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Discard sampling of the Dutch *Nephrops* fishery in 2007-2008

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Summary

This report describes the results of a discards sampling programme of the Dutch fishery for *Nephrops* in the North Sea in 2007 and 2008. The sampling programme has been carried out as a pilot study under the EC Data Collection Regulations 1543/2000 and 1639/2001. In both years, three trips were made on board of vessels fishing with twin trawls using 80 mm cod-end. Most of the fishery by the Dutch fleet takes place in the area Botney Gut - Silver Pit (functional unit 5)) Samples of the discards and landings were counted and measured, and raised to catches per hour, per quarter and per year.

This study shows that discards rates of *Nephrops* were high in the sampled trips and varied between 44%-79% in numbers and 32%-61% in weight. As well in numbers as in weight discards of *Nephrops* are higher than for all other species. Most *Nephrops* discards were larger than the minimum landing size indicating that there are problems with the market for ‘smaller’ individuals or problems with the quota. Besides *Nephrops*, the amount of bycatch of other benthos species in this fishery was much lower in comparison with observations in the Dutch beam trawl fishery. This is due to the different gears used In both fisheries.

There are bycatches of flatfish and roundfish in this fishery. Dab was the most abundant fish species in the catch in all trips. Most of the dab is discarded because it undersized or has no or low economic value. Plaice was the most important bycatch in the landings. The absolute amount of discards per hour in the Nephrops fishery is much lower then for the beam trawlers. However, the calculated percentage discarded for plaice and dab are the same as in the beam trawl fishery.

Samenvatting

Dit rapport bevat de resultaten van een bemonsteringsprogramme van discards (DCR programma) in de Nederlandse visserij op Noorse kreeft in de Noordzee in 2007 en 2008. Het bemonsteringsprogramma is als "pilot studie" uitgevoerd binnen EU Verordeningen 1543/2000 en 1639/2001. Gedurende deze jaren zijn 6 reizen uitgevoerd, 3 in ieder jaar, aan boord van otter trawl schepen vissend met 80 mm maaswijdte op *Nephrops.* Het grootste gedeelte van de Nederlandse visserij op *Nephrops* vindt plaats in Botney Gut – Silver Pit (functional unit 5). De discards en aanlandingen werden bemonsterd en gemeten en vervolgens opgewerkt tot vangsten per vis uur, per reis, per kwartaal en per jaar.

Dit onderzoek geeft aan dat de hoeveelheid weer overboord gezette *Nephrops* (discards) hoog was gedurende de zes bemonsterde reizen. Het discard percentage varieerde tussen 44%-79% in aantallen en 32%-61% in gewicht. Het merendeel van de *Nephrops* discards zijn boven de minimum aanvoerlengte. Mogelijk is er geen markt voor de ‘kleinere’ individuen of een gebrek aan voldoende quota. Met uitzondering van *Nephrops*, is de hoeveelheid andere benthos, dat per uur over boord wordt gezet, lager dan in de Nederlandse boomkorvisserij. Dit wordt waarschijnlijk veroorzaakt door verschil in tuig.

Er vindt bijvangst van platvis en rondvis plaats. Schar is de meest voorkomende soort in de discards. Deze soort wordt voornamelijk gediscard vanwege een lage economische waarde heeft of omdat het ondermaats gevangen is. Schol is de meest belangrijke commerciële aangelande bijvangst. De absolute hoeveelheid waargenomen schol en schardiscards per uur is veel lager dan bij de boomkor visserij. Hoewel het berekende discardpercentage voor deze soorten gelijk is aan die van de boomkorvisserij..

1 Introduction

Norway lobster (*Nephrops norvegicus*), better known as *Nephrops,* is an important commercial species in the north-eastern Atlantic and North Sea, found from the most southern part of Portugal up to Iceland and northern Norway. The tail of this lobster is used for human consumption and is often sold under the name “scampi” or “langoustine*”. Nephrops* lives on muddy substrate in which it digs burrows. The lobster spends most of its time within its burrow which provides shelter and protection from predators. It emerges for a short time to feed on prey that lives in or on the muddy seabed. The lobster can only be caught when it is emerged from its burrow. Emergence from its burrow is usually done for foraging during dawn and dusk. Fishing for *Nephrops* is, therefore, most effective during these periods and at full moon (Chapman, 1980; Ingle & Christiansen, 2005).

In the past few decades the amount of *Nephrops* in the North Sea has increased. This increase is associated with a decline of its major predator North Sea cod (ICES, 2008a). In value (financially), the fishery for *Nephrops* in the North Sea is now one of the most important fisheries.

In the North Sea, *Nephrops* occurs in areas which are spatially separated. The animals within these areas are considered to be local populations. These areas are called functional units. There are eight functional units in the North Sea (Figure 1.1). The biological characteristics of the *Nephrops*, such as growth and recruitment, differ between the functional units. Also the fisheries in the functional units are different (different countries, gears, catch composition and by-catches).

Generally, *Nephrops* is caught using bottom trawl. The gear commonly used for this activity in the North Sea is the twinrig trawl. During twinrig trawling one vessel tows two nets along the seabed. Between these two nets a heavy weight keeps the nets at the bottom (Figure 1.2). Similar to all otter trawling activities otter boards are used to keep the mouth of the net open during trawling. The hydrodynamic forces playing on the boards push the net outwards. Compared to the beam trawl, the twinrig trawl is lighter and is towed with a lower speed (4 knots) which results in lower fuel costs and less bottom disturbance.

The fishery for *Nephrops* by the Netherlands is carried out with twinrig trawl in the southern North Sea in the functional units 5 (Botney Gut - Silver Pit) and 33 (Off Horn Reef)

Besides *Nephrops* a variety of flatfish (plaice, dab, brill, turbot) are frequently caught and landed within this fishery. However, catch rates of Dover sole are low, indicating that this gear type is unsuitable to catch this high valuable species. Several studies (e.g. Briggs, 1992; Catchpole *et al*., 2006; Catchpole & Revill, 2008) have shown that different technical net measurements, such as square-shaped meshes, the Swedish grid and separator panels, can improve the selectivity in *Nephrops* lobster trawls and successfully reduce by-catch of fish (e.g. whiting, cod) if these are unwanted. Square mesh panels were made mandatory by the EU in 2000 for all EU-managed North

Box 1: Life history *Nephrops*
Nephrops, or Norway lobster, is a species that has a lifespan between 5-15 years. In the North Sea, the mature males and females molt during the period May-July. Mating takes place while the female is still ‘soft’. This means that she is in the post-moult stage. The eggs are laid in August-November and are incubated under the females abdomen for 8-9 months before the larvae hatch. Most of this time the females stay in their burrow. Females produce between 250-2000 larvae. The larval stage duration is about 2-3 weeks after which they undergo metamorphosis. Thereafter they soon settle on the seabed. The juveniles grow fast and molt frequently. After reaching sexual maturity the males molt more frequently than females and consequently grow faster. This results in males being larger than females (Chapman, 1980; Sardà, 1995; Ingle & Christiansen, 2005).

Sea demersal fisheries. Fishing with 80 mm is permitted above 55° latitude unless 30% of the landings consist of *Nephrops*. This derogation is enforced for demersal otter trawls targeting *Nephrops*.

The catch is sorted on deck and marketable fish and *Nephrops* are kept on board. The part of the catch of no commercial value, e.g. commercial fish under minimum landing size[1] or of undesirable quality, and fish exceeding quota are all considered as unwanted and therefore not retained on board and returned to the sea. This practice is called *discarding*. For most fish species a large part of the discards will not survive the catching and sorting process (van Beek *et al*., 1990; Jennings & Kaiser, 1998). For the *Nephrops* fishery in particular the survival of fish species (including *Nephrops*) are thought to be close to 0% (Evans *et al*., 1994). A more recent study indicated that survival rate of *Nephrops* fifteen days after capture is less than 30% for long trawls (5 hours) (Ridgway *et al*., 2006). However, specific survival experiments with *Nephrops* in the Dutch twinrig fishery have not been carried out so far.

From 2007 onwards discards data on board of twinrig bottom trawl vessels fishing for *Nephrops* have been collected by the Netherlands under the EC Data Collection Regulations 1543/2000 and 1639/2001. This report gives an overview of the results of the Dutch demersal discard sampling programme of the *Nephrops* fishery on board of Dutch vessels in 2007 and 2008.

[1] The minimum landing size (MLS) of Norway lobster is 8 25 mm of carapace length for ICES area IV (ICES, 2008a).

2 Methods

2.1 General information

Selection of the vessels is quasi-random and based on co-operative sampling (ICES, 2000). This means that co-operation of a skipper with the project is on voluntarily basis. Three trips were made on board of Dutch twinrig trawl vessels fishing for *Nephrops* both in 2007 and 2008. The vessels had an engine power of 221, 360 and 588 horse power and fished with a 80 mm mesh size in the cod-end (Table 2.1.1).

Haul duration of these twinrig trawlers is significantly longer in comparison with beam trawl vessels. In general, a beam trawl vessel hauls every two hours, while the sampled twinrig vessels had average haul duration of approximately six hours. Therefore, it was possible to sample 60% of the hauls with only one observer, unlike in the beam trawl sampling programme where two observes are needed to sample 60% of the hauls (or just 25% of the hauls when there is only one observer).

2.2 Sampling procedures

For each sampled haul (Box 2), a sub-sample of the discards was taken at the end of the conveyer belt. The conveyer belt transports the catch on deck towards the crewmembers, who sort and process marketable fish and lobster. All fish in the sub-sample were counted and measured. Benthic invertebrates were only counted. Total and sampled volume of discards was recorded. Sub-samples of the landed fish were measured, and total and sampled weight were recorded. All data are recorded on haul-by-haul basis and later transported into a central database.

