Discards in fisheries – a summary of three decades of research at IMARES and LEI

Christine Röckmann, Floor Quirijns, Harriet van Overzee and Sebastian Uhlmann

Report number C068/11

IMARES Wageningen UR

(IMARES - Institute for Marine Resources and Ecosystem Studies)

Client:	Ministry of EL&I Directie AKV Postbus 20401 2500 EK Den Haag
	Bascode: BO-12.04-001-013
Publicatiedatum:	8 June 2011

IMARES WAGENINGEN UR

IMARES is:

- an independent, objective and authoritative institute that provides knowledge necessary for an integrated sustainable protection, exploitation and spatial use of the sea and coastal zones;
- an institute that provides knowledge necessary for an integrated sustainable protection, exploitation and spatial use of the sea and coastal zones;
- a key, proactive player in national and international marine networks (including ICES and EFARO).

This research is performed within "beleidsondersteunend Onderzoek "(BO)

P.O. Box 68	P.O. Box 77	P.O. Box 57	P.O. Box 167
1970 AB IJmuiden	4400 AB Yerseke	1780 AB Den Helder	1790 AD Den Burg Texel
Phone: +31 (0)317 48 09 00	Phone: +31 (0)317 48 09 00	Phone: +31 (0)317 48 09 00	Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 26	Fax: +31 (0)317 48 73 59	Fax: +31 (0)223 63 06 87	Fax: +31 (0)317 48 73 62
E-Mail: imares@wur.nl	E-Mail: imares@wur.nl	E-Mail: imares@wur.nl	E-Mail: imares@wur.nl
www.imares.wur.nl	www.imares.wur.nl	www.imares.wur.nl	www.imares.wur.nl

Contents

Summary

Discards and the possible ecological and economic effects of discarding are a hot topic in discussions about sustainable fisheries. The perception of the effects of discarding differs between parties and it is influenced by the ecosystem functioning and the state of the species under consideration. This report provides an overview of the current scientific knowledge at IMARES and LEI about discard levels, effects, and discard reduction from an ecological, technical, economic and management perspective. The following Dutch commercial marine wild capture fisheries with active gear are considered: pelagic, beam trawl, otter trawl (demersal fish and nephrops) and shrimp fisheries.

Monitoring programmes such as observer schemes or self-sampling are used to estimate the magnitude of discarding. Discard percentages depend on a variety of factors, such as the abundance of the species (age structure, year class strength), the type of fishery (gear and mesh size), vessel, fishing area, season and time of the day. Published discard percentages are based on estimated averages; very often these estimates are uncertain due to low sampling coverage. In general, targeted single species fisheries generate few discards but can cause incidental bycatch of megafauna. Under the EU's species-specific total allowable catch system, multispecies fisheries can lead to overquota bycatch.

The ecological effects of discarding can be both favourable and unfavourable for the ecosystem:

- Organisms that are caught and discarded have a high likelihood of being injured or dead. If the abundance of discarded species is high, this might have no noticeable effect on the ecosystem. However, if species are discarded that are not as abundant, this might influence species diversity and predator-prey interactions.
- Discards provide food for benthic carnivores, demersal fish and seabirds. There is no proof that seals also feed on discards, but seals may hunt species that feed on discards and thus indirectly benefit from discards. The same applies to harbour porpoises.

From an economic point of view, one can distinguish between incentives for or against discarding. Incentives for discarding can be created by law and by the market, e.g.:

- Regulation: Undersized fish is not allowed on board, hence fishers are obliged to throw undersized fish over board, if it is caught. Overquota fish is not allowed on board either. Fishers are to stop fishing a particular species once its quota is fully taken. The nature of mixed fisheries, however, is to target different species at the same time, i.e., they do not catch their target species selectively. The single species TACs can thus result in discarding overquota species in mixed fisheries. This type of discarding overquota fish can be difficult to distinguish from high-grading, which is prohibited by law in the North Sea and Skagerrak.
- Market: In the absence of a market for a caught species (e.g. due to size or species type), fishers rather discard the species instead of land it without earning money from it.

Incentives against discarding arise through the costs of discarding (e.g. forgone income) and through ethical values.

Options for discard reduction include fishing closures, catch limits, mesh size and gear modifications, modification of catch processing, and economic measures:

- Long term fishing closures: The two major examples in the North Sea (Cod Box and Plaice Box) have not proven to have effectively reduced discarding of undersized target species. However, it is impossible to state whether discard levels would have been higher or lower without the establishment of the Cod Box and/or Plaice Box because comparisons cannot be made.
- Temporary fishing closures: the effectiveness of this measure has not been proven yet in the North Sea. During the winter 2010/2011 areas have been temporarily closed in order to protect cod. The effect of these temporary closures is not yet known, and their effectiveness is difficult to measure.

- Adjusting quotas to mixed fisheries, taking into account that in a mixed fishery it might be difficult or even impossible to avoid certain species: In the mixed sole and plaice fishery for example, the ratio between the sole and plaice quota influences the choice of fishing area. If the ratio forces fishers to go to areas with high abundances of undersized plaice, the amount of discards will increase. Within the sole and plaice fishery there are differences in targeting behaviour: not all fishers catch sole and plaice in the same ratio.
- Changing minimum landing size and minimum mesh size: Catches will remain unaffected, if only the minimum landing size (MLS) of species is changed. In order to affect catches, it is necessary to also adjust the minimum mesh size at the same time as changing the MLS. Reducing MLS alone should lead to smaller grades being landed. In this case, a market for the small grades needs to be created as well, otherwise reducing MLS will not have any positive effect. It needs to be investigated whether a market exists for the small grades. Research has shown that increasing the minimum mesh size to 90mm does not significantly reduce catch of undersized plaice in the 80mm sole fisheries.
- Gear modifications: The effects of gear modifications on discard reduction strongly depend on the type of fishery, gear used, target species and discard species. To make separation by technical means feasible, there needs to be a difference in either size and shape, distribution, or behaviour of the target and discard species. If a modification is effective, it needs to be practical in use and not lead to a loss of marketable target species. Otherwise there won't be incentives for fishers to use the modified gear.
- Operational (pre- and post-capture) modifications can be considered to improve survival of discards. IMARES and LEI have not carried out a lot of research related to this subject.
- (Socio-) economic solutions: Fishers need a positive incentive to implement modifications in fishing behaviour or gear that are expected to result in discard reduction. Incentives are, for example, additional revenue, quota or days at sea, additional rights for fishers who adjust their behaviour or gear so that they have an advantage compared to their peers.

It is important to realise that any management measure may incur changes in behaviour sometimes having unwanted or unexpected effects.

In the future, IMARES and LEI will carry out more work on discards. The work focus will depend on future developments in EU policy and the outcome of the discussions on the subject between different stakeholders.

1. Introduction

In fisheries, sometimes parts of the catch that are of no or little commercial interest, are thrown back into the sea. This is referred to as discarding. Discards are a hot topic in discussions about sustainable fisheries, in particular if it is assumed that discards do not survive or at least do not sustain the catch-and-release process unharmed. The possible effects of discarding raise concerns among scientists, managers, stakeholders, and resource users both overseas (e.g. Harrington et al. 2005), and in Europe (e.g. Catchpole et al. 2005). The European Commission (EC) of the European Union (EU) aims for a reduction of discards and considers the introduction of a discard ban (EC 2007, 2011). A discard ban as defined by the EC entails that no fish - be it above or below the minimum landing size – can be thrown overboard. Discard bans have already been implemented outside the EU, for example in Norway and Iceland. According to current EU legislation, it is prohibited to land fish that is smaller than the minimum landing size, and hence, it has to be discarded. Additionally, it is not prohibited to discard fish that is above the minimum landing size in European waters (EC 2009). The benefits and costs related to the implementation of a discard ban are the topic of a related research project (KBA discard-ban, project number: 2272000100 (Buisman et al. forthcoming)).

The perception of the effects of discarding differs between parties, and it is influenced by the ecosystem functioning and the state of the species under consideration. Under an ecosystem approach to fisheries management, the effects of reducing discards may benefit those species that are being discarded, but may harm species that feed on discards (Zhou 2008). While some say discarding is a waste of resources, others emphasize the positive influence on food availability for seabirds and other marine predators.

