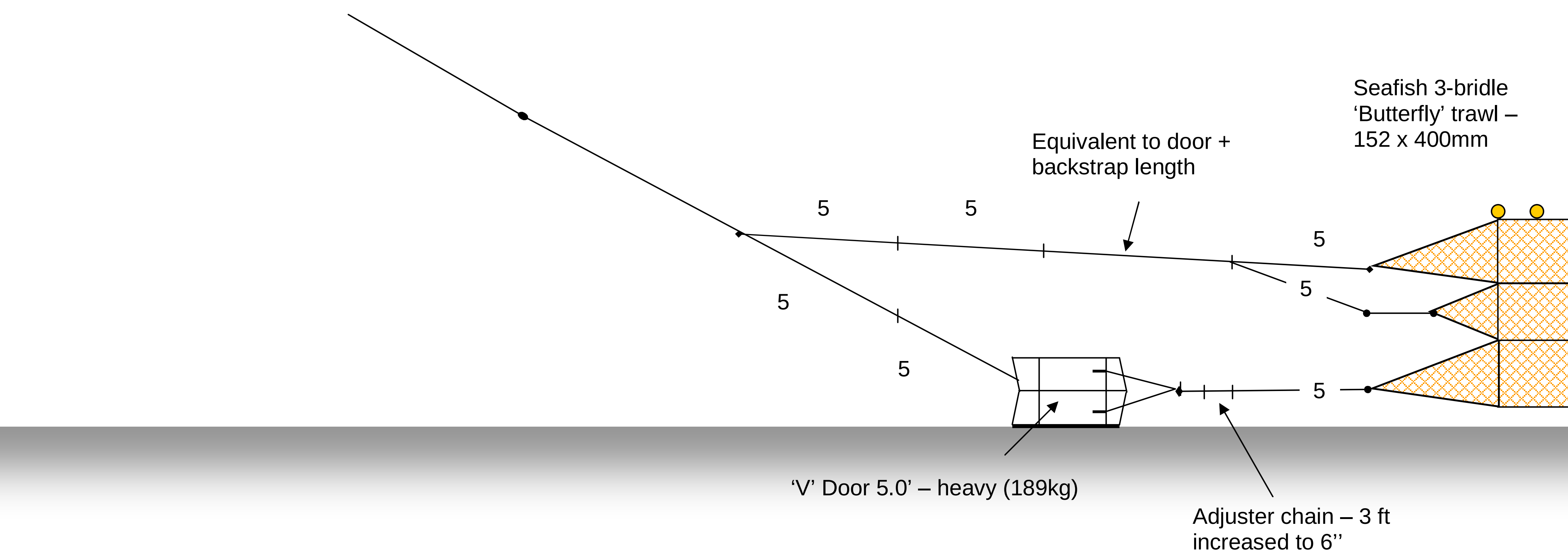
SW Skippers Gear Workshop – Rig 2

Net: Seafish 3–bridle 'Butterfly' trawl – 152 x 400mm, Simulated low diameter twine version. Headline: ~ 86 Ft, Fishingline: ~ 111 Ft.

Rig	Warp:Depth	Speed (k)	Warp Loads (Kg)		Door Spread (Ft)	Wing-end Spread (Ft)	Headline Ht (Ft)	Off-bottom Ht (Ft)	Comments
			Port	Stbd					
Refer to Fig.:*Workshop Rig 2* Fork set at 10 fthm. up warp. 5ftm. Sweep between net and 5 'V'-door. Middle bridle at 5fthm. from net – 3' tight in top and middle bridles compared to bottom (3' ext.)	3:1	3.0	~500	~500	87.5	63.0	16.75	7.5	Doors light on bottom, (nose-down) and lifting off bottom slightly at 4k and completely on short wire (warp:depth 2.5:1).
	3:1	4.0	~800	~800	87.5	64.0	16.5	7.25	
	2.5:1	4.0							
	2.5:1	3.0							
Doors replaced with heavier model of 'V'door – 189kg	3.75:1	3.0							Net all square, doors down.
	3.75:1	4.0							Doors down but light contact.
									Rig could still benefit from heavier doors especially with short bridles between net and doors and at speeds above 3k.
Additional 3' extention in bottom wire.	3:1	3.0	~600	~600			16.5	6.0	Improves tensions in gear and squares up net