Box 2: Sampling protocol per haul

1) Estimation total catch per haul. Registration of total catch in volume (hoops).
2) Take sample of discards.
    a. Take a sample of the discards (total sample size: 35 kg). In order to get a representative sample, different sub-samples are taken repeatedly at different moments from the conveyer belt whilst the haul is processed.
3) Measuring discard sample:
    a. Sort all fish species and Norway lobster, take length measurements of the carapace (Figure 2.2.1). Register total number by species and length class.
    b. Sort all benthos and register total number by species.
4) Measuring landings sample:
    a. Sample landings from target species (Norway lobster), 10-15 kg. Register total number by species and length class.
    b. Sample landings from non-target species (e.g. dab, turbot, brill, whiting, cod, plaice) 10-15 kg. Register total number by species and length class.
5) Registration of total landings:
    a. Information on total landings is collected at the end of the trip.
6) Information on position, haul duration, wind direction, fishing depth en landed catch is collected in cooperation with the skipper for each haul (trawllist).

2.3 Raising procedures

The raising procedures for the *Nephrops* fishery are the same as applied for the beam trawl fleet (Van Helmond & van Overzee, 2008). Sampled numbers of *Nephrops* and fish per haul were raised to numbers at length for both discards and landings. Different

raising procedures were used for discards and landings because different sources of information were used for these catch components. For landings the total landed weight per species by trip was available from the auction, while such data was not available for discards.

2.3.1 Raising discards per trip

The sampled number per length and haul were raised per species to total number per length and haul

$$DN_{l,h,s} = \frac{V_h}{v_h} Dn_{l,h,s}$$

where $DN_{l,h,s}$ is the total number discarded at length (l) in haul (h) for species (s), V_h is total volume of haul (h), v_h is sampled volume of haul (h) and $Dn_{l,h,s}$ sampled number discarded at length (l) in haul (h) for species (s).

The total number discarded at length per haul and species was summed over the sampled hauls to obtain the total sampled number discarded at length (l) for species (s) over all sampled hauls (h). The total number discarded ($DN_{l,t,s}$) at length (l) per trip (t) and species (s) was calculated by multiplying the total number discarded ($DN_{l,h,s}$) over all sampled hauls with the ratio of total trip duration (U_t) and duration of all sampled hauls (Σu_h):

$$DN_{l,t,s} = \frac{U_t}{\sum u_h} \sum_{h=i}^{h} DN_{l,h,s}$$

The number discarded at length per hour and species ($DN_{l,o,t,s}$) was calculated by dividing the total number at length per trip ($DN_{l,t,s}$) by total trip duration (U_t).

$$DN_{l,o,t,s} = \frac{DN_{l,t,s}}{U_t}$$

The obtained number discarded at length per hour ($DN_{l,o,t,s}$) was summed over length to obtain the number discarded per hour ($DN_{o,t,s}$):

$$DN_{o,t,s} = \sum_{l=i} DN_{l,o,t,s}$$

Discarded weight per hour per species at length was calculated using length-weight relationships:

$$DW_{l,o,t,s} = \sum_{l} \left(\frac{DN_{l,o,t,s} * A_s * l^{Bs}}{U_t} \right)$$

where $DW_{l,o,t,s}$ is the weight per length, per hour and per species, $DN_{l,o,t,s}$ is the number discarded at length, per hour and per species and A_s and B_s species specific constants.

2.3.2 Raising landings per trip

The sampled number landed at length per haul and species ($Ln_{l,h,s}$) were summed over all sampled hauls (*h)* to calculate the sampled number at length for the trip ($n_{l,t,s}$). The total number landed at length for the entire trip ($LN_{l,t,s}$) was calculated by multiplying the sampled number at length for the trip ($Ln_{l,t,s}$) with the ratio of total trip weight obtained from auction data ($WT_{t,s}$) to sampled landings weight of the trip ($wt_{t,s}$):

$$LN_{l,t,s} = \frac{WT_{t,s}}{wt_{t,s}} \left(\sum_{h=i}^{h} Ln_{l,h,s} \right)$$

Number landed at length per hour per species ($LN_{l,o,t,s}$) was calculated by dividing total number landed at length per trip ($LN_{l,t,s}$) by the trip duration *(U_t).*

$$LN_{l,o,t,s} = \frac{LN_{l,t,s}}{U_t}$$

The obtained total number at length per hour ($LN_{l,o,t,s}$) was summed to calculate number per hour per species ($LN_{o,t,s}$):

$$LN_{o,t,s} = \sum_{l=i} LN_{l,o,t,s}$$

Total landings weight per hour ($LW_{o,t,s}$) was calculated per species by dividing total landings weight ($WT_{t,s}$) from auction data per species by total trip duration (U_t).

$$LW_{o,t,s} = \frac{WT_{t,s}}{U_t}$$

On board of the vessels *Nephrops* is sorted in two market classes. The ratio between these two classes is calculated from the auction data. Samples are taken on board of both classes and raised in the same ration available from the auction.

3 Results

3.1 Sampling

The total number of hauls varied within the trips between 7 and 22. The average fishing time was 74 hours per trip (Table 3.1.1). Overall, 94% of the hauls were sampled for discards and 70% for landings.

The spatial distribution of fishing effort in the Dutch bottom trawl fleet targeting *Nephrops* with 80 mm cod-end mesh size in 2007 and 2008 was extracted from VIRIS and is shown in Figures 3.1.1a,b. The distribution of the sampled vessels is presented in Figures 3.1.1c,d. In 2007 the sampled vessels fished in Botney Gut and Off Horn Reef and in 2008 only in Botney Gut (Figure 1.1). Sampling effort in 2007 and 2008 was 0.65% and 0.59% in hpeffort respectively for this fleet segment (Table 3.1.2).

3.2 Numbers and weight

The weight of total landings per trip, fish and *Nephrops* together, for the observed vessels varied between 2083 and 8786 kg. *Nephrops* and plaice were the most abundant species in the landings (Table 3.2.1a). In most trips, sampling was directed to discards only. Landings were not sampled in all trips. For *Nephrops* landings were not sampled during trips R91 and R92. Landings of other non-target species (e.g. dab, turbot, brill, whiting, cod, plaice) were not sampled regularly (Table 3.2.1b).

The average weight of total discards for the observed vessels (both fish and invertebrate discards) was estimated to be around 7.4 tonnes per trip in 2007 (CV 63%, Table 3.2.2b) and around 7.6 tonnes per trip in 2008 (CV 56%, Table 3.2.2b). *Nephrops* was the most abundant species in the discards in both years (Table 3.2.3b) while amongst the fish species dab was the most abundant discarded (Table 3.2.3a, Figures 3.2.1, 3.2.2).

3.3 Species

Nephrops
On average 111,536 *Nephrops* individuals (CV 93%) or 2370 kg in weight (CV 121%), were discarded per trip in 2007. In 2008 on average 83,473 *Nephrops* individuals (CV 29%) or 1908 kg in weight (CV 51%), were discarded (Tables 3.2.2a,b). The discard percentage between the trips ranged between 44%-79% in numbers and 32%-61% in weight (Table 3.3.1).

The length frequency distribution of *Nephrops* is based on the trips during which both landings and discards were measured (Table 3.3.2, Figures 3.3.1a,b). It shows that *Nephrops* was caught from 1.8 cm (carapace length) onwards.

The length frequency distribution of 2007 is based on one trip (R93). Two distinct peaks are observed in the length distribution (Figure 3.3.1a). The peak of the discards length distribution was around 3 cm (carapace length) while the landings have a peak around 4 cm (Table 3.3.2). The length frequency distribution of 2008 shows a single peak at 3.5 cm (Figure 3.3.1b).

Fish species

Plaice
The most abundant fish species observed in the landings was plaice in both years (Table 3.2.1a). On average 4,178 plaice individuals (CV 51%) per trip or 513 kg in weight (CV 57%) were discarded in 2007. In 2008, on average 11,094 plaice individuals (CV 105%) or 1031 kg in weight (CV 96%) were discarded (Tables 3.2.2a,b).

Since the landings were not measured in all trips, the discard percentage in numbers could only be calculated for those trips where measurments have been made. The discard percentage in numbers in these trips varied between 63%-80%. The discard percentage in weight could be calculated from all trips because landings in weight were available from the fish auction. The percentage discards in weight varied between 14%-67% (Table 3.3.3).

The most abundant length class in the discards was 24 cm (in 2007) and 22 cm (in 2008). In 2007 plaice was discarded up to 30 cm, which is 3 cm above the minimum landings size of 27 cm (Table 3.3.4, Figure 3.3.1).

Dab
Dab was the most abundant fish species in the discards in both years. On average 24,957 dab individuals (CV 54%) or 1639 kg in weight (CV 54%), were discarded per trip in 2007. In 2008 on average 28,647 dab individuals (CV 37%) or 1530 kg in weight (CV 21%) were discarded (Tables 3.2.2a,b).

The discard percentage in numbers varied between 97%-100%. Similar as for plaice landings were not measured in all trips and discard percentage in numbers could only be calculated for those trips where measurments have been made. The discard percentage in weight are based on all trips and varied between 89%-100% (Table 3.3.5). The most abundant length class in the discards in both years was 16 cm (Table 3.3.6, Figure 3.3.1).

Cod
On average 190 (CV 101%) and 365 (CV 75%) cod individuals were discarded per trip in 2007 and 2008 respectively (Tables 3.2.2a,b). In weight this corresponds to 34 kg (CV 88%) and 80 kg (CV 71%) or 1 to 2 boxes per trip.

The discard percentage in numbers varied between 54%-100% and is based on the vessels where landings of cod were measured. The discard percentage in weight are based on all observations and varied between 0%-100% (Table 3.3.7). These estimates are, however, highly uncertain because of the low catches.

Whiting
On average 2309 (CV 68%) and 15,908 (CV 51%) whiting individuals, 142 kg (CV 66%) and 1167 (CV 71%) in weight, were discarded per trip in 2007 and 2008 respectively (Tables 3.2.2a,b).