The quality of discard discussions in the Netherlands could be improved by establishing an unbiased source of information, sharing facts, figures and references on discarding with all relevant parties. This report provides an overview of the current scientific knowledge at IMARES and LEI (both part of Wageningen University and Research Centre) about discards and discard reduction from an ecological, technical, and economic perspective and presents some options for management action. Where possible, conclusions from research related to discards over the past three decades is summarized. The focus of the report is on research carried out in the Netherlands by IMARES and LEI, in collaboration with the Dutch fishing industry. With regard to discards and discarding in Dutch fisheries, this reports deals with the following commercial marine wild capture fisheries with active gear: pelagic, beam trawl, otter trawl (demersal fish and nephrops), and shrimp fisheries. Furthermore, this report focuses on fish discards; discards of benthos are mentioned where relevant. Since IMARES and LEI have not always had the opportunity to deal thoroughly with all the issues relevant for a discard discussion and synthesis, it was indispensable at some points to also refer to information derived from international research not carried out by IMARES or LEI. The report does not aim to give positive or negative judgments on the possible effects of discarding.

This work was carried out within "Beleidsondersteunend onderzoek" funded by the Ministry of Economic Affairs, Agriculture and Innovation (EL&I). It is co-financed by the Dutch Fish Product Board.

2. Review approach and structure of the report

During a workshop with scientific staff who have been and/or are involved in discard projects, an inventory was made of all projects related to discards and carried out by IMARES and LEI. The following information was gathered and assembled in an overview table: Project name; description; starting and ending year; contractor; principle institution; principle staff; external outreach; fishing gear; mesh size (mm); target species; output/ references; main conclusions. A summary of this table including project name, description and output/references is presented in Appendix A. Based on this inventory list, we identified and consulted the relevant project reports and scientific publications in order to summarize the exhaustive knowledge base on discards at IMARES and LEI. Where possible, conclusions were formulated. Where appropriate, additional information was gained from the international literature.

This report is structured in seven chapters. The first two provide an introduction and overview of how the work was carried out. Chapter 3 gives our applied definition of discards. Chapter 4 provides an overview of discard monitoring activities and results. Chapter 5 deals with the effects of discarding from an ecological and economic point of view. Chapter 6 presents measures to reduce discards. Chapter 7 finalises the report with a discussion.

3. Definitions

There are a number of different definitions regarding discards which are not all mutually consistent. In this report the following definition for discards is used:

Discards, or discarded catch, is that portion of the total organic material of animal origin in the catch, which is thrown away at sea. It does not include plant materials and post-harvest waste such as offal. Discards may be dead or alive (Kelleher 2005).

Organisms can be discarded for different reasons:

- specimen of commercial species that dot no comply with the minimum landing size;
- surplus quota: fish not allowed to be landed because it would result in exceeding legal quota;
- catches of species of no commercial value, including benthos;
- commercially-valuable species with an undesired quality (low value) in order to fill the quota with higher quality specimen; this kind of discarding is commonly referred to as high-grading[1].

In this report we use the term “discards” according to Kelleher’s (2005) definition (see text in *italics* above). We only use the term bycatch when referring to incidental catches of megafauna. Megafauna refers to bycatch such as sea mammals, sharks, sea turtles, sunfish, swordfish, and birds.

[1] In 2009 a high-grading ban was implemented by the EU in the North Sea and Skagerrak (EC 2009).

4. Monitoring to assess the quantity of discarding

Monitoring programmes are used to estimate the quantity of discarding. As it is often not feasible within such monitoring programmes to cover all fishing activities, there is a level of uncertainty in the discard estimates. This uncertainty may result in an over- or underestimation of the amount of discards.

4.1. Discard monitoring programmes in Dutch fisheries

From 2002 onwards, the Netherlands have monitored discarding under the EC Data Collection Regulations (DCR) (EC 2000; 2001; 2008). Annually, a number of observer trips are made on board commercial vessels within different fisheries (Table 4.1). The collected data are used to estimate discard rates in those fisheries. Discard estimates are raised in different ways for different métiers (e.g. by trip for pelagic trawlers or by horsepower-effort (HP-effort) for beam trawlers). In the following tables (4.1 – 4.8), we have indicated the respective reference level in the table headers. It is important to realise that, due to a low sampling coverage, discard estimates of the less abundant species are considered to be highly uncertain.

Table 4.1: Number of sampled trips on board commercial vessels of different types of fisheries (characterised by horse power or target species and mesh sizes) under the Data Collection Framework from 2002 to 2010 and under the self-sampling programme (in brackets, 2009 and 2010) (Appendix A: P3, P4).

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Pelagic fishery	4	5	6	12	12	12	12	11	9
Beam trawl fishery[2]									
- > 221 kW, 80 mm mesh	6	9	8	8	9	10	10	8 (40)	8 (65)
- > 221 kW, 100+ mm mesh		1	1	1				(10)	(12)
- < 221 kW, 80 mm mesh			1					(4)	(22)
Otter trawl fishery									
- Demersal fish, 80 mm mesh					1			1 (2)	(11)
- Demersal fish, 100 mm								(4)	(9)
- Demersal fish, >120 mm								1	
- Nephrops						3	3	1 (6)	2 (13)
Shrimp fishery							3	5	7

[2] For the beam trawl fishery there are also data available on discards for 1976-1983 and 1989-1990 from Beek (1998) and for 1991-2001 from the Netherlands Institute for Fisheries Research (unpublished data).

Details on the self-sampling programme are presented in evaluation reports (Helmond et al. 2010c; Helmond et al. 2011). Results from the discard observer programmes in the Netherlands are presented in the next section.

From 2009 onwards, a new DCR (2008/949/EG) obligates member states of the European Union to increase the sampling effort of their discard monitoring programmes in order to achieve a sampling coverage of 90% of their métiers (EC 2008). Apart from discard observer programmes, alternative monitoring activities are self-sampling and fully documented fisheries by means of cameras on board fishing vessels. Constrained by high costs and lack of trained observers, the Netherlands chose to expand the existing monitoring programme with a self-sampling project in cooperation with the Dutch fishing industry. The self-sampling programme increases the sampling coverage. Self-sampling is carried out on an *ad-hoc* basis by a fixed group of fishers. They use IMARES protocols when they sample several hauls during a fishing trip and data are analysed by either IMARES or another party (Appendix A: P11). Mostly, the data from this kind of sampling are not publicly available. For fully documented fisheries, trials have started in 2010. The first results from these trials are expected in the course of 2011. The discard observer programme (cf. Table 4.1) remains important to validate the discard estimates of this new sampling method. Under the self-sampling programme, 69 and 133 trips were sampled from 5 different métiers in 2009 and 2010, respectively.

4.2. Results from discard observer programmes in the Netherlands

Beam trawl fishery (Appendix A: P3, P5, P13)

The Dutch beam trawl fishery is one of the main fisheries in the southern North Sea. The majority of the observer trips were conducted onboard beam trawl vessels with an engine power > 221 kW and a mesh size of 80 mm (Table 4.1). The sampling coverage for this fleet segment for the period 2002-2008 varied between 0.1%-0.3% of the entire fleet (Table 4.2). For these sampled vessels the average catch composition (in weight) for the period 2003-2008 consisted of 17%-42% landings, 21%-28% fish discards and 37%-60% discarded benthos and debris[3] (Figure 4.1). Dab was the most abundant species in the fish discards. The average discard percentage (i.e., the amount discarded of the total catch of each species) in the period 2002-2008 was estimated in weight at 46%-57% for plaice and at 6%-17% for sole (Tables 4.3, 4.4). The discard percentages for plaice are higher than those observed during 1976-1990, while the discard percentages for sole coincide with those observed during 1976-1990 (Tables 4.3, 4.4).

---

[3] It is not possible to determine the discard percentage of only benthos because benthos and debris are estimated together.

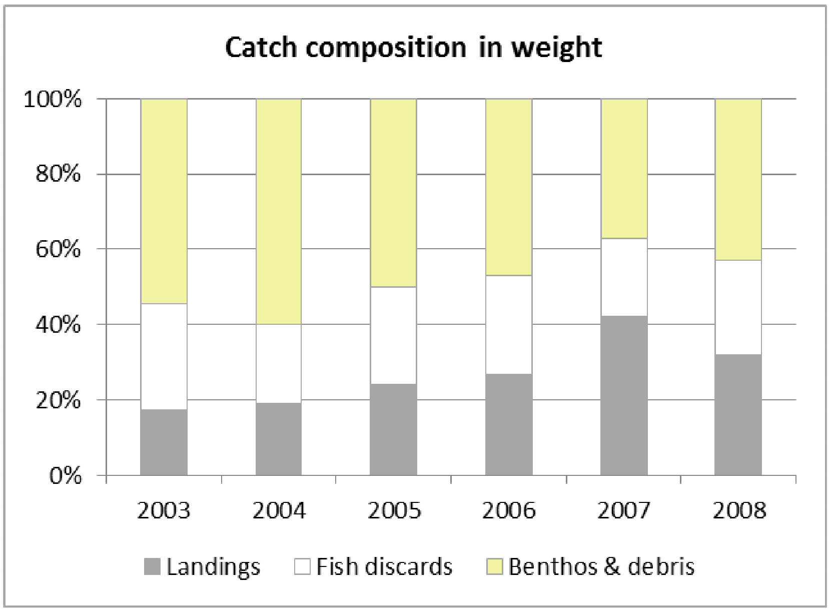

Figure 4.1. Average composition of the catch in weight for the sampled beam trawl vessels (engine power > 221 kW, 80 mm mesh) per year.