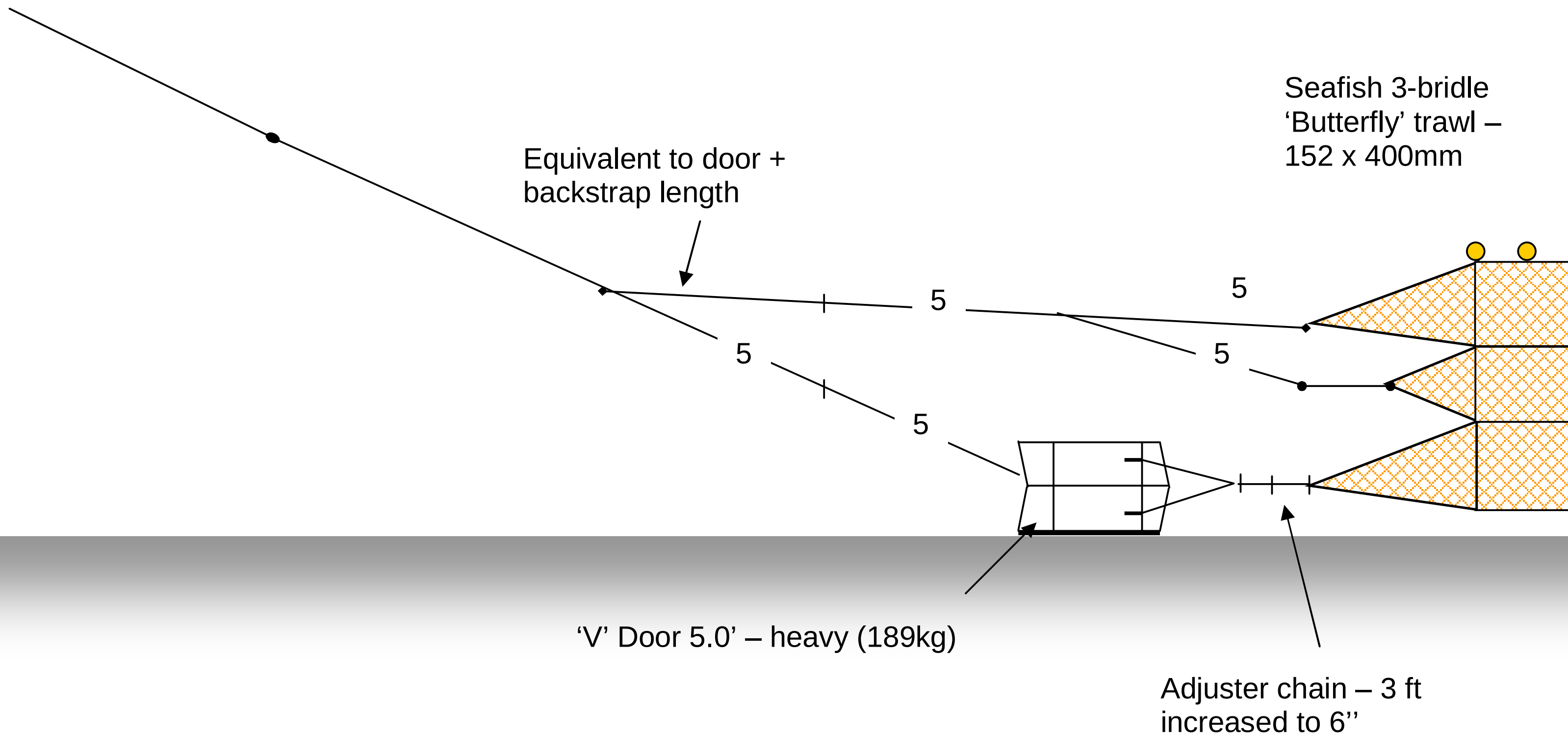
Workshop – Rig 2

- Wire lengths in fathoms
- Floatation equivalent to 23 x 8''floats



Workshop – Rig 3

- Wire lengths in fathoms
- Floatation equivalent to 23 x 8''floats



Off-Bottom Trawl Gear – FT Model Tests – Scale: 1:10

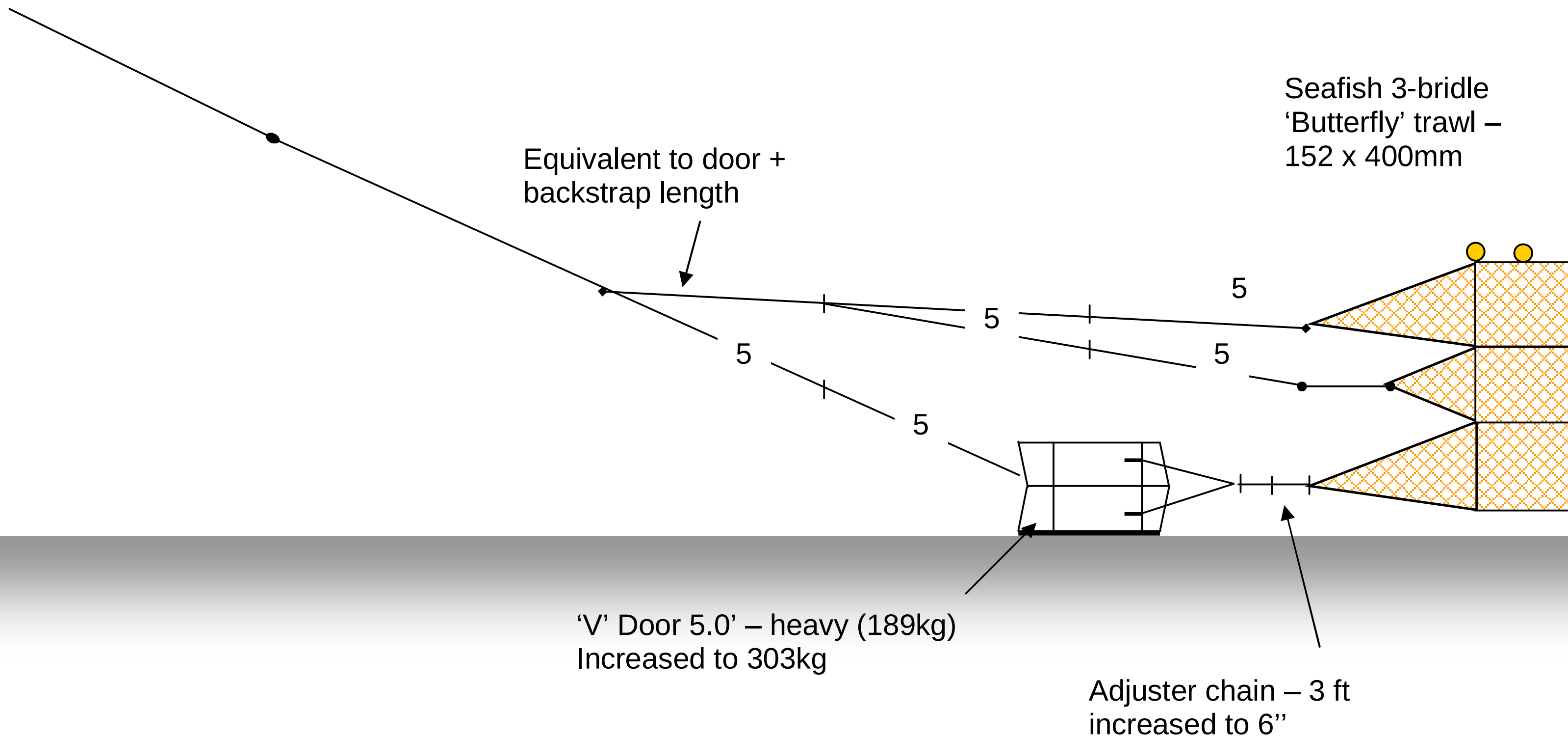
SW Skippers Gear Workshop – Rig 4

Net: Seafish 3–bridle ‘Butterfly’ trawl – 152 x 400mm, Simulated low diameter twine version. Headline: ~ 86 Ft, Fishingline: ~ 111 Ft.

Rig	Warp:Depth	Speed (k)	Warp Loads (Kg)		Door Spread (Ft)	Wing-end Spread (Ft)	Headline Ht (Ft)	Off-bottom Ht (Ft)	Comments
			Port	Stbd					
Refer to Fig.:*Workshop Rig 4* Fork set at 10 fthm. up warp.	3:1	3.0	~650	~650	75.0	64.0	15.75	6.75	Doors light on bottom, (nose-down) and lifting off bottom slightly at 4k and completely on short wire (warp:depth, 2.5:1).
No Sweep between net and 5’ heavy ‘V’-door.	3:1	4.0	~800	~800	75.0	64.0	14.5	5.2	
Middle bridle at 10 fthm. from net – 3’ tight in top and middle bridles compared to bottom (3’ ext.)	3:1	5.0	~1100	~1100	75.0	64.0	14.25	5.75	Drags increased with heavier doors at high speed.
	3:1	3.0	~600	~600	73.0	67.0	16.25	5.5	
Additional weight added to doors– 114kg – 303kg total.									
Floatation removed	3:1	3.0	~500	~500			11.75	4.0	As expected height lost and loss of shape to net.
Equivalent of 8 x 8’’ floats added.	3:1	4.0	~800	~800	73.0	67.0	14.0	4.75	
	3.75:1	4.0	~650	~650			12.5	4.0	Increased warp:depth ratio brings net down.
									This general arrangement seen as one of the preferred options incorporating the use of heavy doors.