Only few fish are kept on board and landed. Most of the whiting catch is discarded. For 2008, the percentage discards in numbers could not be calculated because no whiting landings were measured in this year. The average discard percentage in 2007 is 98%. The discard percentage in weight is based on all trips and varied in both years between 87%-100% (Table 3.3.8).

Sole
With the exception of one trip in 2008, sole catches were very low. No sole discards were observed during the observed trips (Tables 3.2.2a,b).

Turbot and brill
An average of 79 and 198 kg of turbot was landed per trip for 2007 and 2008, respectively (Table 3.2.1a). Turbot is an important species in terms of profits for the fishermen (Table 3.3.9). The high valuable species brill is of lesser importance for them, since this species is caught In low amounts (Table 3.2.1a).

4 Discussion

The fishery for *Nephrops* in the Netherlands has started to develop in de second half of the nineties and is a relative new fishery in the Netherlands. The most common gear used in this fishery is the twin trawl. Attracted by a substantial increase in abundance of *Nephrops* and relative low fuel costs marks the twin trawl fishery as more cost effective than the beamtrawl fishery (Van Keeken ***et al***., 2004). Also the fact that the twin trawl causes less disturbance of the sea bed compared to the beam trawl was considered to be a positive development. The fishing grounds are in the southeren North Sea, predominantly in functional units 5 (Botney Gut - Silver Pit) and 33 (Off Horn Reef).

Yet, reliable time series with discard data on the *Nephrops* fishery in these areas using twin trawls are not at hand. The discard pilot sampling programme conducted by IMARES in 2007 and 2008 gives a first indication on the amount of discarding in the fishery in these areas.

Six vessels fishing for *Nephrops* were sampled in 2007 and 2008. Despite the low spatial and temporal coverage by the sampling programme of the activity of the total fleet, we believe that the results give a reasonable impression on the magnitude of discarding by the twin trawl fleet fishing for *Nephrops* in these areas. However, given the low number of observations and the observed variability in the results, point estimates of total discards obtained by extrapolating the data to the fleet level must be considered to be very imprecise.

Nephrops is the most abundant species observed in the discards in all trips. Based on observations in the field it is thought that survival rates of these discarded individuals is considerable. However, these observations are not yet supported by Dutch survival studies. It is known that the light intensity to which *Nephrops* are exposed when they come onboard can damage their eyes which may have long-term after effects (Loew, 1976; Phillips ***et al***., 1980). There is a clear need to conduct survival studies of *Nephrops* which are discarded, taking into account the specific biological behaviour of this species.

In the sampled trips more than 90% of the *Nephrops* discards were above the minimum landing size of 25 mm carapace. The reason for this is not fully understood. It may be that there is no commercial interest for small sizes. Auction lists of the sampled vessels confirmed that only the larger, more valuable, market classes were landed. It may also be caused by a shortage of quota. In such situation high grading may occur.

The length frequency distribution of *Nephrops* in 2007 (Figure 3.3.1.a) shows two peaks suggesting a strong young cohort entering the fishery which is entirely discarded. However, this observation is based on only one trip. In 2008 this pattern was not found in the length frequency distribution. Given the low number of observations in only two years, care should be taken in the interpretation of the results. Variations between years in length frequency distributions or strong yearclass effects are not known from literature (Briggs, 1985; Evans ***et al***., 1994).

A total of 25 species were observed in the discard programme in the *Nephrops* fishery. This is considerably lower compared than 51 species observed in the beam trawl fleet. (Van Helmond & van Overzee, 2008). Also the total catch of benthos is considerably less in twinrig fishery compared to the beam trawl fishery. For example sea urchin and brittle star, two of the most abundant benthos species in the bycatch of the the beam trawl fleet in 2007, were absent in de bycachtes of the twin trawl trips in both years. Most likely the main reason for the difference between de bycatch of the twin trawl and the otter trawl is the difference in the penetration in the sea bed. The twin trawl, which is a kind ottter trawl, penetrates less in the seabed compared to the heavy beam trawl (Lindeboom & De Groot, 1998; Van Keeken ***et al***., 2004). This causes less disturbance of the seabed and a consequently lower catch of benthic organisms.

Dab was the most abundant fish species in the catch. Most of the dab was discarded because it was below the 'commercial' minimum landing size that is applied by the industry (23 cm). Through time dab has also been the most frequently discarded species in the Dutch beam trawl fishery.

In the trips which were sampled *Nephrops* made up for 51%-82% of the total profit (Table 3.3.9). Plaice was the most abundant fish species in the landings and made up for 3%-33% of the total profit and can therefore be considered as the most important commercial bycatch in this fishery. Also, other high-valuable species, such as turbot, cod and brill, can contribute a considerable amount to the overall profit (Table 3.3.9). High-grading of commercial fish species was observed for plaice in 2007.

Four trips were sampled in functional unit 5 (Botney Gut), one in functional units 5 and 33 (Off Horn Reef) (trip 92) and one in functional unit 33 (trip R93). Most observations were made in functional unit 5. We did not find different discard percentages for *Nephrops* between the two different areas. Absolute numbers and weight discarded per hour for trip R93 are much higher (Table 3.3.1), but this is most likely caused by the difference in engine power (Table 2.1.1). The length frequency distribution of trip R93 (Off Horn Reef) indicates a deviant pattern from the other trips (Botney Gut), with two distinct peaks for discard and landings, as discussed above.

In conclusion, we observed that the Dutch twin trawl fishery is effective in targeting *Nephrops*. However, discard rates of *Nephrops* are considerably high consting for a significant part of lobsters which are above the minimum landings size. Without the knowledge of survival rates it is difficult to determine the actual impact of the twin trawl fishery targeting this species. For dab and plaice the percentage discarded are not lower than the rates observed for the Dutch beam trawl fishery (Van Helmond & van Overzee, 2008). However, the absolute amounts of discards in number and weight are much lower than observed in the beam trawl fishery. This is most likely caused by the difference in fishing speed, which is considerably slower for a twinrig trawler in comparison with a beam trawler.

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Appendix I: Tables and Figures

Table 2.1.1. Characteristics per trip sampled in 2007 and 2008. For each vessel the gear (OTB=otter bottom trawl), the engine power in hpower, the mesh size in mm and sampled ICES rectangles are represented.

Year	Mesh	Gear	Vessel	Hpower	Quarter	Sampled ICES rectangles
2007	80	OTB	R91	360	2	36/F3, 37/F2
			R92	221	4	38/F4, 40/F5
			R93	588	4	40/F5, 41/F5
2008	80	OTB	R99	360	2	36/F2, 36F3, 37/F2
			R100	360	2	36/F3, 37/F2
			R101	221	3	36/F4, 36/F5, 37/F4, 37/F5

Table 3.1.1. Sampling effort per trip sampled in 2007 an 2008. For each trip the duration and number of hauls sampled for landings and discards and total duration and number of hauls for the total trips are given.

				Number of hauls			Duration (hours)		
Mesh size	Year	Gear	Vessel	Land	Disc	Tot	Land	Disc	Tot
80	2007	OTB	R91	6	9	9	41	58	58
			R92	0	7	7		40	40
			R93	11	11	11	65	65	65
			Total	**17**	**27**	**27**	**106**	**163**	**163**
			%Total	**63%**	**100%**		**65%**	**100%**	
80	2008	OTB	R99	8	9	11	55	62	72
			R100	8	10	11	55	68	71
			R101	17	21	22	106	131	137
			Total	**33**	**40**	**44**	**216**	**261**	**280**
			%Total	**75%**	**91%**		**77%**	**93%**	

Table 3.1.2. Sampling effort in 2007 and 2008 in days at sea (D.A.S.) and hp-effort (HPeff, days at sea corrected for engine power) per trip and per quarter for the sampled trips and for the fleet larger than 260 HP using 80 mm mesh size using otter bottom trawl (OTB) and otter twin trawl (OTT) targeting *Nephrops* (fleet data from VIRIS), and fleet coverage by the sampled trips.

			Sampled effort		Fleet effort		Fleet coverage	
Quarter	**Year**	**Vessel**	**D.A.S.**	**HPeff**	**D.A.S.**	**HPeff**	**D.A.S.**	**HPeff**
1		Total			210	89865	0%	0%
2		R91	4	1930				
		Total	4	1930	745	294776	0.54%	0.65%
3		Total			827	293637	0%	0%
4		R92	4	1185				
		R93	3	2364				
		Total	7	3549	416	165778	1.68%	2.14%
All	**2007**	**Total**	**11**	**5479**	**2198**	**844056**	**0.50%**	**0.65%**
1		Total			127	60066	0%	0%
2		R99	5	2412				
		R100	5	2412				
		Total	10	4824	436	256359	2.29%	1.88%
3		R101	7	2073				
		Total	7	2073	977	578548	0.72%	0.36%
4		Total			474	280757	0%	0%
All	**2008**	**Total**	**17**	**6897**	**2014**	**1175730**	**0.84%**	**0.59%**

Table 3.2.1a. Total landings weight (kg) per trip in 2007 and 2008 for plaice, sole, cod, whiting, dab, turbot, brill and *Nephrops* for the twinrig trawl vessels using 80 mm cod-end mesh size.

Mesh	Year	Vessel	Quar	*Nephrops*	Plaice	Cod	Whiting	Dab	Turbot	Brill	Sole
80	2007	R91	2	1375	330	245	19	21	86	3	4
		R92	4	724	1875	15	0	142	60	18	10
		R93	4	3240	1559	101	0	0	92	16	12
			Mean	**1780**	**1255**	**120**	**6**	**54**	**79**	**12**	**9**
80	2008	R99	2	1562	233	670	95	37	131	16	17
		R100	2	854	383	731	86	40	160	1	9
		R101	3	5459	2241	0	96	220	304	53	413
			Mean	**2625**	**952**	**467**	**92**	**99**	**198**	**23**	**146**

Table 3.2.1b. Sampled landings weight (kg) per trip in 2007 and 2008 for plaice, sole, cod, whiting, dab, turbot, brill and *Nephrops* for the twinrig trawl vessels using 80 mm cod-end mesh size. *nm*=not measured.