Table 4.2. Fleet coverage in horsepower (HP) effort (days at sea corrected for engine power) for the sampled beam trawl vessels (engine power > 221 kW/ > 296 hp, 80 mm mesh)

Year	Nr sampled trips	Fleet coverage in HPeff
2002	6	0.08%
2003	9	0.09%
2004	8	0.09%
2005	8	0.15%
2006	9	0.24%
2007	10	0.23%
2008	10	0.30%

Table 4.3. *Sole.* Average landings (L), discards (D) and percentage discards (%D) per hour, trip and per period in numbers (left) and weight (right, in kg) for sampled beam trawl vessels (engine power > 221 kW, 80 mm mesh). Results over 1976-1983 and 1989-1990 from Beek (1998), 1999-2001 from Netherlands Institute for Fisheries Research unpublished data, 2002-2008 collected under the EC Data Collection Regulations (DCR) (Helmond and Overzee 2010a, Appendix A: P5)

		Numbers			**Weight**		
Year/Period	**Nr trips**	**L**	**D**	**%D**	**L**	**D**	**%D**
1976-1979	21	116	8	6%	32	1	4%
1980-1983	24	85	24	22%	19	3	15%
1989-1990	6	286	83	22%	48	12	20%
1999	3	112	16	13%	32	2	5%
2000	12	90	25	22%	22	2	10%
2001	4	82	17	17%	17	1	6%
2002	6	126	38	23%	18	3	13%
2003	9	95	32	25%	20	3	14%
2004	8	175	69	28%	31	7	17%
2005	8	99	29	23%	20	2	11%
2006	9	64	26	29%	16	2	13%
2007	10	94	27	23%	22	2	10%
2008	10	95	16	16%	23	1	6%

Table 4.4. *Plaice.* Average landings (L), discards (D) and percentage discards (%D) per hour and per period in numbers (left) and weight (right) for sampled beam trawl vessels (engine power > 221 kW, 80 mm mesh). Results over 1976-1983 and 1989-1990 from Beek (1998), 1999-2001 from Netherlands institute for Fisheries Research unpublished data, 2002-2008 collected under the EC Data Collection Regulations (DCR) (Helmond and Overzee 2010a, Appendix A: P5)

		Numbers			**Weight**		
Year/Period	**Nr trips**	**L**	**D**	**%D**	**L**	**D**	**%D**
1976-1979	21	253	185	42%	108	28	20%
1980-1983	24	309	418	57%	99	51	34%
1989-1990	6	392	330	46%	104	46	30%
1999	3	145	181	55%	42	18	29%
2000	12	194	601	76%	50	47	48%
2001	4	364	1184	76%	84	89	51%
2002	6	263	868	77%	69	71	51%
2003	9	196	945	83%	52	70	57%
2004	8	158	792	83%	42	57	57%
2005	8	143	710	83%	47	51	52%
2006	9	166	997	86%	57	67	54%
2007	10	214	700	77%	67	57	46%
2008	10	169	902	84%	61	69	53%

Otter trawl fishery (Appendix A: P1, P2)

Over the sampling period 2007-2008 six vessels fishing for nephrops (*Nephrops norvegicus,* Norway lobster) were sampled. The sampling coverage for this fleet segment was 0.7% in 2007 and 0.6% in 2008 (in HP effort - days at sea corrected for engine power). During these trips Norway lobster was the most abundant species that was observed in the discards (including benthos). In the sampled trips more than 90% of the discarded Norway lobster were above the minimum landing size of 25 mm carapace. The average discard percentage of Norway lobster observed during the sampled trips in 2007-2008 was estimated in weight at 45%-53% (Table 4.5). Dab was the most abundant fish species in the discards. The average discard percentage (i.e. the amount discarded of the total catch of each species) based on all trips sampled in the period 2007-2008 in weight was estimated at 97%-99% for dab and at 26%-53% for plaice (Table 4.5).

Table 4.5. Average landings (L), discards (D) and percentage discards (%D) per hour and per period in numbers (left) and weight (right) for sampled otter trawl vessels targeting nephrops (Nephrops norvegicus, Norway lobster; 80mm mesh size)). Results collected under the EC Data Collection Regulations (DCR) (Helmond and Overzee 2009a, Appendix A: P2).

		Species	**Numbers**			**Weight**		
Year/Period	**Nr trips**		**L**	**D**	**%D**	**L**	**D**	**%D**
2007	3	Nephrops	1335	3394	72%	34	39	53%
2008	3	Nephrops	583	919	61%	24	20	45%
2007	3	Dab	2	298	99%	1	34	96%
2008	3	Dab	8	288	97%	1	18	95%
2007	3	Plaice	37	79	68%	25	9	26%
2008	3	Plaice	45	179	80%	8	10	53%

Shrimp fishery (Appendix A: P4)

Over the sampling period 2008-2010, catches (landings as well as discards) of shrimp varied enormously between hauls (Figure 4.2, Table 4.6). The discard sampling coverage for this fleet segment was estimated at 0.3% (in days at sea). Overall, the catch (in weight) consisted of 38% shrimp landings. The remaining catch was discarded, consisting of 38% shrimp discards (below the minimum landing size), 3% flatfish, 6% roundfish, 14% epibenthos and 1% others (Tulp 2009; Tulp et al. 2010, Appendix A: P4). Most flatfish catches occurred during spring and summer while roundfish was caught throughout the year (Tulp 2009; Tulp et al. 2010).

Table 4.6. Minimum and maximum catch percentages in the shrimp fishery, averaged over the sampling period 2008-2010 (Tulp 2009; Tulp et al. 2010, Appendix A: P4).

	Shrimp discards	**Shrimp landings**	**Flatfish**	**Roundfish**	**Epibenthos**	**Others**
Minimum	30.1	7.4	0.0	0.0	0.0	0.0
Maximum	92.5	64.3	14.5	9.5	4.8	3.4

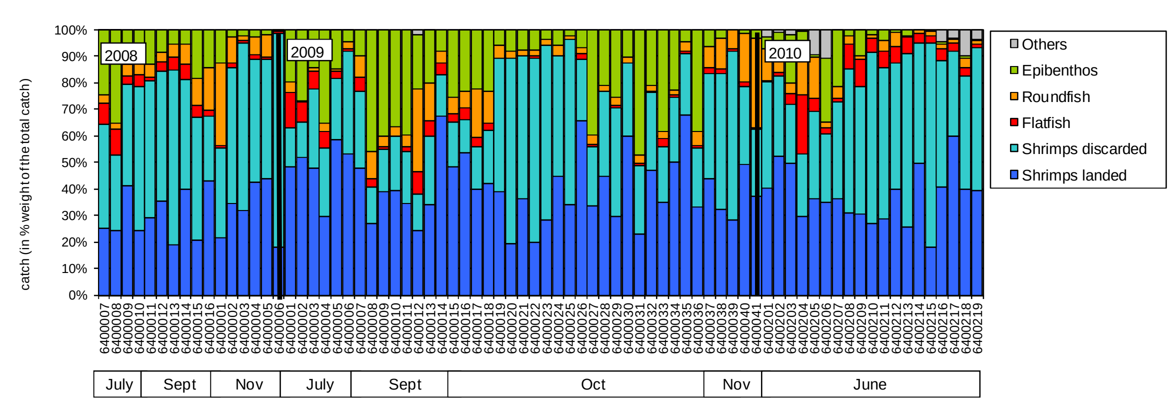

Figure 4.2. Catch composition (in % weight) of shrimp vessels per sampled haul. The numbers on the x-axis represent the haul numbers (modified after Tulp et al. 2010).

Pelagic freezer fishery (Appendix A: P3)

Apart from the routinely sorted discards, part of or the entire catch can be discarded before the catch has been sorted (i.e. released from the tank or from the net). This type of discarding - specific to pelagic fisheries – cannot be sampled due to practical reasons. Therefore, discard estimates per species are only based on the sorted catch and are thus underestimates.