Workshop – Rig 4

- Wire lengths in fathoms
- Floatation equivalent to 23 x 8''floats



Off-Bottom Trawl Gear – FT Model Tests – Scale: 1:10

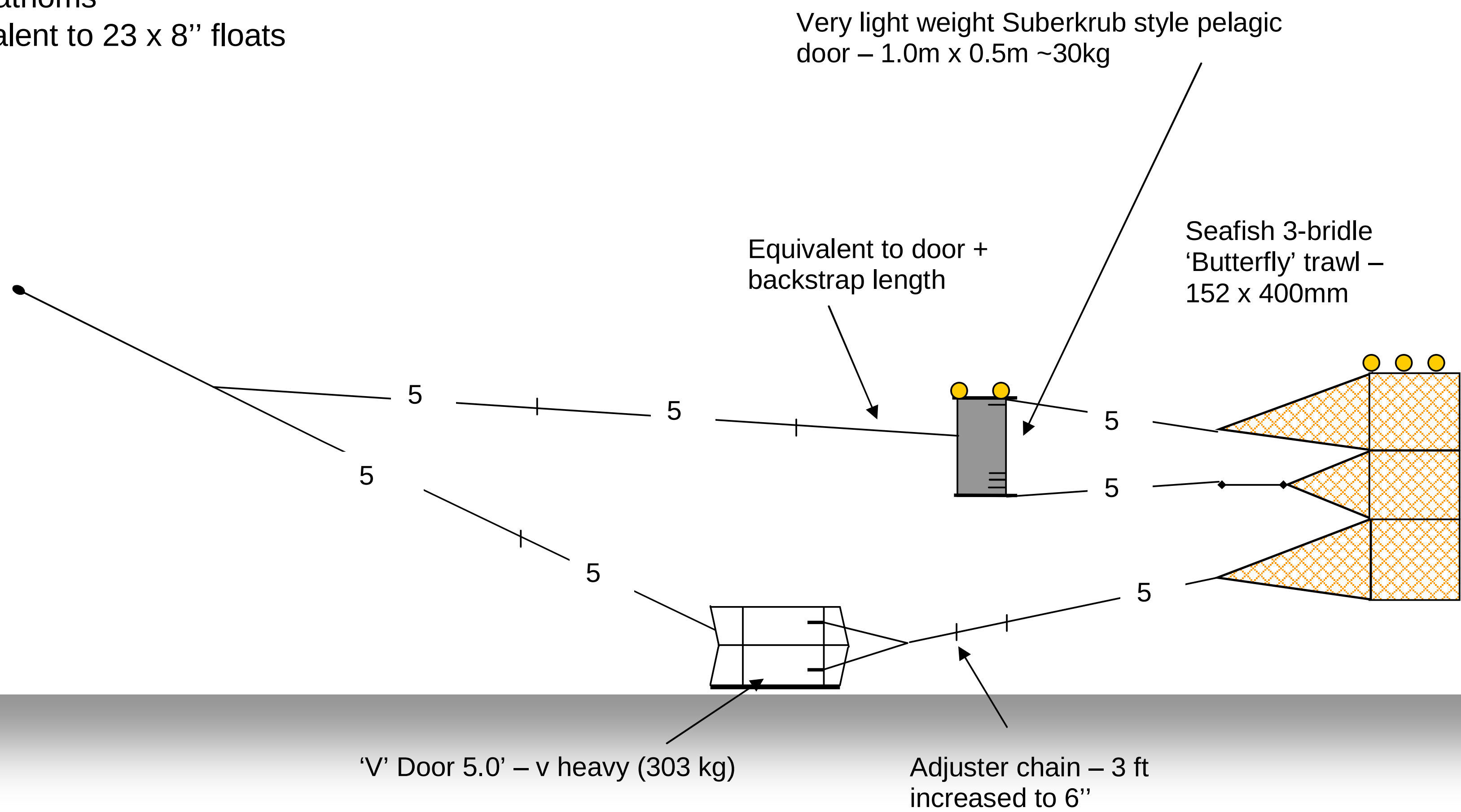
SW Skippers Gear Workshop – Rig 5

Net: Seafish 3–bridle 'Butterfly' trawl – 152 x 400mm, Simulated low diameter twine version. Headline: ~ 86 Ft, Fishingline: ~ 111 Ft.

Rig	Warp:Depth	Speed (k)	Warp Loads (Kg)		Door Spread (Ft)	Wing-end Spread (Ft)	Headline Ht (Ft)	Off-bottom Ht (Ft)	Comments
			Port	Stbd					
Refer to Fig.:*Workshop Rig 5* Very responsive to speed changes. 2 x 8'' floats attached to top of Suberkrub door.	3:1	3.0	~450	~450	100.0	60.0	18.25	9.75	Good tensions and shape to net. Very slight distortion/slackness in top wingline lower edge running back to top selvedge indicating further tightening of top bridle may be required, e.g. 18''. May be caused by pelagic door having a backward leaning aspect instead of being upright. Squaring door up should resolve problem. Doors light on bottom despite increased ballast. Pelagic doors tending to lift bottom door.
	3:1	3.5	~600	~600	90.0	60.0	18.0	10.5	
	3:1	4.0	~800	~800	90.0	60.0	17.75	11.75	
Fork increased to 15fthm.above door	3.75:1	4.0	~750	~750	95.0	60.0	17.75	9.5	This extended fork produced a better overall geometry to the rig, particularly at speeds above 4k.
	3:1	4.0	~800	~800	92.0	60.0	17.5	12.5	

Workshop – Rig 5

- Wire lengths in fathoms
- Floatation equivalent to 23 x 8'' floats



Cornish Fisheries Development

Development of off-bottom trawl and trawling techniques

Report on gear handling and engineering trials – MFV *Shiralee* (BM 35) – Newlyn 02/06/05 - 09/06/05

Objectives:
Initially, a period of 5 days was programmed to carry out gear engineering/instrumentation trials on three variations of the 4-panel 'off-bottom' trawl designed by Seafish for the Cornish Fisheries development project (FEP 592). The nets were used in three different configurations:

- Low drag Dyneema trawl (176x200) rigged as French style 'fork-rig' (fig 1)
- Larger mesh PE trawl (152x400) rigged using 4-door arrangement (fig 2)
- Pelagic style trawl (104x800) rigged in conventional pelagic mode (fig 3)

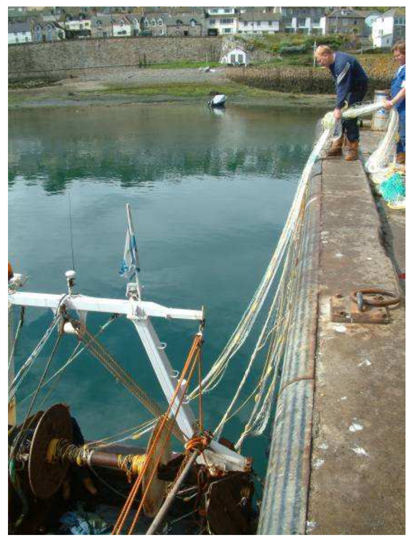
As a result of lost operating time due to poor weather conditions, the exercise was extended to 7 days to enable sufficient time to evaluate all three nets in the three configurations chosen.