Mesh	Year	Vessel	Quar	*Nephrops*	Plaice	Cod	Whiting	Dab	Turbot	Brill	Sole
80	2007	R91	2	*nm*	45	115	8	3	30	1	2
		R92	4	*nm*	*nm*	*nm*	0	*nm*	*nm*	*nm*	*nm*
		R93	4	14	89	11	0	0	26	*nm*	*nm*
			Mean	**14**	**67**	**63**	**4**	**2**	**28**	**1**	**1**
80	2008	R99	2	32	*nm*	*nm*	*nm*	*nm*	*nm*	*nm*	*nm*
		R100	2	32	*nm*	*nm*	*nm*	*nm*	*nm*	*nm*	*nm*
		R101	3	34	50	0	*nm*	10	*nm*	*nm*	*nm*
			Mean	**33**	**50**	**0**		**10**			

Table 3.2.2a. Total number in 2007 and 2008 of *Nephrops*, plaice, sole, dab, cod, whiting and sole discards for the twinrig trawl vessels using 80 mm cod-end mesh size.

Mesh	Year	Vessel	*Nephrops*	Plaice	Dab	Cod	Whiting	Sole
80	2007	R91	100208	3312	23882	186	2661	0
		R92	13792	2636	38975	0	603	0
		R93	220608	6585	12013	383	3664	0
		Mean	**111536**	**4178**	**24957**	**190**	**2309**	**0**
		CV	**93%**	**51%**	**54%**	**101%**	**68%**	
80	2008	R99	74369	4368	18364	549	13990	0
		R100	64817	4392	28001	495	8924	0
		R101	111234	24521	39577	51	24811	0
		Mean	**83473**	**11094**	**28647**	**365**	**15908**	**0**
		CV	**29%**	**105%**	**37%**	**75%**	**51%**	

Table 3.2.2b. Total weight (kg) in 2007 and 2008 of all discards per trip (fish and benthos) and of *Nephrops*, plaice, sole, dab, cod, whiting and sole for the twinrig trawl vessels using 80 mm cod-end mesh size. *na*=not available.

Mesh	Year	Vessel	All discards	*Nephrops*	Plaice	Dab	Cod	Whiting	Sole
80	2007	R91	5140	*na*	394	1427	46	229	0
		R92	4240	346	299	2612	0	44	0
		R93	12680	4393	847	879	56	153	0
		Mean	**7353**	**2370**	**513**	**1639**	**34**	**142**	**0**
		CV	**63%**	**121%**	**57%**	**54%**	**88%**	**66%**	
80	2008	R99	5063	1362	463	1167	114	816	0
		R100	5241	1324	459	1680	111	567	0
		R101	12465	3039	2170	1743	15	2117	0
		Mean	**7590**	**1908**	**1031**	**1530**	**80**	**1167**	**0**
		CV	**56%**	**51%**	**96%**	**21%**	**71%**	**71%**	

Table 3.2.3a. Numbers of fish discarded per hour in 2007 and 2008 for the twinrig trawl vessels using 80 mm cod-end mesh size.

English name	Dutch name	Number per hour 2007	Number per hour 2008
Bull-rout	Zeedonderpad	0.3	0.9
Cod	Kabeljauw	3.0	5.0
Dab	Schar	520.3	312.6
Dragonet	Pitvis	6.6	14.3
Five-bearded rockling	Vijfdradige meun		0.1
Flouder	Bot		<0.1
Four-bearded rockling	Vierdradige meun	4.6	2.5
Grey gurnard	Grauwe poon	42.4	29.8
Herring	Haring	0.7	
Hooknose	Harnasmannetje	0.1	0.5
Horse mackerel	Horsmakreel	0.1	
Lemon sole	Tongschar	2.2	4.7
Lesser spotted dogfish	Hondshaai	<0.1	<0.1
Long rough dab	Lange schar	24.6	8.5
Lumpsucker	Snotolf		<0.1
Mackerel	Makreel	0.9	
Plaice	Schol	74.5	100.4
Poor cod	Dwergbolk	1.7	0.1
Recticulated dragonet	Rasterpitvis	2.5	
Roker	Stekelrog		0.1
Scaldfish	Schurftvis	12.8	6.5
Smoothhound	Gladde haai	<0.1	<0.1
Solenette	Dwergtong	0.3	5.8
Spotted ray	Gevlekte rog	<0.1	0.4
Sprat	Sprot		<0.1
Starry ray	Sterrog		0.6
Striped red mullet	Mul	0.1	0.7
Tope	Ruwe haai	<0.1	
Tub gurnarad	Rode poon	0.2	0.3
Twaite shad	Fint		0.1
Whiting	Wijting	39.1	166.9
Witch	Witje	0.5	4.2
Bib	Steenbolk	1.7	1.5

Table 3.2.3b. Numbers of benthic species discarded per hour in 2007 and 2008 for the twinrig trawl vessels using 80 mm cod-end mesh size.

Latin name	Dutch name	Number per hour 2007	Number per hour 2008
Acanthocardia echinata	Gedoornde Hartschelp	1.3	
Alcyonium digitatum	Dodemansduim	2.7	0.1
Anthozoa	Zeeanemonen	0.1	0.5
Aphrodita aculeate	Fluwelen zeemuis	33.2	62.8
Arctica islandica	Noordkromp	0.2	
Ascidiacea	Zakpijp	1.5	
Asterias rubens	Zeester	29.1	45.0
Astropecten irregularis	Kamster	37.6	20.8
Buccinum undatum	Wulk	6.1	1.9
Cancer pagurus	Noordzeekrab	2.3	0.6
Chrysoara hysoscella	Kompaskwal		1.1
Corystes cassivelaunus	Helmkrab	0.7	5.8
Echinocardium cordatum	E. cordatum	15.5	33.3
Eledone cirrhosa	Eledone	<0.1	
Goneplax rhomboides	G. rhomboides	0.7	2.7
Hyas sp.	Spinkrab	0.4	0.3
Liocarcinus depurator	Blauwpootzwemkrab	62.9	59.4
Liocarcinus holsatus	Gewone zwemkrab	77.4	35.7
Loligo forbesi	L. forbesi		0.1
Loligo sp.	Loligo	0.9	<0.1
Nephrops norvegicus	Noorse kreeft	1821.0	918.8
Pagurus bernhardus	P. bernhardus	47.6	61.5
Pagurus sp.	Pagurus sp.	0.8	
Pecten maximus	St. Jacobsschelp	0.7	0.1
Spatangus purpureus	Purperen zeeklit	0.3	

Table 3.3.1. *Nephrops*. Landings (L), discards (D) and percentage discards (%D) per hour in round numbers (left) and weight (right) for twinrig trawl vessels using 80 mm mm cod-end mesh size in 2007 and 2008. *nm*=not measured. Discards in numbers and weight and landings in numbers are calculated from the values obtained during the sampled trips while the landings in weight are calculated from the auction values.

				Numbers			Weight		
Mesh	**Year**	**Vessel**	**Quart**	**L**	**D**	**%D**	**L**	**D**	**%D**
80	2007	R91	2	*nm*	1728		24	*nm**	
		R92	4	*nm*	341		18	9	32%
		R93	4	1335	3394	72%	50	68	58%
			Mean	**1335**	**3394**	**72%**	**34**	**39**	**53%**
80	2008	R99	2	460	1033	69%	22	19	47%
		R100	2	236	913	79%	12	19	61%
		R101	3	1052	810	44%	40	22	36%
			Mean	**583**	**919**	**61%**	**24**	**20**	**45%**

* No length measurements were taken of *Nephrops* discards during trip R91. As numbers were converted to weight using standard length-weight relationships, it was not possible to calculate the weight of *Nephrops* for this trip

Table 3.3.2. *Nephrops*. Number landed and discarded per hour per length class (carapace length) for twinrig trawl vessels using 80 mm cod-end mesh in 2007 and 2008.

Length carapace	Number per hour 2007*		Number per hour 2008	
(cm)	Discards	Landings	Discards	Landings
1.5				
1.6				
1.7				
1.8			1.5	
1.9	4.2		1.1	
2			1.5	
2.1	20.0		5.0	
2.2	33.2		2.8	
2.3	101.4		2.9	
2.4	112.2		16.1	
2.5	150.9		28.7	
2.6	217.8		37.6	
2.7	210.9		87.6	0.2
2.8	348.4		86.6	
2.9	337.0		64.9	
3	373.3		78.9	0.4
3.1	336.7		115.9	1.1
3.2	331.0		110.9	4.4
3.3	276.9	3.4	46.1	3.9
3.4	170.4	7.1	86.5	24.0
3.5	132.1	3.6	52.7	32.4
3.6	114.5	17.8	32.3	41.9
3.7	32.1	42.7	25.7	52.5
3.8	39.5	67.6	13.7	64.0
3.9	21.3	110.4	11.8	53.4
4	8.7	178.0	4.3	51.3
4.1	3.5	128.2	2.5	53.1
4.2	7.1	146.0	0.9	51.1
4.3	10.6	170.9		35.3
4.4		117.5	0.1	26.1
4.5		113.9	0.1	22.0
4.6		78.3		19.7
4.7		39.2		18.6
4.8		46.3		8.8
4.9		14.2		6.2
5		17.8		3.2
5.1		10.7		4.5
5.2		3.6		2.2
5.3		7.1		0.6
5.4		3.6		1.0
5.5				0.5
5.6				
5.7				0.2
5.8				
5.9		3.6		
6				
6.1		3.6		
6.2				

* These values are only based on trip R93

Table 3.3.3. Plaice. Landings (L), discards (D) and percentage discards (%D) per hour in round numbers (left) and weight (right) for twinrig trawl vessels using 80 mm mm cod-end mesh size in 2007 and 2008. Discards in numbers and weight and landings in numbers are calculated from the values obtained during the sampled trips while the landings in weight are calculated from the auction values.