Mackerel shows the highest discard rate (between 16% and 37% in weight in the period 2003-2009). For the other target species, namely herring, horse mackerel and blue whiting, the discard estimates within the fishing season vary between 1%-6% (in weight) (Helmond and Overzee 2009b; 2010b).

For the Dutch fleet of freezer trawlers fishing in the North East Atlantic, discard estimates obtained during the observer trips are raised to fleet level by number of trips (Table 4.8). The highest discard percentage (in weight) was observed in 2003: 17% (Table 4.8). This was at the beginning of the sampling programme when sampling coverage was low (Table 4.9). In the following years (2004-2009) the estimated discard percentage (in weight) for the pelagic freezer fleet was estimated between 6%-8% (Table 4.8).

Table 4.8. Total catch, landings, discards (tonnes) and discard percentage raised to the entire Dutch pelagic fleet per year (Helmond and Overzee 2009b; 2010b, Appendix A: P3)

	Weight			
Year	**Catch**	**Landings**	**Discards**	**%D**
2003	306252	255556	50696	17%
2004	332963	313916	19047	6%
2005	381590	352446	29144	8%
2006	300908	278534	22374	7%
2007	292306	271600	20706	7%
2008	241967	223172	18795	8%
2009	188763	174442	14321	8%

Table 4.9 Fleet coverage in number of trips for the sampled pelagic trips (in all areas of the Dutch discard sampling programme)

Year	Number of trips sampled	Fleet coverage in number of trips
2003	5	3.8%
2004	6	4.6%
2005	12	8.5%
2006	12	9.8%
2007	12	9.8%
2008	12	10.9%
2009	11	11.8%

Bycatch in the pelagic freezer fishery (Appendix A: P6-P9)

The monitoring of incidental bycatch in the pelagic freezer fishery is integrated with the collection of discard data. Generally, incidental bycatch consists of megafauna, such as sea mammals, sharks, sea turtles, sunfish, swordfish, and birds. A legal obligation is in force to monitor incidental bycatch of cetaceans caught incidentally in pelagic fisheries (EC 2004). There is no legal obligation to monitor seabirds and other incidental bycatch. Nonetheless, observers are instructed to record incidental bycatch of protected species. The absolute number of bycatch is so low, that it proves difficult to implement this monitoring in the protocol as a routine. The manual is currently being updated by IMARES, in order to improve recording of incidental bycatches.

Incidental catches of cetaceans on board Dutch pelagic freezer trawlers were monitored in ICES divisions VI, VII, and VIII during 98 observer days in 2004/2005 (fleet coverage is 11.8%) and 87 observer days in 2006 (fleet coverage is 12.7%); in total, 2 common dolphins and 1 white sided dolphin were observed on deck during these 185 observer days in the period 2004-2006 (ICES 2008). No incidental catch of cetaceans was observed in the period 2007-2009 during 541 observer days in fleet segments NLD003 - NLD006[4] (fleet coverage > 10%, Couperus, 2008; 2009; 2010). However, in 2007, 4 seals were caught during three incidents. It is possible that incidents of seals had occurred during the previous trips as well, but possibly they had not been reported properly due to unclear instructions (Couperus 2008).

4.3. Results of others monitoring projects (Appendix A: P9, P10)

Since 1996, the Dutch pelagic freezer fleet exploits small pelagic fish stocks in the waters off Mauritania. The seasonal and annual catches of this fishery were investigated (16% of all fishing trips were covered) between 1999-2003 (Appendix A: P10). The percentage of discards was less than 10% of the total catch (by weight) and consisted mainly of commercial fish. The reason for this was that when catches were high, the processing focussed on the abundant commercial species in the hauls, and commercial fish of less abundance were discarded (Hofstede and Dickey-Collas 2006). In addition, all registered catches of

---

4 Observer coverage of fleet segments NLD003 - NLD006 was in ICES areas VI, VII and VIII in the period 1 December – 31 March in 2007-2009. Additionally, observer coverage of fleet segments NLD004 and NLD006 was year round in European waters.

pelagic megafauna caught by the Dutch pelagic fleet in Mauritania during 12 trips in the period 1999-2003 are presented in Hofstede et al.(2004) and Zeeberg et al. (2006). During these 12 trips, there were considerable bycatches of ocean sunfish, swordfish/marlins, hammerhead sharks, other sharks, dolphins, and sea turtles, and they were highest during the summer (Zeeberg et al. 2006). Since 2006, the Dutch pelagic freezer fleet is also active in the waters off Chile. Data on catch composition in this fishery has not been available for the present report; anecdotal information from a bilateral meeting between the Netherlands and Germany suggests that discarding is low (Frans van Beek, pers. comm.).

5. Effects of discarding

This chapter describes the effects of discarding, both from an ecological and economic point of view.

5.1. Ecological effects of discarding

Discarding can impact ecosystem dynamics directly and indirectly, and it can cause increases or decreases in population sizes of different species. A direct effect of discarding is injury and/or death of the discarded specimen. This may lead to a reduction in species diversity and changes in predator–prey interactions (Kaiser and de Groot 2000; Callaway et al. 2002; Stobutzki et al. 2003). Discarding can indirectly affect population dynamics of species that prey on discards and species that are predated by discard scavengers (Tasker et al. 2000). A reduction in discards could, for example, change the abundance of scavenging sea birds (Camphuysen and Garthe 2000; Garthe et al. 1996), or could lead to increased predation on other seabirds by the scavenging species (Stenhouse and Montevecchi 1999; Votier et al. 2004). In the southern North Sea, it is estimated that discards contribute 1–10% of the annual food demand for benthic carnivores and demersal fish (Catchpole et al. 2005).

Survival of discards (Appendix A: P39)

Generally, it is assumed that the majority of discarded animals do not survive (Broadhurst et al. 2006; Chopin et al. 1996). Reviews of studies that have tested this assumption acknowledge that discard mortality is determined by a range of biological, technical, or environmental factors or 'stressors' (Broadhurst et al. 2006; Davis 2002). Biological factors relate to e.g. the species, physiology, size, catch weight/ volume, composition; technical stressors relate to e.g. gear design, deployment duration, fishing speed; environmental stressors relate to e.g. temperature, hypoxia, depth, wind force, availability of sunlight.

For the beam trawl fishery, discard mortality is influenced by the duration the organisms are confined in the codend and their concurrent injuries (Beek et al. 1990; Broadhurst et al. 2006). If the fish were brought on board alive, then the processing of the catch on board would also matter. However, Beek et al. (1990) found that processing on board hardly affects the survival of the discards because approximately 70% of the catch is dead upon boarding. Based on experimental studies on board of commercial vessels, it was estimated that less than 10% of the plaice and sole discards in the beam trawl fisheries survive the process of discarding (Bult and Schelvis-Smit 2007; Beek et al. 1990). These are lower than survival rates of beam-trawled sole (approx. 40% survival), monitored in more recent trials in Belgium (Depestele et al. 2009). The experiments differed in setup and thus cannot be compared quantitatively. In the experiments of Depestele et al. (2009), fish were caught from small-sized chain-mat gears (4 m) and from shorter trawls (1.5 h) compared to the configurations of the monitored operations on commercial vessels by Beek et al. (1990).

For the nephrops (*Nephrops norvegicus,* Norway lobster) fishery, immediate mortality assessments of five species of fish discards and one crustacean (Norway lobster) were made during three trawls on a research vessel in the Farne Deep (North Sea) (Evans et al. 1994). All, but hagfish, died within 15 minutes after being brought on board. An experimental study of delayed mortalities of discards up to 60 hours after trawling estimated less than 10% survival for plaice (Keeken et al. 2004). A more recent study indicated that survival rate of Norway lobster 15 days after capture was less than 30% for long (5 hours) trawls (Ridgway et al. 2006). Specific survival experiments with Norway lobster in the Dutch otter trawl fishery have so far not been carried out (Helmond and Overzee 2009a).

In 2008, a pilot study on discard survival in the shrimp fishery was carried out (Quirijns et al. 2010). This study investigated the effect of the sorting process on survival of plaice and dab. Up to 70 hours after discarding, there was added mortality due to the sorting process of about 44% for plaice and 14% for dab.