The Seafish Scanmar net monitoring instrumentation was fitted to the gear to measure the main gear parameters and to establish basic gear geometry for comparison with Flume Tank based predictions of performance.

The intention was to measure warp loads, door spread, wing-end spread, headline height, off-bottom height for a range of warp: depth ratios, (2:1 to 4:1) and trawling speeds (2.5k to 4.0k).

During the course of the trials the general handling and operation of the different gears was monitored closely to identify any changes/improvements that may be required prior to the next stage of commercial fishing trials.

Daily operations:
Day 1 – Thursday 02/06/05
The Dyneema net and fork-rig were put together on the quayside and then put onboard MFV *Shiralee* for a 'shakedown' trip to check rigging, gear handling and test the instrumentation.

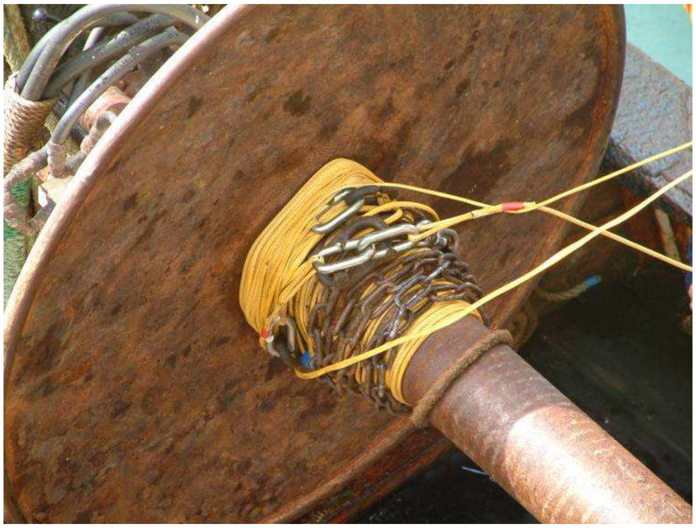


During the sea trial problems were encountered with some of the instrumentation giving out erroneous readings and only one of the tension meters/load cells was working, despite recent overhaul. These problems were later resolved.

Without reliable indications from the instrumentation, performance of the gear could only be assessed by visual observation. This was judged to be satisfactory at this stage, however, it was noted that the very light twine used for the construction of the Dyneema net could cause handling problems in windy conditions. The light, large mesh material was vulnerable to snagging on the net drum during hauling and shooting procedures.

This 'shakedown' trip was used to establish the best working arrangement for hauling and shooting using the fork-rig. This had to be compatible with the vessel's existing gear handling procedures, particularly with respect to the transfer of the warps and bridles between main winch and net drum and *vice versa.* This was achieved quite satisfactorily by utilising 'G' and recessed 'flat' link combinations between the main warp and split wires in the fork-rig arrangement. The vessel's main warp was terminated in a swivel and 'G' link combination which connected to a double flat link and swivel combination in the end of the split fork legs. One eye of

the swivel was connected to the (in line) double flat links and the eyes from the two fork splits were spliced into the other eye of the swivel.
All rigging between the end of the main warp and the net was constructed in 8mm Dyneema braided rope. With this arrangement, the main warp and fork splits could be hauled onto the main winch during hauling.



The trawl and fork-rig were connected to the net drum. This was done by clipping ‘G’ links in the ends of the net drum’s pennant wires into one of the in-line flat links in the end of the fork-rig. The net was hauled onto the main net drum taking care not to snag the light Dyneema netting.

During the shooting operation, the trawl and rigging wires were deployed from the net drum. Once the end of the fork-rig was reached at the net drum connection, the main warp running through the main gallows block was connected to the remaining free flat link in the end of the fork splits. As the weight of the gear was taken on the main winch the ‘G’ links from the net drum could be disconnected, freeing the net drum. The splits of the fork-rig were then hauled onto the main winch to the point where the trawl doors were connected using a conventional pennant chain arrangement. Once connected, the doors were lowered away and the gear shot in the normal way. During the hauling operation this procedure was repeated in reverse. The gear was hauled up to the trawl doors which were secured and disconnected. Lowering the fork splits clear of the towing block allowed the net drum pennant wires to be connected to the flat links in the end of the fork splits. Once the weight was taken onto the net drum, the main warp was unclipped at the ‘G’ link and the hauling procedure continued using the net drum.

Day 2 – Friday 03/06/05
Following the ‘shakedown’ trip on day one, the net was taken off the net drum on day 2 to undertake some minor modifications. The net drum pennant wires were replaced with ropes to reduce net snagging and small mesh netting panels were added to support the Scanmar instrumentation.

The net was replaced on the net drum and the vessel proceeded to sea to carry out full instrumented trials and evaluations of the Dyneema net and fork-rig.

While the vessel was at sea conducting the trials, the second larger mesh PE trawl (152x400) rigged using 4-door arrangement (fig 2) was prepared for day 3.

During the instrumented trials problems were experienced with the speed and depth sensors. These were later withdrawn as faulty units. The problems with the tension /load cell persisted which also lead to these being withdrawn from the system. The other instrumentation performed as required enabling spreads and heights to be recorded. Most of the required information was being fed back via the Scanmar trawl sounder which provided headline height above seabed, mouth opening and footrope clearance above seabed.

Instrumentation runs were carried out at different trawl speeds and warp: depth ratios recording the various parameters as previously stated (log sheet (1)).

The lower wing-end extension was altered from 6' to 3' during the runs and then returned to the original setting of 6'.

The indications were that the gear was performing generally as expected, however, the vessels trawl doors (Bison No 7.5), which had previously been identified as being larger than required for the vessels standard gear/hp, were tending to overspread the gear. It was decided to use these doors for the trials to take advantage of the weight characteristics which had previously been identified from Flume Tank tests as an advantage in the fork-rig arrangement being evaluated.

Bison trawl doors

The overall impression was that of good, responsive net performance. The general gear handling improved with fewer problems encountered as experience and practice was gained.

All instrumentation was checked and re-charged for the following days trials.

The pelagic trawl and wires were delivered from Coastal Fishing Supplies, Bridport, Dorset.