				Numbers			Weight		
Mesh	**Year**	**Vessel**	**Quart**	**L**	**D**	**%D**	**L**	**D**	**%D**
80	2007	R91	2	15	57	79%	6	7	54%
		R92	4	*nm*	65		46	7	14%
		R93	4	58	101	63%	24	13	35%
			Mean	**37**	**79**	**68%**	**25**	**9**	**26%**
80	2008	R99	2	*nm*	61		3	6	67%
		R100	2	*nm*	62		5	6	54%
		R101	3	45	179	80%	16	16	49%
			Mean	**45**	**179**	**80%**	**8**	**10**	**53%**

Table 3.3.4. Plaice. Number landed and discarded per hour per length class for twinrig trawl vessels using 80 mm cod-end mesh in 2007 and 2008.

Length	Number per hour 2007		Number per hour 2008	
(cm)	Discards	Landings	Discards	Landings
4				
5				
6				
7				
8				
9				
10				
11				
12			0.3	
13			0.3	
14			0.5	
15	0.2		2.5	
16	0.2		6.6	
17	0.1		8.0	
18	0.2		11.7	
19	3.5		15.6	
20	6.7		22.4	
21	9.4		21.4	
22	7.2		29.0	
23	8.3		26.2	
24	11.0		15.0	
25	8.5		12.4	
26	8.8	0.3	6.2	1.0
27	7.9	0.3	0.6	4.6
28	2.8	3.4		6.9
29	2.9	3.6		7.5
30	1.5	5.7		5.5
31		4.1		3.9
32		4.2		2.9
33		3.4		2.3
34		2.5		2.6
35		3.7		2.0
36		1.3		1.3
37		0.8		0.7
38		0.9		1.0
39		0.3		1.0
40		0.4		0.3
41		0.5		0.7
42		0.3		0.3
43		0.3		0.3
44		0.3		
45		0.1		
46				
47		0.1		
48				
49				
50				

Table 3.3.5. Dab. Landings (L), discards (D) and percentage discards (%D) per hour in round numbers (left) and weight (right) for twinrig trawl vessels using 80 mm cod-end mesh size in 2007 and 2008. *nm*=not measured. Discards in numbers and weight and landings in numbers are calculated from the values obtained during the sampled trips while the landings in weight are calculated from the auction values.

				Numbers			Weight		
Mesh	**Year**	**Vessel**	**Quart**	**L**	**D**	**%D**	**L**	**D**	**%D**
80	2007	R91	2	3	412	99%	<1	25	99%
		R92	4	*nm*	964		4	65	95%
		R93	4	0	185	100%	0	14	100%
			Mean	**2**	**298**	**99%**	**1**	**34**	**96%**
80	2008	R99	2	*nm*	255		<1	16	97%
		R100	2	*nm*	394		<1	24	98%
		R101	3	8	288	97%	2	13	89%
			Mean	**8**	**288**	**97%**	**1**	**18**	**95%**

Table 3.3.6. Dab. Number landed and discarded per hour per length class for twinrig trawl vessels using 80 mm cod-end mesh in 2007 and 2008.

Length	Number per hour 2007		Number per hour 2008	
(cm)	Discards	Landings	Discards	Landings
4	0.4			
5				
6			0.2	
7	0.4			
8			0.5	
9			0.8	
10	1.0		6.6	
11	3.0		9.7	
12	5.2		18.0	
13	14.6		30.2	
14	19.2		30.6	
15	28.7		36.1	
16	36.0		43.5	
17	33.7		38.0	
18	32.2		27.9	
19	33.4		16.6	
20	31.7		11.8	
21	20.6		9.3	
22	13.2		4.9	0.5
23	14.7		1.7	1.0
24	6.4		1.3	1.6
25	2.2	0.1	0.6	1.3
26	0.8	0.1		1.1
27	0.7	0.2		0.8
28	0.3	0.2		1.0
29		0.4		
30		0.4		0.3
31		0.1		
32		0.1		
33				
34				
35				
36				
37				
38				
39				
40				
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				

Table 3.3.7. Cod. Landings (L), discards (D) and percentage discards (%D) per hour in round numbers (left) and weight (right) for twinrig trawl vessels using 80 mm cod-end mesh size in 2007 and 2008. *nm*=not measured. Discards in numbers and weight and landings in numbers are calculated from the values obtained during the sampled trips while the landings in weight are calculated from the auction values.

				Numbers			Weight		
Mesh	**Year**	**Vessel**	**Quart**	**L**	**D**	**%D**	**L**	**D**	**%D**
80	2007	R91	2	3	3	54%	4	<1	16%
		R92	4	*nm*	0		<1	0	0%
		R93	4	<1	6	88%	2	<1	36%
			Mean	**2**	**5**	**72%**	**2**	**<1**	**21%**
	2008	R99	2	*nm*	8		9	2	15%
		R100	2	*nm*	7		10	2	13%
		R101	3	0	<1	100%	0	<1	100%
			Mean	**0**	**<1**	**100%**	**7**	**1**	**14%**

Table 3.3.8. Whiting. Landings (L), discards (D) and percentage discards (%D) per hour in round numbers (left) and weight (right) for twinrig trawl vessels using 80 mm cod-end mesh size in 2007 and 2008. *nm*=not measured. Discards in numbers and weight and landings in numbers are calculated from the values obtained during the sampled trips while the landings in weight are calculated from the auction values.

				Numbers			Weight		
Mesh	**Year**	**Vessel**	**Quart**	**L**	**D**	**%D**	**L**	**D**	**%D**
80	2007	R91	2	2	46	96%	<1	4	92%
		R92	4	0	15	100%	0	1	100%
		R93	4	0	56	100%	0	2	100%
			Mean	**1**	**39**	**98%**	**<1**	**2**	**96%**
	2008	R99	2	*nm*	194		1	11	90%
		R100	2	*nm*	126		1	8	87%
		R101	3	*nm*	181		<1	15	96%
			Mean				**1**	**12**	**91%**

Table 3.3.9. Contribution of different species to the overall profit (in percentage)

Year	**Vessel**	***Nephrops***	**Plaice**	**Dab**	**Cod**	**Whiting**	**Turbot**	**Brill**	**Other**
2007	R91	80.1	4.3	0	4.4	0.1	6.4	0.3	4.4
	R92	56.2	33.1	0	0.5	0	5.3	1.2	3.7
	R93	81.5	12.0	0	1.4	0	3.0	0.3	1.8
2008	R99	68.3	2.5	0	15.1	1.0	9.2	0.8	3.1
	R100	50.5	6.3	0	22.1	0	16.0	0.1	5.0
	R101	59.4	14.0	0	0	0.2	11.8	1.8	12.8

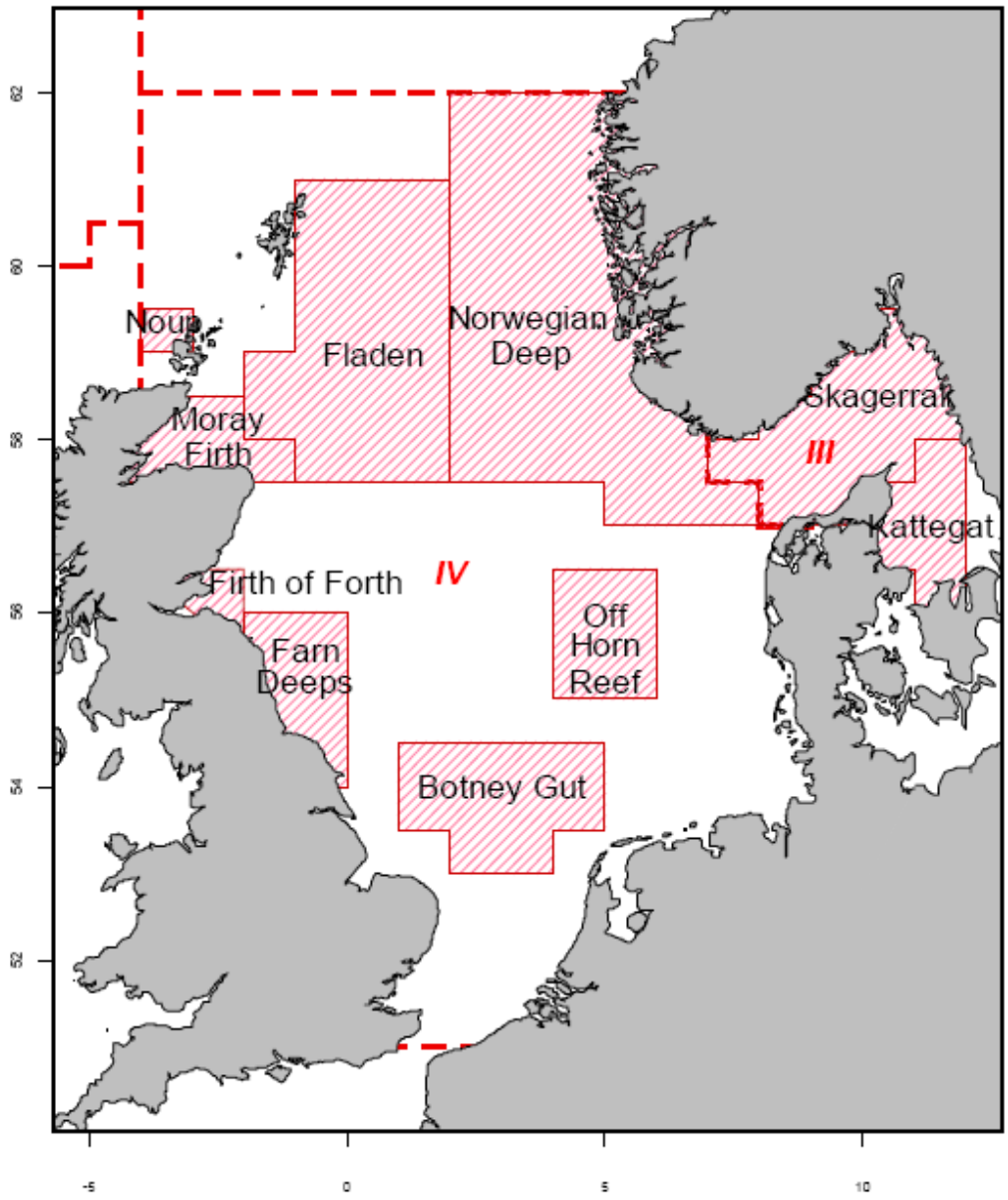

Figure 1.1 Functional units for management of *Nephrops* in the North Sea and the Skagerrak/Kattegat region (ICES, 2008a).