Discards as food for seals and harbour porpoises

There is no clear indication that discards serve as food for seals. The diet of seals is very diverse, depending on location and season (Brasseur et al. 2004a). Seals appear to feed primarily on living individuals. This can be concluded from stomach and faeces analyses, indicating the species combination preyed upon and an absence of marine litter in the examined stomachs and faeces. Additionally, no clear spatial nor temporal overlap was found between the distribution of fishing vessels and the distribution of radio-tagged seals (Brasseur et al. 2004a). Nevertheless, seals might still be attracted by fishing vessels and benefit from discards rather indirectly than directly. For example, seals may hunt species that primarily feed on discards. The fact that no overlap was found between seal and fishery distribution does not exclude possible interactions between seals and fisheries. Since 2004, more accurate tracking devices have been applied to seals, and methods have been developed to analyse the collected data (Aarts et al. 2008). Further analysis of these data in a spatial context and in relation to information on discards in the future should enable IMARES to conclude whether there is a relationship between seals and discards or not.

The situation concerning harbour porpoises is comparable to that of seals. Neither stomach nor faeces analyses indicate that harbour porpoises prey on discards. Nonetheless, a possible interaction cannot be excluded either (Brasseur et al. 2004b).

Discards as food for birds (Appendix A: P17-P19)

Seabirds are opportunistic predators and can vary and adapt their diet according to availability. Various species of seabirds benefit from discards[5] as a source of nutrients and energy. Catchpole et al. (2005) state that "discards are considered responsible for the growth of several seabird populations in the North Sea including the Northern Fulmar (*Fulmarus glacialis*), Herring Gull (*Larus argentatus*) and Lesser Black-backed Gulll (*Larus fuscus*) […]. Scavenging seabirds utilise around 70–92% of roundfish, 20–35% of flatfish and 3–17% of invertebrate discards […]." It is estimated that over the entire North Sea, discards could potentially support about 5.9 million seabirds (Garthe et al. 1996). This figure represents an absolute maximum (assuming that 100% of the discards is taken by seabirds) and is undoubtedly an overestimate, because consumption rates of discards (measured during discard experiments at research vessels) are always less than 100%. In these experiments, items are discarded one by one and their fate

---

[5] Bird ecologists do not generally use the strict definition of discards that we apply in this report. They often do not differentiate between discards and offal, the latter referring to parts of fish, such as the left-overs from processing the catch. However, it is not always possible to distinguish between the two. It is impossible to distinguish between discards and offal in e.g. pellets and stomach contents, which will therefore be underestimated. In feeding experiments, discards and offal can be and have been treated separately. Bird ecologists do have knowledge about species preferences when it comes to discards versus offal. In this paragraph we use the terminology of the ornithologists.

recorded. However, this does not reflect normal practise at commercial trawlers, where various items are discarded at once and consumption rates are lower (Garthe and Hüppop 1998). Stratoudakis (1999) argues that due to this and other sources of variance, the number of seabirds supported by fishery discards is more likely to be in the order of 3 million birds.

The question whether discards are of nutritional importance to sea birds is one of energy balance. This specific subject was not studied by IMARES and LEI but it is relevant to the discussion. How much energy does it cost to search for and eat the food, and how much energy is gained by eating it? Energy requirements vary by season. Currently, a general understanding is that discards form an important contribution to the diet and condition of scavenging birds in winter (Hüppop and Wurm 2000), when more energy is needed than in summer. However, when it comes to breeding and feeding the young, it has been hypothesized that the nutritional value of discards is insufficient for successful offspring development (Grémillet et al. 2008). Studies supporting this "junk-food hypothesis" (Whitfield 2008) show that non-breeding birds can survive when complementing their diet with fishery wastes, but that they struggle to reproduce if nutrient-rich prey is scarce (Grémillet et al. 2008).

Eight species of seabirds were found to use fishery waste on a large scale, at least during a part of the year (Camphuysen et al. 1995): Northern Fulmar (*Fulmarus glacialis*), Northern Gannet (*Morus bassanus*), Great skua (*Stercorarius* skua), Common Gull (*Larus canus*), Lesser Black-backed Gull (*Larus fuscus*), Herring Gull (*Larus argentatus*), Great Black-backed Gull (*Larus mariunus*) and Black-legged Kittiwake (*Rissa tridactyla*). During the study by Camphuysen et al. (1995), the highest numbers of scavenging seabirds were observed in association with otter trawlers and stern trawlers, relatively small numbers of seabirds were seen associated with purse seiners, beam trawlers and anchor seiners. Seabirds consumed 95% of the offal (intestines of gutted marketable fish), 80% of the discarded roundfish, 20% of the discarded flatfish and 6% of the discarded benthic invertebrates (Campuysen et al. 1995). These numbers relate to discarding experiments rather than observations of regular discards, and they are therefore probably overestimates. The competition for fishery waste was higher in summer than in winter and increased from south to north.

The size of the scavenging sea birds and of the discards/offal is also important (e.g. Camphuysen et al. 1995). Larger scavenging seabirds, like Northern Gannets, Great Skuas, and Greater Black-backed Gulls tend to consume larger discards and can easily feed on whole fish. Smaller birds like Black-legged Kittiwakes select the smaller discarded fish, cut off pieces or offal. Many discards were stolen from smaller species by larger species, resulting in lower success rates for smaller birds than those for larger species. All length classes in the discards fraction of commercial fisheries in the North Sea can be consumed by seabirds; limiting factors are the width of the discarded fish and the size of the bird's mouth opening. Between 2.5 and 3.5 million seabirds are potentially supported by fishery waste in the North Sea. The spatial distribution of Northern Fulmar (Camphuysen and Garthe 1997), Great Black-backed Gull and Lesser Black-backed Gull (Camphuysen et al. 1995) seems to be largely explained by the presence or absence of commercial fishing vessels.

Three of the eight discard-scavenging seabirds are on the list of birds requiring protection under the Birds Directive (EC 1979) and in the framework of Natura 2000 areas in the Dutch EEZ: the Great Skua, the Lesser Black-backed Gull, and the Greater Black-backed Gull (Bemmelen 2010). If these species heavily rely on discards as a food source, a discard reduction policy could cause these bird populations to decrease in abundance due to decreasing food availability. This could be in contradiction to the specific Natura 2000 conservation objectives for these species.

5.2. Economic effects of discarding (Appendix A: P21-P23)

The Common Fisheries Policy of the European Union together with its related regulations creates unwanted side-effects, which can be considered as 'incentives for discarding'. The regulations indirectly lead to discarding by making it the most economically viable approach, or legally impossible not to discard. For example, it is forbidden to have undersized fish on board. Also, it is illegal to land marketable fish, once the total allowable catch quota has been exhausted. In addition to these regulatory incentives, there are economic incentives for discarding fish that could otherwise be landed legally:

- Catch that is currently not marketable due to the absence of a market is normally discarded. This catch could be landed if it created economic revenues.
- Price differences depending on quality, weight or length of a fish create economic incentives to discard low value fish above the minimum landing size that can be landed legally. The EU has prohibited this practice of "high-grading" since 2009 in the North Sea and Skagerrak (EC 2009).

The "economic incentive to discard" is defined as the difference between the "costs of landing" and the "costs of discarding" (Buisman et al. 2001). A species or grade of a species will be discarded whenever (the perception of) the "costs of landing" will exceed (the perception of) the "costs of discarding". The "costs of landing" include preliminary fish processing, landing levies, auction costs and transport costs to the market. The "costs of discarding" include the forgone price received on the market (i.e. only for non-marketable fish), and the labour costs of separating discards from the other fish. In the long-term, the "costs of discarding" also include the foregone future revenues because of the decrease of fish stocks (target or non-target species) and potentially resulting harmful effects on ecosystems (see section 5.1). For the individual fisher these are external (future) costs and will not have (much) impact on the individual decision to discard in the present. Buisman et al. (2001) give examples of how economic incentives for discarding (high-grading and discarding of low value grades, with the latter also including non-quota species) can be calculated. These incentives fluctuate throughout the year because they depend on prices.

In contrast to these state and market driven incentives *for* discarding, there are societal norms and values that create incentives *against* discarding. Discarding of fish, sensitive species (e.g. mammals, sharks) and benthos is often regarded as an unethical way of operating, due to animal suffering and the waste of potential food. These ethical concerns create an incentive for fishers to implement methods to avoid discarding. Indirectly, ethical concerns can trigger economic incentives again, for examples, if consumers boycott fish products originating from fisheries with high discard percentages.

Economic incentives to avoid discarding relate to the costs associated with discarding. Pascoe (1997) suggests that the economics of discarding can be classified into four categories:

- Foregone present or future income associated with discarding adult target species or juveniles, respectively (intra-fishery costs)
- costs associated with discarding juvenile species for different fisheries with mutual target species (inter-fishery costs)
- costs associated with discarding non-commercial species, and
- costs associated with measuring/estimating the levels of discards.