Note: Some of the seine-net clips or ‘C’ links used to connect the various lengths of wire and Dyneema rope used in the sweep and bridle arrangements showed serious signs of weakness during the trials. This was despite initially being thought to be ‘over-the-top’ for the systems into which they were being incorporated. The suspect links were replaced where possible.

Day 3 – Saturday 04/06/05
Completed the rigging of the 4-door arrangement using the Seafish designed Suberkrub style ‘pony’ doors (see photos). This was put onboard for sea trials.

The pelagic trawl was prepared as the last variant for testing using the ‘pony’ doors from the 4-door rig. Although theoretically undersized for a pelagic style net of the size being used, Flume Tank testing had indicated that the doors may be suitable. The net was rigged as shown in fig 3. Wingend weights were prepared in 3x 25kg ‘clumps’ for ease of handling. All three ‘clumps ‘could be linked together to make-up the desired 75kg weight. (See Photo)

The vessel encountered poor weather during the trials which made gear handling very difficult. The ‘pony’ doors at one stage were spinning resulting in twisting of the Dyneema backstraps with the turns running right through to the wing-ends on one side of the gear. Problems were also encountered with the floatation. Due to the large mesh sizes used in the construction of the top panels of the net, the 8’’ floats being used had to be mounted x3 in netting bags which were then clipped to the headline of the net. These were prone to spinning, particularly in poor weather conditions. Additionally, the floatation added to counter the weight of the Scanmar instrumentation units also caused problems for similar reasons.

As a result of the poor weather and the problems with the net, the vessel returned to port having completed some instrumentation runs (Log sheet (2)). The indications were that the net and rig were showing promising signs of achieving the predicted performance despite the poor weather conditions. The skipper and crew were particularly impressed by the ease of handling and the subsequent performance of the ‘pony’ doors.

Day 4 – Sunday 05/06/05
The 4-door rig was taken off the net drum to clear the twists and turns resulting from the previous days trials. The net and rig was cleared in preparation for sea.

The vessel went to sea, initially to clear the net on the net drum in preparation for completion of the trials using the same arrangement. After clearing the gear to the team’s satisfaction, the vessel proceeded to the trawl testing area to attempt completion of the previous days work. The weather deteriorated during the trial resulting in similar problems to the previous day. The vessel returned to port where the gear once again had to be taken off and hauled back onto the net drum.

While the gear was off the drum some minor alterations were made to the rigging to try and ease some of the handling problems previously encountered. Additional swivels were incorporated into the ‘Y’ pennant arrangement for the ‘pony’ doors to try to remove the tendency to twist up. The Dyneema rope legs (5 fathom) between door and net were replaced with combination wire legs (14mm), again to try and ease the same problem.

Additional weight was added to the lower wing-ends by doubling-up the extension chains. This was done to help the footrope drop away from the headline during shooting which was seen as a means of easing the shooting operation.

Some alterations were made to the ‘pony’doors. Additional links were incorporated into the ‘G’ hook on the doors to ease the clipping and un-clipping of the doors. The ballast weights were added to provide extra stability during shooting and towing and hopefully reducing any tendency to spin.

The net sustained some minor damage when it came into contact with the seabed and picked up some debris. The damage was repaired while the net was off the drum.

The skipper was keen to persist with the 4-door rig as indications to date had shown this net and configuration to have considerable potential as a workable rig to target the species previously identified.

The gear was replaced on the net drum and the decision made to make another attempt at completing the instrumentation runs the following day which was promising to be a better day from the point of view of weather/sea conditions.

No valid readings were recorded for this days instrumentation runs due to the problems encountered with the weather.

Day 5 – Monday 06/06/05
The weather on Day 5 allowed unhindered operation of the 4-door rig. Instrumentation runs were completed (log sheet (3)) and time was given to conduct some further tows to satisfy the skipper's curiosity as to the flexibility and responsiveness of the 4-door rig (log sheet (4)).

Day 5 confirmed that most of the previous handling problems encountered with the gear were weather related and that the alterations to the rig had proved beneficial.

The 4-door arrangement was shown to be extremely responsive to warp length and speed changes. The skipper and team were confident enough to suggest that the net and rig should be tested under more representative conditions on actual fishing ground. This would provide the opportunity to iron-out any final handling difficulties.

The decision was made to leave the 4-door rig onboard the trials vessel for an additional day and postpone the testing of the pelagic version until later.

Shore based preparations of the pelagic net and rig were completed.

Day 6 – Tuesday 07/06/05
MFV *Shiralee* headed for fishing grounds around the Wolf Rock. Unfortunately, a fresh to strong SE wind prevented fishing operations and the vessel was forced to return to Newlyn without conducting any further tows.

As the weather forecast for the following day was similar, the decision was taken to abandon any further attempts at this time to carry out any further work with the 4-door rig.

The net was swapped over to the pelagic version and the sweep and door arrangements changed to a conventional pelagic mode.

The vessel's main warp-end termination had to be modified to accommodate the pelagic doors. The swivel and double, in-line flat-link assembly used in the end of the fork-rig was transferred to the end of the warp. An additional 'Trawlex' flat-link had to be incorporated (in-line with the other two), to take the 'Trawlex' 'G' link connection on the pelagic ('pony') door. This enabled a simple transfer of sweeps and net from the net drum to the doors and main warp.

The pelagic rig was hauled onto the net drum with the intention of conducting instrumented tows on the more sheltered inside grounds on day 7, weather permitting.

Some minor repairs and modifications were made to the net used with the 4-door rig before it was returned to the gear store. Additional weight was added to the full length of the footrope using double No 7 leadline (~14kg).

Day 7 – Wednesday 08/06/05
The vessel steamed to the sheltered inshore grounds to carry out the instrumented tows with the pelagic rig.

During the initial tow excessive warp out resulted in a loss of control of the net which went to the bottom causing the net to collapse, the doors to come together and the net to twist up.

The gear was eventually hauled back and the vessel returned to port to clear the net and bridles. Once back on the net drum the vessel returned to sea to complete the trials.

The pelagic net and doors performed reasonably well, with indications that the small 'pony' doors were spreading the net adequately. This was based on wing-end spread readings only as problems with the door sensors prevented reliable readings of door spreads. Headline heights and wing-end spreads were within the range of those expected (log sheet (5)).

On completion of the trials the vessel returned to Newlyn. All gear was off-loaded and stored in Newlyn for follow-up work.

The Seafish team returned to Hull with the instrumentation.

Findings:

The three net designs and rigs under test behaved generally as expected when compared to the model scale observations from Flume Tank trials.

The vertical mouth openings of the Dyneema net in the fork-rig and the larger mesh PE version in the 4-door configuration were not as high as expected. This was seen as a consequence of the large door size being used by the vessel. For the same reason the door spreads achieved for the full-scale trials were in excess of those predicted from the Flume Tank tests, (overspreading of gear).