FU no.	Name	ICES area	Statistical rectangles
5	Botney Gut - Silver Pit	IVb,c	36-37 F1-F4; 35F2-F3
6	Farn Deeps	IVb	38-40 E8-E9; 37E9
7	Fladen Ground	IVa	44-49 E9-F1; 45-46E8
8	Firth of Forth	IVb	40-41E7; 41E6
9	Moray Firth	IVa	44-45 E6-E7; 44E8
10	Noup	IVa	47E6
32	Norwegian Deep	IVa	44-52 F2-F6; 43F5-F7
33	Off Horn Reef	IVb	39-41E4; 39-41E5

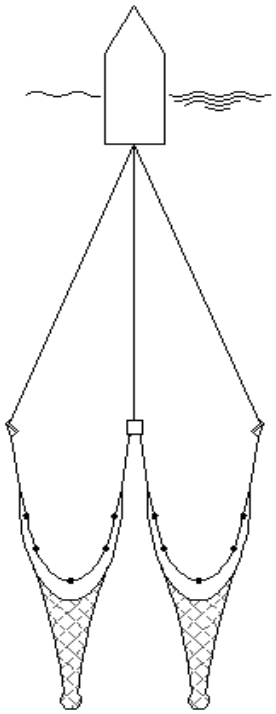

Figure 1.2: Schematic picture of twinrig trawl.

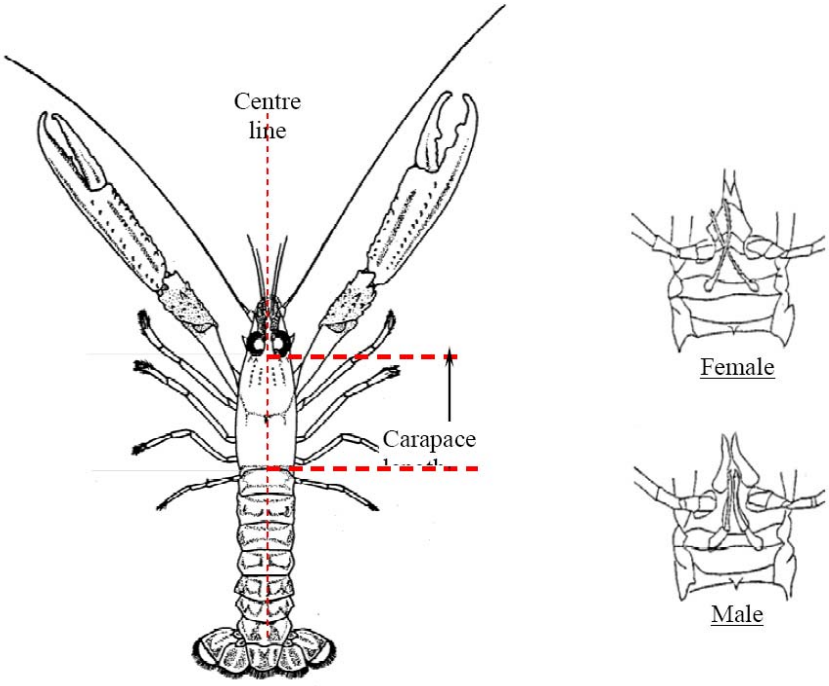

Figure 2.2.1: Measurement of *Nephrops* (ICES, 2008b).

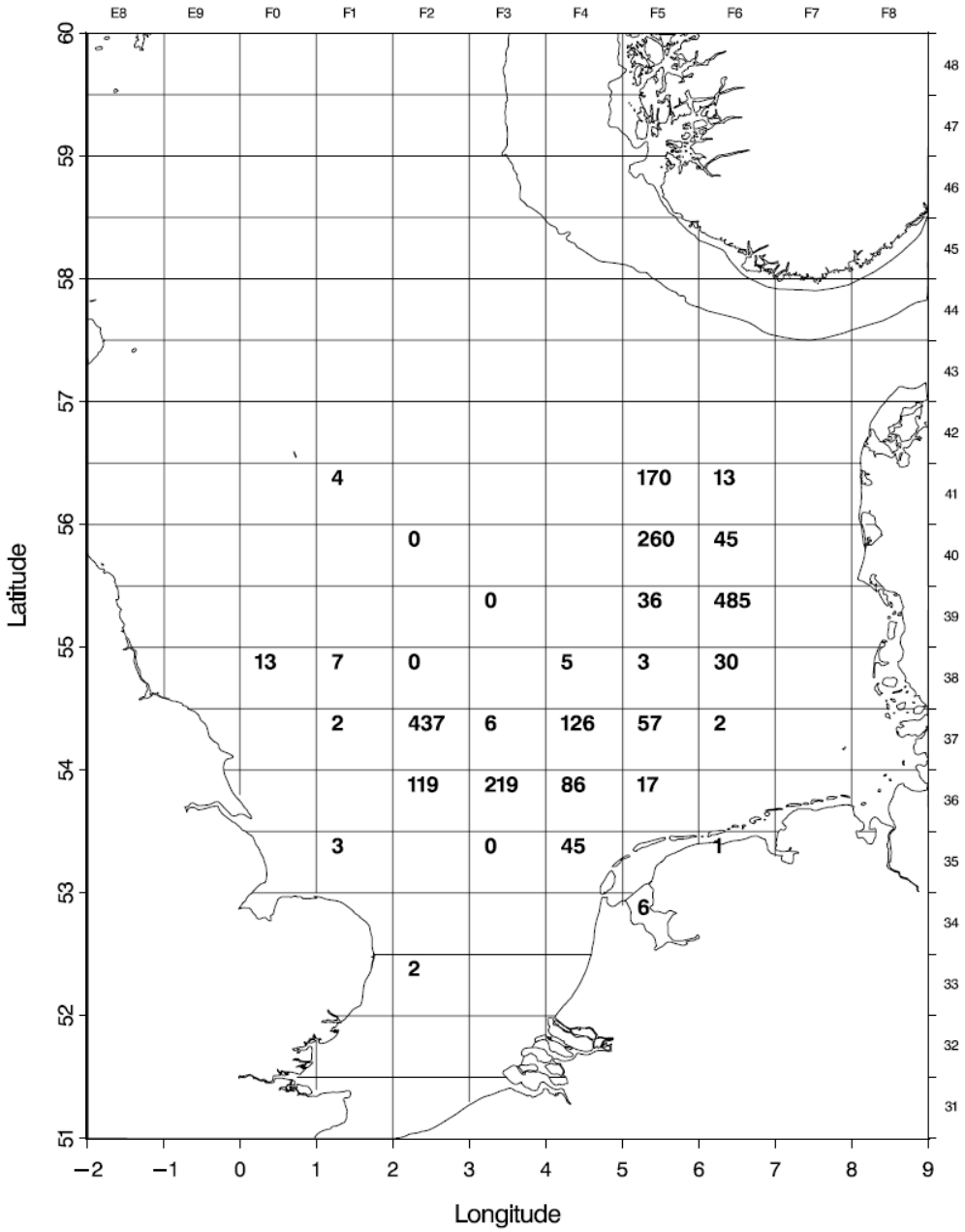

Figure 3.1.1a: Distribution of effort in days at sea by the Dutch otter bottom trawl fleet in 2007, for all vessels (OTB and OTT) targeting *Nephrops* using 80 mm cod-end mesh size. Data from VIRIS database.