Foregone present or future income associated with discarding

Based on the assumption that a large portion of discarded fish do not survive (Chopin et al. 1996; van Beek et al. 1990; Broadhurst et al. 2006, Depestele et al. 2009), the act of discarding undersized fish today results in loss of potential catches in the future. Discarded undersized fish are therefore considered "forgone revenues of future catches" (Buisman et al. 2001). Buisman et al. (2001) estimate the foregone future revenues due to discarding based on discard estimates and assumptions of prices and costs of the Dutch beam trawl fishery in 1976-1990. The estimated value of annual discards in terms of foregone revenues from future catches in the Dutch beam trawl fishery was estimated at 70% of annual landings value (Buisman et al. 2001).

Costs associated with discarding

Discarding non-target species can result in costs being imposed on other fisheries (inter-fishery costs) where these species may be the main target species. This has particularly been a problem with a number of shrimp fisheries where the discards comprise juveniles of target species of other fisheries (e.g. plaice in the brown shrimp fishery; Pascoe (1997) and references herein).

For more information on costs associated with discarding, we refer to Buisman et al. (2001 and forthcoming). The potential costs and benefits of the implementation of a discard ban in the Dutch flatfish fishery are the focus of the recent report by Buisman et al. (forthcoming).

6. Options to reduce discards

Total elimination of all discards and bycatch in any one fishery is not feasible without compromising catch efficiency. Hence, complete elimination of discarding is illusionary. Approaches to reduce discarding usually comprise a combination of technical, regulatory and economic measures, including for example:

- Fishing closures
- Quota and minimum landing size limits
- Gear modifications
- Operational (pre- and post-capture) modifications
- Economic approaches and incentives.

This list is not exhaustive; it includes measures that have been studied by IMARES and LEI. In general, overall reduction of fishing pressure can be effective in discard reduction (Appendix: P24). This decreases the absolute amounts of discards and may not change discard levels per fishery. Note that it is difficult or even impossible to study the effects of single measures individually, notably because a discard reduction approach usually consists of a combination of different measures.

Options around the implementation of a discard ban are currently highly disputed in the EU (e.g. EC 2011). A discard ban can be considered a regulatory measure with economic consequences. Effectiveness and consequences, both ecological and economic, depend on how a discard ban is defined and organized. In short, the objectives of a discard ban are three-fold:

(1) to improve the selectivity of the fisheries,
(2) to decrease the capture of potential discards, and
(3) to avoid food waste.

Discard bans in Europe are legislated for some fisheries in Iceland and Norway. A discard ban does not necessarily reduce discard mortality rates, but may even increase them as discards will be dead when landed at the port (see section 5.1). Knowledge and research experience around discard bans are still limited at IMAERS. At LEI, a recent study by Buisman et al. (forthcoming) assesses the effects of introducing a discard ban in the Dutch flatfish fishery. This report deals with (1) different options for implementation of a discard ban, (2) costs and benefits for state and industry, and (3) market opportunities for discards.

Most projects carried out by IMARES and LEI deal with technical solutions like gear modifications. Some deal with economic aspects of the discard problem, such as economic incentives or costs and benefits of discarding. Only a few studies deal with the evaluation of the effects and effectiveness (ecologically and economically) of measures. Solution-based projects in the Netherlands have predominantly evolved around reducing discards of commercial demersal fish species such as European plaice (*Pleuronectes platessa*), Atlantic cod (*Gadus morhua*), pelagic fish species such as Atlantic horse mackerel (*Trachurus trachurus*), invertebrate species such as Norway lobster (*Nephrops norvegicus*) and shrimp (*Crangon crangon*), and non-target benthic organisms such as starfish, crabs and shellfish.

The following paragraphs summarise key conclusions from solution-based projects. The summary is not extensive; instead, we refer to the projects themselves and to outputs/ products from these specific projects. Information about the projects is listed in Appendix A.

6.1. Fishing closures (Appendix A: P24, P40)

Fishing closures can be implemented in areas where, or periods when, juvenile fish concentrate in order to prevent juvenile catches. These fishing closures may be permanent or temporary. In the North Sea, two examples of 'permanent' fishing closures have been established, the North Sea Cod Box and the Plaice Box. The Cod Box was closed in 2001 for 75 days with the intention to protect cod during the spawning season. Eventually this closure did not meet its objective, but resulted only "in minimal positive effects", mainly due to inappropriate timing and positioning of the area (Beare et al. forthcoming). Total effort was not reduced, merely displaced to the borders of the Cod Box, and therefore the pressure on spawning cod did not effectively decrease as it was aimed to be. The closure probably had a negative impact on the rate of discarding of vulnerable components of the ecosystem (e.g. elasmobranchs and long-lived benthic species) due to an increase in trawling activities in areas that are not normally fished (ICES 2004). In summary, the closure of the Cod Box was poorly designed, did not consider side effects on the level of discarding in demersal stocks, and did not consider the wider ecosystem implications (Rijnsdorp et al. 2001).

The Plaice Box was established as a technical fisheries management measure to reduce discarding of undersized plaice, closing the area for trawl fisheries with vessels >221kW, with the expectation that yield and spawning stock biomass would increase because this was an area where juvenile plaice was found (Beare et al. 2010). The Plaice Box regulation affected fisheries differentially, as the fleets >221kW lost fishing grounds, while the exemption fleets benefited from a reduction in competition with larger vessels. Contrary to expectations, plaice stock biomass decreased. This resulted in doubts challenging the usefulness of closed areas as a fisheries management tool. The most probable reason for the decrease in stock biomass is a shift in distribution of juvenile plaice to offshore areas outside the Plaice Box, caused by higher temperatures in combination with a decreased food availability. Instead of being protected within the Plaice Box, the juveniles went outside the Plaice Box where they were vulnerable to discarding (Beare et al. 2010).

Temporary area closures are sometimes enforced if catch quotas are exceeded (e.g. references in Buisman et al. 2001; Holmes et al. 2009; Beare et al. 2010; Catchpole and Gray 2010; Holmes 2010; Catarinio 2010), or following mass mortality events (Rotherham 2010) to allow for a period of recovery. Currently, plans of so called 'real time fishing closures' to reduce the discarding of Atlantic cod as part of a Cod Recovery Plan are being discussed (Pastoors and Röckmann 2009; Beare et al. forthcoming). For a closed area to be effective for discard reduction, it is important that there is limited dispersal in space and in time of the species that need protection (Densen et al 2008).

6.2. Quota and minimum landing size limits (Appendix A: P24, P26, P37, P41)

Quota and Total Allowable Catches (TACs)

TACs and quota are an example of output control in fisheries management. In the EU, currently TACs are set for *landings*. One disadvantage of using landing quota or TACs is that in mixed fisheries fishers can continue fishing even though they have reached their quota limit for one of their targeted species; as a consequence, these fishers might discard marketable fish, i.e. over-quota discarding or high-grading (Poos et al. 2010). TACs can also be set for catch, like in Norway or Iceland. It is a matter of definition and organisation of catch quotas to evaluate whether fishing will have to stop when the catch quota is reached.

The single species approach in the current TAC system might indirectly result in unwanted effects on discarding: The proportion between the sole and plaice quota in the Dutch mixed fishery fleet triggered this fleet to shift towards fishing areas further south, where catches of plaice were lower (Appendix A: P41). However, the high abundance of juvenile plaice in those southern regions lead to an increase in the discard percentage of undersized plaice in the Dutch fleet, because of the higher concentration of fishing effort in those regions. When setting TACs, it should be taken into account whether a fishery is a mixed or a single species fishery.

Minimum landing size (Appendix A: P24, P26)

Another output control is minimum landing size (MLS): Fish landed should not be below this MLS. Some analyses were carried out to investigate the effect of reducing MLS for plaice or increasing MLS for sole in the mixed sole and plaice fishery on plaice discarding (Appendix 1: P24, P26). Reducing MLS for frequently discarded species (e.g. plaice) without changing the minimum mesh size could result in higher landings of a new size category of relatively small specimen. For this new size category there needs to be a market, otherwise the measure could result in increased high-grading of the smaller specimen (cf. section 5.2). Reducing the MLS does not result in reduction of fishing mortality of the different age groups: the only difference is that the fish are landed instead of discarded. A consequence of a new market category of smaller fish could be that the national quota for the species will be exhausted in an earlier stage – unless the national quota is increased. (Appendix 1: P24)

Increasing MLS for a high value species in a mixed fishery (e.g. sole) would need to be combined with increasing the minimum mesh size, if the aim is a discard reduction of lower value species in that fishery. Densen et al. (2008) examined the effects of increasing the MLS of European sole from 24 to 27 cm (Appendix 1: P26).