The pelagic version however, did give a better indication of the potential mouth opening of this general net design when used in the pelagic mode with the relatively small 'pony' doors. Openings of 12'-26' were achieved over the speed range of 2.5-4.0k as compared to 8'-15' over the speed range 2.5-3.5k for the fork and 4-door rigs.

The critical factor of clearance of the footrope from the seabed was achieved satisfactorily with all three gears. With the Dyneema net in the fork-rig, the net generally settled at about 1 fathom from the seabed at a towing speed of 3k using 3:1 warp: depth. This compared to ~2 fathoms for the larger mesh PE net in the 4-door rig for the same settings. The height off the bottom of both nets and rigs responded well to relatively small changes of towing speed and/or warp: depth ratio. Increasing the amount of warp out dropped the net closer to the bottom, e.g. a change to 4:1 for the Dyneema net at the same speed (3.0k) dropped the net from ~6.5' to 4.0'. A drop in speed from 3.5k to 3.0k for the same warp: depth ratio dropped the net from ~7.5' to ~6.5' from the seabed. Using the 4-door configuration, the responsiveness of the gear was generally greater mainly due to the influence of the 'pony' doors.

Although the rigs under test in the full-scale trials were not directly comparable in all circumstances, the findings have resulted in sufficient confidence in the gear designs to progress to the next development stage.

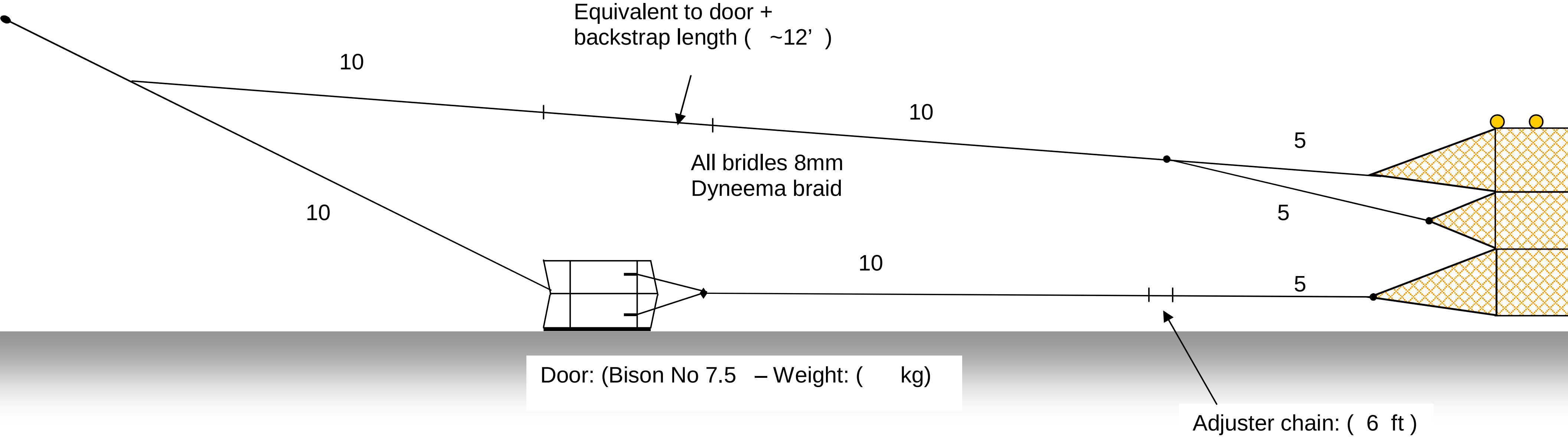
Follow-up work:
The trials identified a number of modifications to be made to the gear and options for further investigation prior to moving into commercial fishing trials:

- All 'C' links to be checked, tested and replaced where required
- All sweep/bridle arrangements to be made compatible with normal commercial practices
- Review weight and floatation distribution on all three nets – replace floats with appropriate specification of *'Floatrope'*.
- Replacement of vessel's doors with smaller size but maintain weight requirements
- Investigate options for simplifying pennant/backstrap arrangement on 'pony' doors
- Review methods/arrangement for attachment of net monitoring instrumentation
- Follow up FT testing of the identical configurations and conditions experienced during the engineering trials to establish model/full-scale correlations
- Indications that all three net designs could be used in fork or 4-door mode should be tested at model scale to improve flexibility of these configurations for future full-scale trials.

General
It should be noted that during the course of the trials in Newlyn, the work being carried out by Seafish attracted considerable interest and attention. In addition the Seafish team, particularly the shore based staff, spent time dealing with a lot of general fishing gear enquiries.

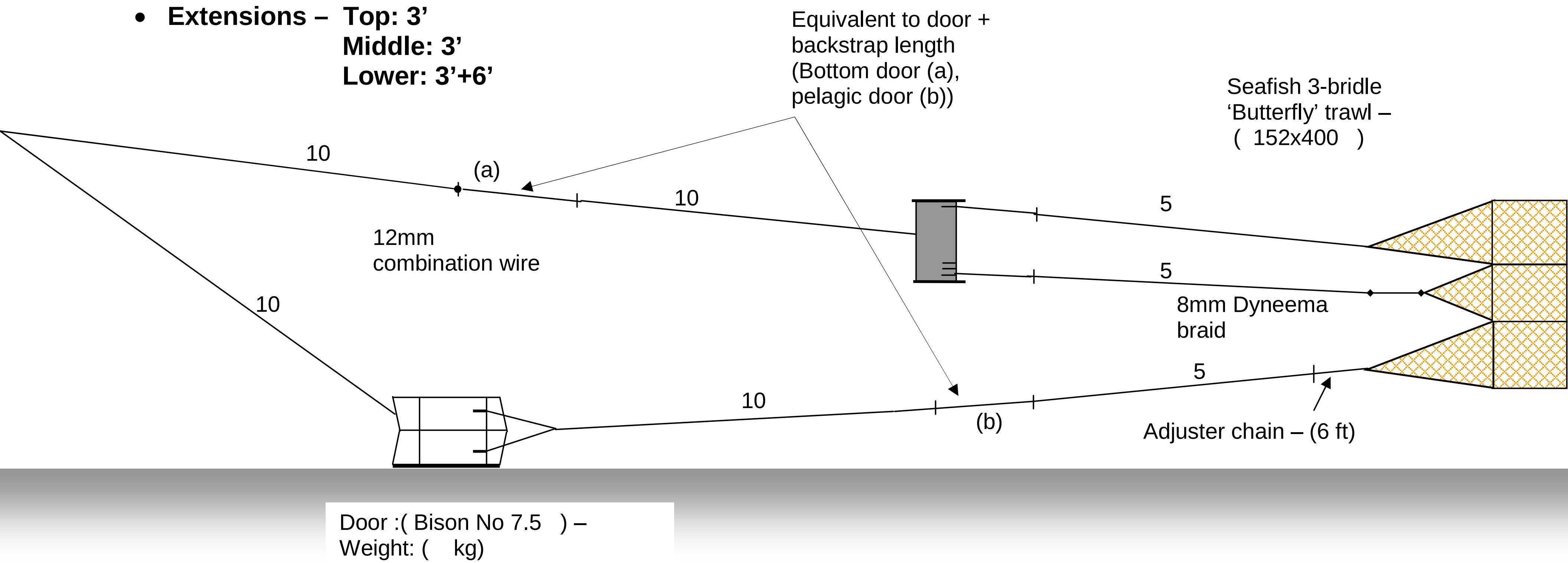
Trials – Rig (1)