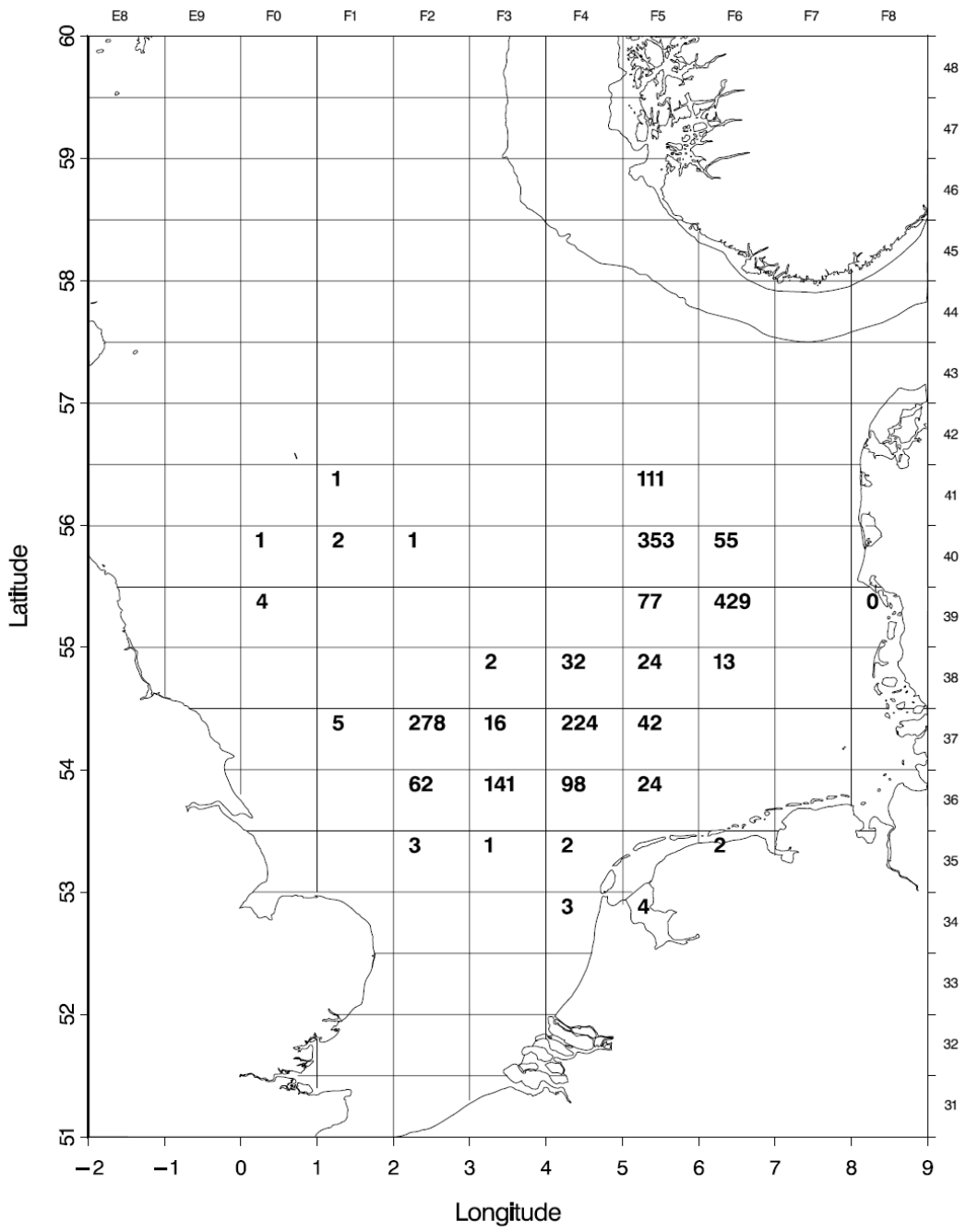

Figure 3.1.1b: Distribution of effort in days at sea by the Dutch otter bottom trawl fleet in 2008, for all vessels (OTB and OTT) targeting *Nephrops* using 80 mm cod-end mesh size. Data from VIRIS database.

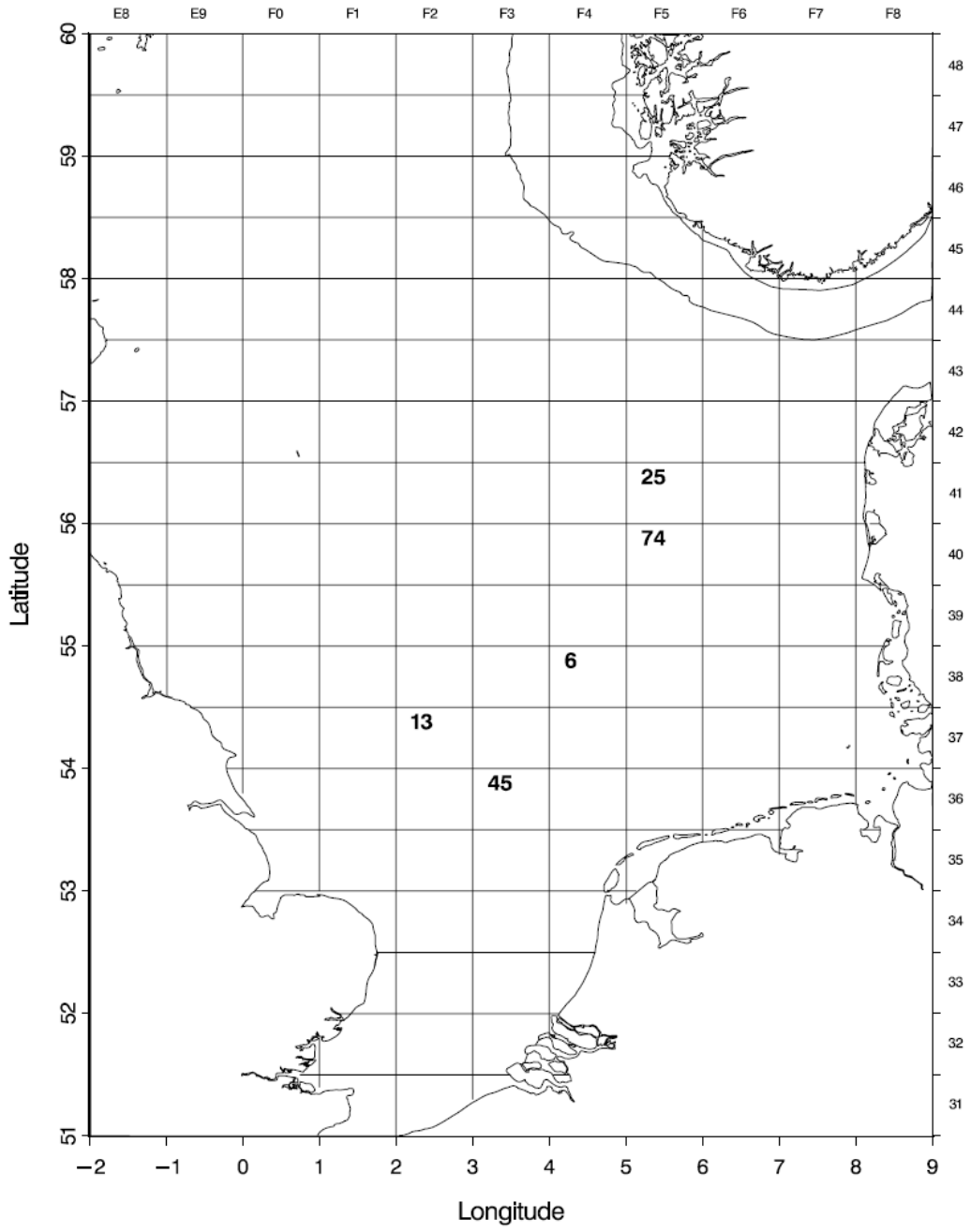

Figure 3.1.1c. Distribution of hours sampled for the sampled Dutch twinrig trawl fleet targeting *Nephrops* in 2007 for vessels using 80 mm cod-end mesh size.

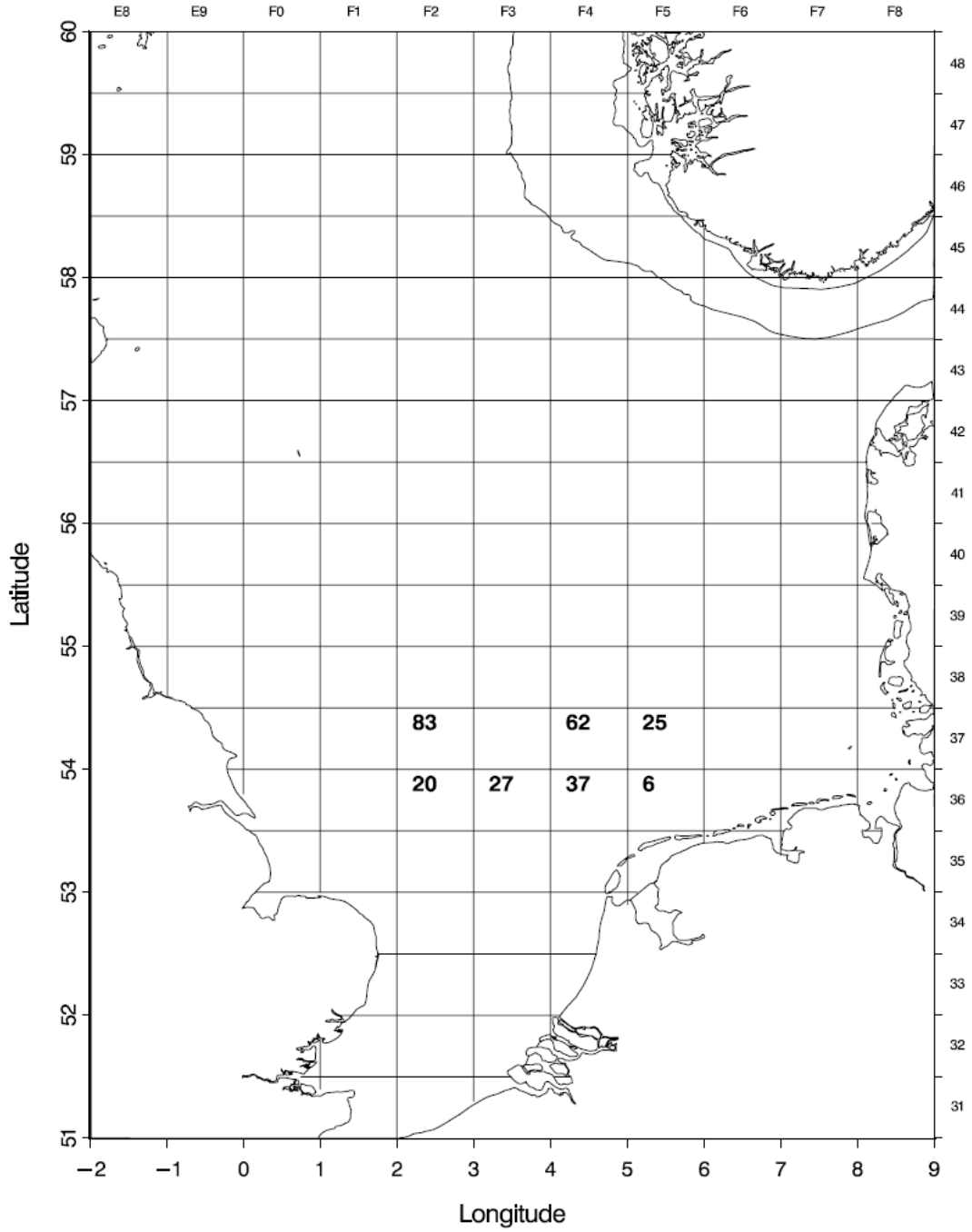

Figure 3.1.1d. Distribution of hours sampled for the sampled Dutch twinrig trawl fleet targeting *Nephrops* in 2008 for vessels using 80 mm cod-end mesh size.