6.3. Gear modifications (Appendix A: P25, P27-P33, P35)

Many of the IMARES studies deal with technical solutions to improve the selectivity of fishing gears. This is in line with research abroad, aiming to reduce overall quantities and hence mortalities of discards (for reviews, see Broadhurst 2000; Broadhurst et al. 2006; Catchpole and Revill 2008; Madsen 2007; Madsen and Valentinsson, 2010). Modifications have been developed and tested depending on differences in behaviour and/or size of target and non-target organisms, and depending on the type of fishery.

The effectiveness of gear adjustments for discard reduction depends on differences in behaviour and size of the target species compared to the organism that will be discarded (Catchpole et al. 2005; Ferro et al. 2007; Krag et al. 2009a, 2009b; Madsen 2007; Marlen et al. 2007). In order to separate target from non-target species, the behaviour and/or size of both species in the net need to be different. Generally speaking, European sole and Nephrops tend to stay at the bottom of the net. European plaice is distributed higher in the net, as are brown shrimp. Benthic organisms stay on the bottom. Roundfish (whiting, haddock, and Atlantic cod) tend to move up in the net (Catchpole et al. 2005 ; Winger et al. 2010). However, this behaviour may be subject to diurnal rhythms, seasonal and environmental variation (pers. comm. Bob van Marlen; Winger et al. 2010).

Here we summarise, by gear type, which gear modifications have been tried so far in Dutch trawl fisheries and fisheries similar to Dutch trawl fisheries with involvement of IMARES. For all gear types, approaches to reduce discards are often associated with the risk of losing marketable catch.

In the **beam trawl fisheries** targeting sole and plaice, several gear modifications were tested (Appendix 1: P25, P29, P31, P32): large-mesh or square-mesh panels at different locations and orientation in relation to the trawl codend; increased codend mesh sizes; and electric pulse fishing. The effectiveness of the modifications varied for different species groups.

- Reduction of undersized flatfish (plaice, dab) discards through gear modifications in most cases leads to the loss of marketable European sole. There is no technical adjustment yet that solves this issue. A collaborative mesh size experiment by the fishing industry and IMARES showed that increasing mesh size from 80 to 90mm does not result in decreasing catches of undersized plaice (Quirijns and Hintzen 2007). Possibly beam trawl fishing using pulse instead of tickler chains might be a fishing technique which can be used to target sole without catching a lot of plaice. This needs further investigation (pers. comm. Bob van Marlen).
- To reduce discards of benthic organisms, several potential solutions were found: square meshes at the bottom (although some loss of European sole); extra net panel at the bottom, leading to a hole in the rear (Benthic Release Hole); pulse fishing (Appendix 1: P29); and hydrorig (Appendix 1: P31).
- Reduction of roundfish discards has focused mainly on cod and whiting. For cod, none of the adjustments have shown a significant discard reduction. For whiting, larger mesh sizes in the upper part of the net are effective, but this only works if the net is long enough (i.e. not in the chain mat fishery where relatively short nets are used). The differences between effectiveness with respect to cod and whiting reduction can be mainly attributed to the difference in behaviour that these species show in the net.

In **otter trawl fisheries** (single or multiple trawls), the use of square-meshes in different parts of the trawl net were tested (Appendix 1: P30). Square-mesh panels in the upper part of the net reduced the presence of undersized plaice discards. In the *Nephrops* fishery (Appendix 1: P27, P29), both square-mesh panels and horizontal or inclined separator panels yielded promising results, separating roundfish (haddock and whiting), which swim upwards inside the net, from *Nephrops,* which typically remain at the bottom of the net.

In **shrimp fisheries**, the following gear modifications have been tested to exclude non-shrimp catches: sieve nets, Nørdmore grid, "Letter box" (NL: *brievenbus*, i.e., a release hole with guidance panel, Steenbergen et al., 2011), and pulse fishing (Appendix 1: P33, P34, P35). Other studies carried out elsewhere also considered changes to the codend mesh sizes (16, 22, 24 and 26 mm mesh) to reduce catches of undersized shrimps (Revill and Holst 2004). The following modifications are considered effective (grouped per discard type):
- Fish larger than 10cm: sieve net (disadvantage: clogging up when there are lots of weeds in the water); Nørdmore grid (disadvantage: rigid construction which renders its use complicated). The "letter box" seems promising in exclusion of small flatfish, but is still under investigation (Steenbergen et al. 2011). Preliminary results show that the letterbox catches 40% less plaice than the sieve net. Additionally, with a small net adjustment, there is no significant difference in loss of marketable shrimp between the letterbox and the sieve net.
- Fish smaller than 10cm: no successful modification available yet. The "letter box" seemed promising in reduction of small flatfish. The final results are not available yet.
- Benthic organisms: pulse fishing seems effective, although still in the testing phase.
- Undersized shrimp: increasing mesh size in the codend (tests were carried out with 16, 22, 24 and 26 mm mesh by Revill and Holst (2004)).

In the **pelagic trawl fisheries**, inner mesh panels for separating herring and Atlantic horsemackerel were tested with limited success, because these species mix shortly after entering the net due to capture stress (Appendix 1: P28).
To avoid megafauna catches some excluder devices were tested (Zeeberg et al. 2006). One excluder device, the "tunnel excluder" reduced bycatch mortality of the most vulnerable megafauna species by at least 40–100%. It is not clear to what extent excluder devices are currently used in the pelagic trawl fishery. Use of devices is not mandatory, but there are fishers using them mainly because it results in cleaner catches that are easier to process.

6.4. Operational (pre- and post-capture) modifications (Appendix A: P34)

In Europe, few studies have investigated the benefits from changing operational catching behaviour in order to maximize survival probabilities of remaining discards. Operational changes can occur as pre-capture events (i.e., before or during capture, e.g. shorter gear deployment durations, timing of operations) and post-capture handling modifications (e.g. sorting under minimal air exposure and/or immediate discharge).

Pre-capture operational modifications may include behavioural changes in the timing and location of fishing. This is related to spatial and or temporal fishing closures (paragraph 6.1). Fishers may decide themselves to avoid certain areas when and where they expect high amounts of discards. An incentive for this would be to have a cleaner catch which is easier to process. A similar behaviour can be applied in the Dutch pelagic trawl fishery to avoid capture of dolphins at night (i.e. Atlantic white-sided dolphins: *Lagenorhynchus acutus*), which may be nocturnal scavengers of discards (Couperus, in preparation). Pre-capture modifications may also include a reduction of gear deployment (e.g. tow duration). No research was carried out by IMARES or LEI to investigate the effects of these measures on discards. It is likely that the chance on survival will increase, while the absolute amount of discards will not reduce.

Post-capture modifications were investigated in 2008 by Dutch scientists and fishers in the shrimp fisheries (Appendix A: P34). The objective of this pilot study was to improve discard survival. One aim was to reduce predation by birds. A method to achieve this was to give the discarded specimen a bigger chance for escape by releasing the discards under the vessel instead of next to the vessel. Another method was to attach shiny ribbons to the vessel, close to the location where discards were released. Both methods seemed effective, but no significant results with respect to discard reduction were found. The second aim was to do a pilot test estimating the added mortality in the shrimp fishery due to the sorting procedure. For plaice the added mortality due to the sorting procedure was estimated at 44%, meaning that there is room for reduction. Fishers suggested that using more water in the sorting process might reduce the discard mortality. This has not been tested. No IMARES or LEI research is available on post-capture modifications for other fisheries.

6.5. Economic approaches and incentives (Appendix A: P22, 23)

Many of the technical and regulatory approaches suffer from a lack of economic incentives to reduce discards (Catchpole and Gray 2010). Fishing is an economic activity and only truly sustainable solutions which consider people, planet and profit equally will be successful. An economic motivation for reducing discards is to generate additional revenue or reduce costs for the fishers, e.g. less production costs, less fuel consumption, and/or higher catches. Additionally, incentives can be created to promote voluntary participation and/or uptake of proposed discard mitigation measures. Such incentives may be additional quota, days at sea, monetary compensation for catch loss, new, profitable market opportunities, gear switching, or effort reduction, and repayable loans (Hall and Mainprize 2005; Catchpole and Gray 2010; Davies and Rangeley 2010). Some of these incentives may only be applicable at the pilot stage, to encourage the active participation of fishers in trialling solutions within the commercial operating environment. Stronger incentives may be required to facilitate the widespread uptake of a successful solution or combination of measures. If fishers are placed at a commercial disadvantage among their peers when adopting discard reduction measures, the solution is doomed for failure (Catchpole and Gray 2010). Above all, from the outset of a project, a solid and trusted cooperative partnership is required. Each party's objectives and perceptions on how to tackle the issue should be synchronized with each other to define common ground (Catchpole and Gray 2010; Verweij and Densen 2010; Vos and Tatenhove 2011).