- **Net: Dyneema version**
- **Rig: Fork - rig**
- **Floatation: initially 21x8''**
- **Weight: Leaded frame rope**
- **Extensions - Top: 3'**
  Middle: 3'
  Lower: 3'+6'
- **Wire lengths in fathoms**



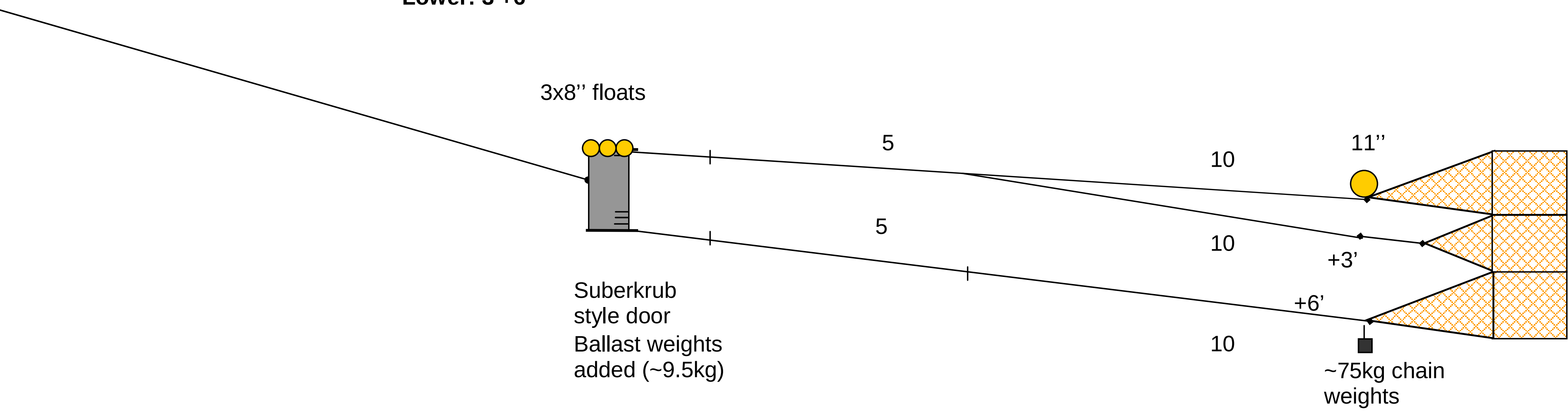
Trial – Rig (2)

- **Net: Large mesh PE version 152x400**
- **Rig: 4-door rig**
- **Floatation: Initially 7x8''**
- **Weight: Frame rope only**
- **Extensions – Top: 3'**
  Middle: 3'
  Lower: 3'+6'



Trial – Rig (3)

- **Net: Pelagic version PE (104x800)**
- **Rig: Conventional pelagic rig**
- **Floatation: Initially 5x11''**
- **Weights: Frame rope only + ~75kg wing-end weights (3x25kg)**
- **Extensions – Top: 3'**
  Middle: 3'
  Lower: 3'+6'



Log 1

Net/Rig: Dyneema (176x200) - Fork-rig	Day 1 03/06/05	(Refer to Fig (1), plan (1))

Rig	Warp	Depth	Speed (k)			Warp Loads (Kg)		Door Spread (Ft)			Wing-end Spread (Ft)			Headline Ht (Ft)			Off-bottom Ht (Ft)			Comments
	(Warp:Depth)		L	S	G	Port	Stbd	E	S	O	E	S	O	E	S	O	H	O	C	
6' extension in lower wing-end	90 f	31 f			2.6							56.4								
	(3:1)																			
	90	31.6			2.6				128			51.7			17.6		15.0	9.0	5.9	
	(3:1)																			
	90	31.6			3.0				128			50.6			18.7		16.2	9.4	6.6	
3' extension in lower wing-end	(3:1)																			
	90	32.0			3.5				126			51.5			18.5		16.6	9.0	7.4	
	(3:1)																			
	120	32			2.5				139			55.0			13.2		13.7	8.4	5.1	Sensor on door backstrap – ok Top wire above door – poor signal Headline unit - ok Trawlsounder – ok/good
	(4:1)																			
	120	32			3.0				137			53.5			13.8		12.5	8.2	4.1	
	(4:1)																			
	120	32			3.3				136			53.3			14.8		12.7	7.8	4.7	
	(4:1)																			
	150	32.3			2.6				151			57.4			12.7		11.5	11.5	0	
	(5:1)																			
	150	32.9			2.9				147			56.4			12.9		11.7	11.7	0	
	(5:1)																			
	150	32.9			2.5				145			57.0			13.5		11.3	2.9	8.4	
	(5:1)																			

Key: E – Estimated Reading S – Scanmar Instrument Reading O – ODS Instrument Reading G – GPS Reading L – Log Reading
H – Height – Headline to seabed O – net opening C – Clearance, footrope to seabed

Log 2

Net/Rig: Large mesh PE (152x400) - 4-door-rig																				Day 2 04/06/05 (Refer to Fig (2), plan (2))
Rig	**Warp**	**Depth**	**Speed (k)**			**Warp Loads (Kg)**		**Door Spread (Ft)**			**Wing-end Spread (Ft)**			**Headline Ht (Ft)**			**Off-bottom Ht (Ft)**			**Comments**
	(Warp:Depth)		**L**	**S**	**G**	**Port**	**Stbd**	**E**	**S**	**O**	**E**	**S**	**O**	**E**	**S**	**O**	**H**	**O**	**C**	
	90 f	27.0 f			2.4				121			54.5			27.5		25.8	10.9	15.2	
	(3:1)																			
	90	27.0			2.4				-			55.2			30.3		26.5	10.9	15.6	
	(3:1)																			
	90	27.0			2.1				-			57.2			33.4		29.3	12.3	15.8	
	(3:1)																			
	90	27.0			2.0				-			57.6			36.3		31.4	12.3	18.9	
	(3:1)																			
	90	27.5			3.0				-			54.7			21.9		19.5	8.0	11.4	
	(3:1)																			Floats twisting – difficult to shoot in poor weather.
	120	23.5			2.2				131			55.6			19.9		16.8	9.0	7.4	
	(5:1)																			
	120	23.5			2.2				133			56.0			18.2		14.1	7.8	6.4	
	(5:1)																			
	120	25.0			2.6				143			58.4			14.6		12.1	7.2	3.3	
	(5:1)																			
	100	25.0			2.5				-			58.0			18.5		14.1	7.8	6.2	
	(4:1)																			
	100	27.0			2.6				-			58.4			17.8		14.8	7.8	7.0	
	(4:1)																			