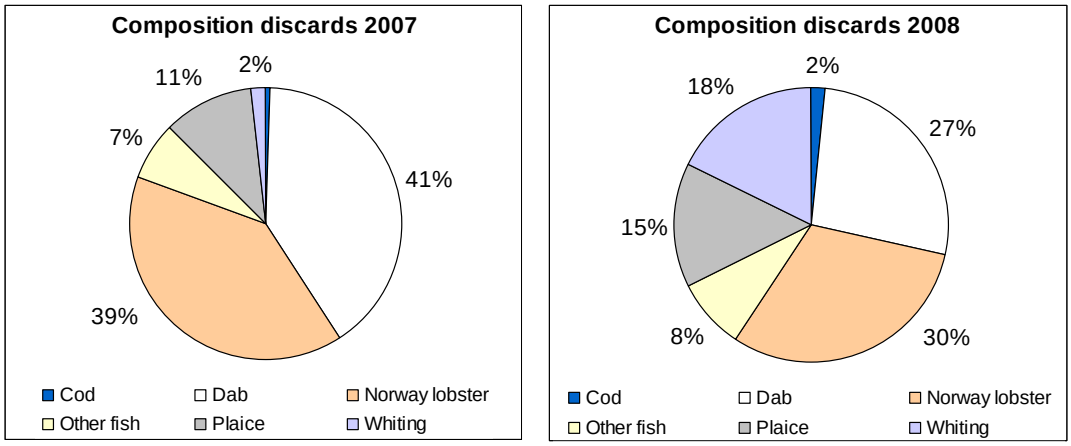

Figure 3.2.1 Composition of fish and *Nephrops* in weight for the sampled twinrig trawl vessels using 80mm cod-end mesh size in 2007 (left) and 2008 (right). The composition of 2007 is based on two trips (R92 and R93).

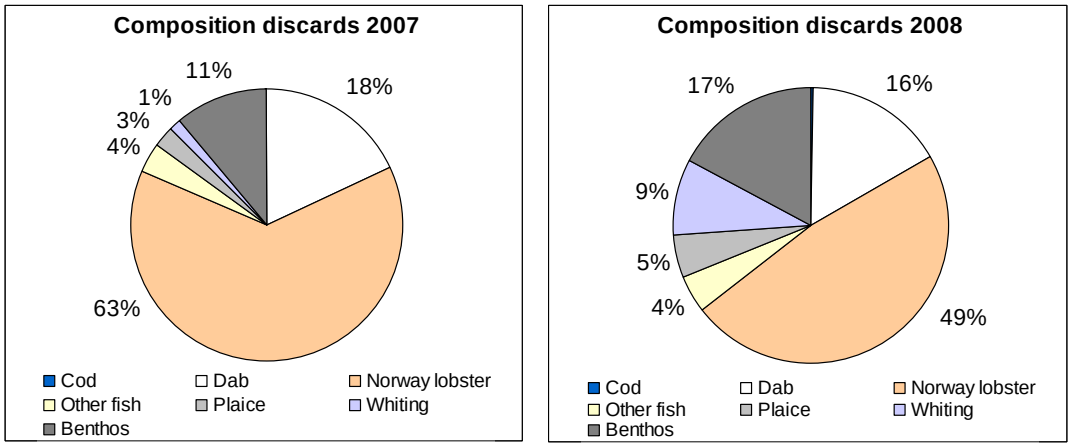

Figure 3.2.2. Composition of fish and *Nephrops* discards in numbers for twinrig trawl vessels using 80 mm cod-end mesh size in 2007 (left) and 2008 (right).

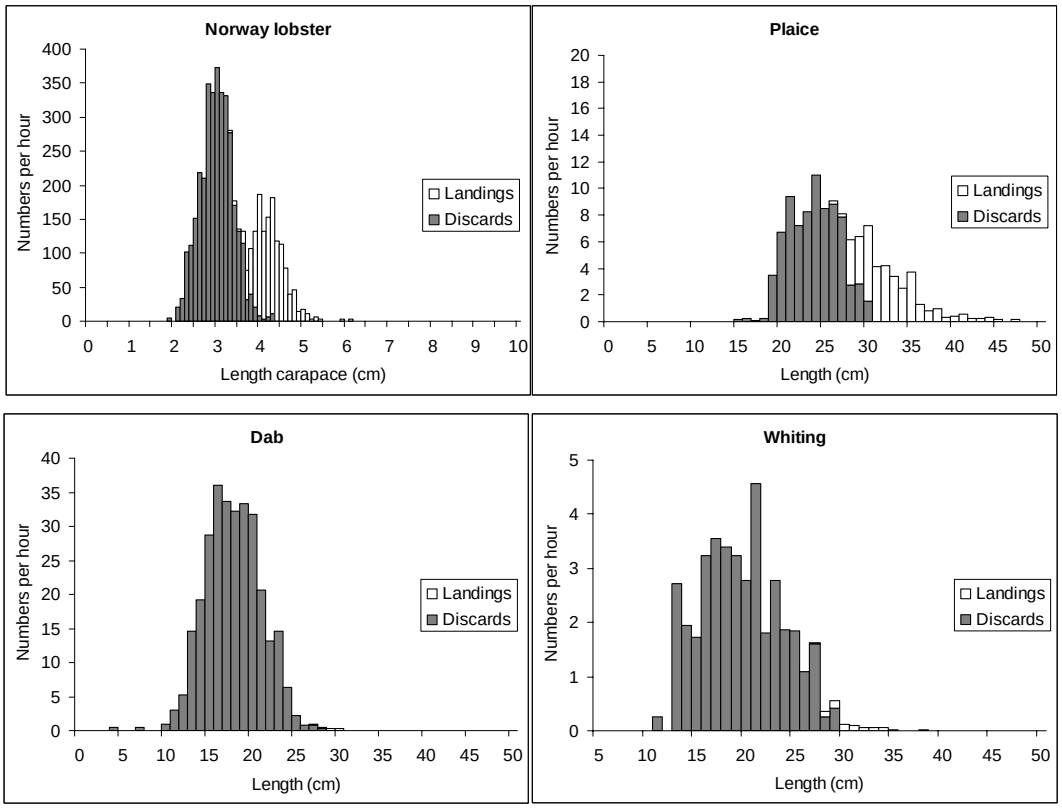

Figure 3.3.1a. Length frequency distribution of *Nephrops*, plaice, dab and whiting in 2007, caught with twinrig trawl vessels fishing with 80 mm cod-end mesh size. Grey bars show discards, white bars show landings.

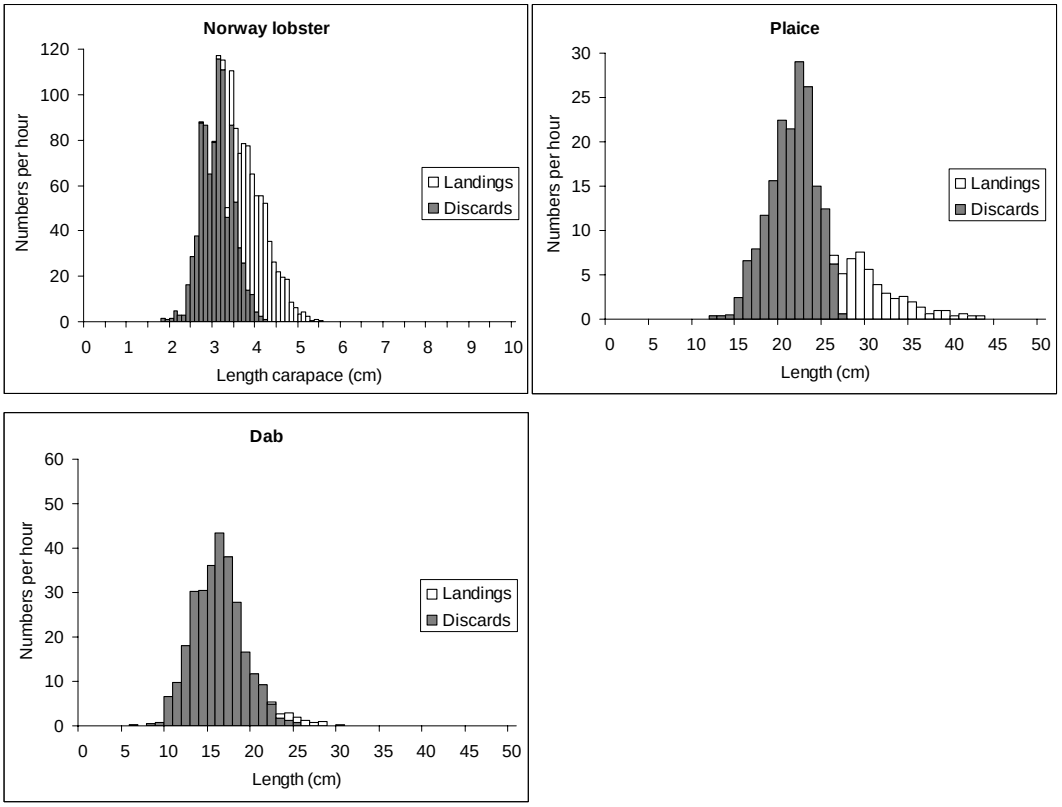

Figure 3.3.1b. Length frequency distribution of *Nephrops*, plaice and dab in 2008, caught with twinrig trawl vessels fishing with 80 mm cod-end mesh size. Grey bars show discards, white bars show landings.