Key: E – Estimated Reading S – Scanmar Instrument Reading O – ODS Instrument Reading G – GPS Reading L – Log Reading
H – Height – Headline to seabed O – net opening C – Clearance, footrope to seabed

Log 3

Net/Rig: Large mesh PE (152x400) - 4- door-rig **Day 06/06/05** **(Refer to Fig (2), plan (2))**

Rig	Warp	Depth	Speed (k)			Warp Loads (Kg)		Door Spread (Ft)			Wing-end Spread (Ft)			Headline Ht (Ft)			Off-bottom Ht (Ft)			Comments
	(Warp:Depth)		L	S	G	Port	Stbd	E	S	O	E	S	O	E	S	O	H	O	C	
	90 f (3:1)	31.5 f			2.5				148			65.0			19.9		15.8	7.4	8.2	Warp: depth measurement is vessel to fork splits – true warp: depth add 10fthm (Fork split length)
	90 (3:1)	31.5			3.1				146			63.4			19.1		15.2	6.2	8.6	
	90 (3:1)	30.5			3.6				-			59.7			16.2		13.3	5.9	7.2	No floats on Trawlsounder above fishing circle.
	75 (2:1)	35.0			2.5				-			69.5			23.4		19.7	12.5	7.0	1x set of three x 8'' floats on headline – none on wing-ends
	75 (2:1)	35.0			3.0				-			64.0			35.3		30.3	14.3	16.0	
	75 (2:1)	36.0			3.6	Warp-end spread			122			54.3			57.4		53.3	14.6	39.4	3x 8'' floats on wing-ends and 3x 8'' in crown.
	90 (2.5:1)	37.5			2.5	157			-			61.1			35.2		31.8	13.7	17.8	
	90 (2.5:1)	37.5			3.0	163			-			54.1			37.7		34.9	13.5	20.9	Calm conditions throughout trial
	90 (2.5:1)	37.5			3.1	159			-			52.5			40.0		36.5	13.7	22.8	
	120 (3:1)	39.0			2.5				-			60.5			32.8		29.9	13.7	16.2	

Key: E – Estimated Reading S – Scanmar Instrument Reading O – ODS Instrument Reading G – GPS Reading L – Log Reading
H – Height – Headline to seabed O – net opening C – Clearance, footrope to seabed

Log 4

Net/Rig: Large mesh PE (152x400) - 4- door-rig **Day 06/06/05 ('skipper's run')** **(Refer to Fig (2), plan (2))**

Rig	Warp	Depth	Speed (k)			Warp Loads (Kg)		Door Spread (Ft)			Wing-end Spread (Ft)			Headline Ht (Ft)			Off-bottom Ht (Ft)			Comments
	(Warp:Depth)		L	S	G	Port	Stbd	E	S	O	E	S	O	E	S	O	H	O	C	
	80 f	40.0 f			3.0		Engine Revs													
	(2:1)																			
	80	40.0			2.0		1225					68.1			25.2		20.9	13.1	8.0	Steady at 7'-8' clearance
	(3:1)																			
	80	40.0			2.4		1300					67.3			28.0		24.6	13.1	11.7	
	(2:1)																			
	80	40.0			-		1400					-			-		-	-	-	
	(2:1)																			
	80	40.0			2.5		1300					66.6			31.0		25.8	13.5	12.3	
	(2:1)																			
	80	40.0			2.6	3mins	1350					65.0			32.6		28.7	14.1	14.6	
	(2:1)																			
	80	40.0			2.6	3mins	1400					63.0			38.3		33.4	14.6	19.0	
	(2:1)																			
	80	40.0			2.8	3mins	1450					61.7			42.4		38.8	15.0	23.0	
	(2:1)																			
	80	40.0			-		1550					-			-		-	-	-	Maximum revs
	(2:1)																			
	80	40.0			2.3		1250					-			24.4		19.7	12.7	7.0	
	(2:1)																			

Key: E – Estimated Reading S – Scanmar Instrument Reading O – ODS Instrument Reading G – GPS Reading L – Log Reading
H – Height – Headline to seabed O – net opening C – Clearance, footrope to seabed

Log 5

Net/Rig: Pelagic version PE (104x800) conventional pelagic-rig								Day 7 08/06/05									(Refer to Fig (3), plan (3))				
Rig	**Warp**	**Depth**		**Speed (k)**			**Warp Loads (Kg)**		**Door Spread (Ft)**			**Wing-end Spread (Ft)**			**Headline Ht (Ft)**			**Off-bottom Ht (Ft)**			**Comments**
	(Warp:Depth)			**L**	**S**	**G**	**Port**	**Stbd**	**E**	**S**	**O**	**E**	**S**	**O**	**E**	**S**	**O**	**H**	**O**	**C**	
	90 f	28.0 f	(3:1)			2.9		Engine Revs 1500					45.5					90.6	21.7	68.5	Wing-end and opening steady
50kg wing-end weights for first 4 runs	90	28.0	(3:1)			2.6		1350					45.4 5					52.3	22.6	29.1	
	90	27.0	(3:1)			2.7		1250					46.1					36.7	23.2	12.9	
	90	27.1	(3:1)			2.6		1250					44.7					33.0	22.4	10.5	Slow decent of net as speed reduced
75kg wing-end weights for remaining runs	25	21.1	(1:1)			3.1		1325					32.4					95.1	26.2	68.1	
	25	21.1	(1:1)			3.5		1500					32.8					101	25.0	75.9	
	50	19.0	(2:1)			3.0		1500					47.6					61.7	13.7	48.2	Rapid response of net upwards with increase in speed and hauling in of warp
	50	18.00	(2.7:1)			3.5		1650					47.8					60.1	12.3	48.6	
	50	17.5	(2.9:1)			3.5		1650					47.8					62.7	12.9	49.2	Speed up to ~4k – doors hit surface
	50	17.4	(2.9:1)			3.7		1800					-					71.4	13.5	57.8	

Key: E – Estimated Reading S – Scanmar Instrument Reading O – ODS Instrument Reading G – GPS Reading L – Log Reading
H – Height – Headline to seabed O – net opening C – Clearance, footrope to seabed