Recognizing the importance of incentives in the discard reduction debate (Catchpole et al. 2006; Campbell and Cornwell 2008; Catchpole et al. 2010), together with the often fairly localized nature of discard/and bycatch patterns (some solutions might not be applicable to all vessels within one fleet), it has been argued to move away from prescriptive to results-based management approaches (Graham 2010). The latter approach defines objectives, such as maximum allowable bycatch and discard levels, instead of prescribing the tools of how to achieve them. In such a novel management scenario, the burden of proof is reversed, whereby the fishing sector is expected to quickly develop and implement specific solutions as soon as discarding is associated with extra costs. In other private sector industries, environmentally-harmful operations are regulated by defining threshold levels (e.g. discarding/discharging of solid/fluid waste). Although maximum allowable bycatch limits do exist for some fisheries overseas, defining plausible and sensitive threshold levels for discards in European fisheries has been difficult (e.g. Rijnsdorp et al. 2001).

Notwithstanding the above, it is important to realize that any management action may incur trade-offs, which need to be accounted for before a given measure is implemented (Hall and Mainprize 2005). For example, spatial closures to protect one species may shift fishing pressures in other, sometimes more sensitive, areas where discarding of (other) species continues.

Apart from economic incentives, economic solutions may also constitute sanctions that incur costs to fishers. Such sanctions may range from monetary penalties in case of non-compliance to a complete discard ban. Monitoring compliance at-sea is expensive. Currently, approaches of fully-documented fisheries (FDF) which use electronic monitoring equipment (close-circuit TV cameras and sensors) are being promoted to cut costs of compliance monitoring and to reliably document all catches under a catch quota management regime (Dalskov and Kindt-Larsen 2009; Miller et al. 2010). FDF management still permits discarding at sea, but the use of catch quotas instead of landings quotas could minimise the uncertainties associated with discard estimation. This should lead to more robust stock assessments.

7. Discussion

To what extent is discarding a problem? An objective answer to that question is not readily available. Whether it is considered a problem and for whom, is a matter of perspective. Effects of discarding relate to increased food availability for discard-scavenging seabirds, fish and benthic organisms. On the other side, effects relate to the possible disturbance of a robust food web structure and endangering of species existence. In this report, possible effects of discarding are listed and described, drawing on IMARES and LEI research results and knowledge. It is impossible, however, to quantify the net effect of discarding by species and fishery.

The amount of discards in fisheries is usually an uncertain estimate of an average. Discard levels depend on a variety of factors, such as abundance of the species, fishery (gear and mesh size), vessel, fishing area, season and time of the day. Discard levels are monitored by means of self-sampling, observers, or cameras (fully documented fisheries). Each of these methods has its advantages and disadvantages, none of them resulting in 100% certain discard estimates.

Monitoring is the only way to get an estimate of discard levels. Monitoring in the Netherlands is done by observers, self-sampling, and cameras.

- **Self-sampling** is a cost effective method, which can result in relatively high monitoring coverage of the fleet. A draw-back of self-sampling is that quality assurance can be complicated. Fishers sample themselves and might not follow the sampling protocol as they should. Differences may arise due to different people collecting the data or misunderstandings. This may lead to problems with the data. Straightforward protocols, clear understanding of these protocols and good follow-up of these protocols are essential. Furthermore, tools are required for quality checks. This can either be done by performing cross-checks with other data sources or by carrying out some of the self-sampling together with observers.
- Monitoring with trained independent **observers** normally results in reliable high quality data. However, this type of monitoring is expensive and therefore often results in low coverage of the fleet.
- Monitoring with **cameras** (Fully Documented Fisheries by means of CCTV) is now being developed in the Netherlands for cod. Although the investments in this system are quite high, and video analyses are time consuming, this method is less costly than having observers on board. The video is a quality check in itself, so there should be relatively little problems with reliability of the data. The drawback of this system is that it might not be applicable to all fisheries. In the North Sea flatfish fishery and the shrimp fishery, for example, the catches may be too diverse to analyse through video images.

If discarding needs to be reduced, the key solution lies in incentives for fishers to reduce discards. Fishing is an economic activity. In general, the aim of an economic activity is to maximise economic gains; discard reduction measures will only work, if they take the economic nature of fishing into account. The measures that can be implemented vary between fisheries, target species and species for which discards need to be reduced. There is not one solution to reduce all discards in all fisheries.

Among the methods for discard reduction that have been investigated by IMARES and LEI, some seem more promising than others. Two long term fishing closures in the North Sea have not appeared to be successful, while temporary closures yet need to prove their effectiveness. Adjusting TAC ratios in mixed fisheries (e.g. for sole and plaice) may help to give fishers an incentive to fish in areas with less undersized plaice as long as the sole/plaice ratio matches with the sole/plaice ratio of their ITQs. Changing the Minimum Landing Size (MLS) for species will not lead to catches with lower discard species by fisheries, unless the minimum mesh size is adjusted accordingly. If reducing MLS leads to smaller grades being landed, then a market for this smallest grade needs to be created as well, otherwise reducing MLS will not have any positive effect. For the fishers, the costs of landing need to be covered and they need to be lower than the costs of discarding. Gear modifications can only be helpful in discard reduction if there is a difference in either size and shape, distribution, or behaviour of the target and discard species. Otherwise, separation by technical means is not feasible. If a gear modification is found to be effective, it needs to be practical in use and not lead to a loss of marketable target species. Otherwise the costs of fishing will increase for fishers leading to economic loss. Pre- and post-capture modifications can be considered in order to improve survival chances of discards. These types of modifications will not reduce the amount of discards. Finally, it is important to realise that any management measure may incur changes in behaviour sometimes having unwanted or unexpected effects (Hall and Mainprize 2005).

In the future, discard monitoring will be continued, using combinations of self-sampling, observers and cameras. This way, an insight and estimate of the quantity of discard levels across Dutch fisheries can be kept. To what extent IMARES and LEI will carry out more work on the effects of discarding and measures for discard reduction, depends on future developments in EU policy and the outcome of the discussions on the subject between different stakeholders.

8. References

Aarts, G. and Poos, J.J. (2009) Comprehensive discard reconstruction and abundance estimation using flexible selectivity functions. ICES Journal of Marine Science 66: 763–771.

Aarts, G., MacKenzie, M., McConnell, B., Fedak, M., and Matthiopoulos, J. (2008) Estimating space-use and habitat preference from wildlife telemetry data. Ecography 31: 140-160.

Ban, N., and Vincent, A. (2009) Beyond marine reserves: exploring the approach of selecting areas where fishing is permitted, rather than prohibited. PLoS One, 4: e6258.

Beare, D.J., Röckmann, C., Uhlmann, S., and Helmond, A.T.M. van (forthcoming). Avoiding Atlantic cod (*Gadus morhua*) through seasonal closures and gear adaptations. IMARES Report No. XX.

Beare, D.J., Rijnsdorp, A.D., Kooten, T. van, Fock, H., Witbaard, R., Meesters, H.W.G., and Quirijns, F.J. (2010) Study for the revision of the plaice box - Draft Final Report. IMARES Report C002/10.

Beek, F.A. van (1990) Discard sampling programme for the North Sea, Dutch participation. RIVO Intern Rapport Demvis 90-303.

Beek, F.A. van (1998) Discarding in the Dutch beam trawl fishery. ICES Conference and Meeting Documents. ICES CM 1998/BB:5.

Beek, F.A. van, Leeuwen, P.I. van, and Rijnsdorp, A.D. (1990) On the survival of plaice and sole discards in the otter-trawl and beam0-trawlbeam0trawl fisheries in the North Sea. Netherlands Journal of Sea Research 26: 151-160.

Bemmelen, R. van (2010) Mogelijke consequenties van reductie van de hoeveelheid discards voor N2000 instandhoudingdoelen. IMARES report C152/10.

Brasseur, S., Reijnders, P., Henriksen, O., Carstensen, J., Tougaard, J., Teilmann, J., Leopold, M., Camphuysen, K. and Gordon, J. (2004b) Baseline data on the harbour porpoise, Phocoena phocoena, in relation to the intended wind farm site NSW in the Netherlands. Wageningen, Alterra-rapport 1043. 80 pp.

Brasseur, S., Tulp, I., Reijnders, P., Smit, C., Dijkman, E., Cremer, J., Kotterman, M., Meesters, E. (2004a) Voedselecologie van de gewone en grijze zeehond in de Nederlandse kustwateren. Wageningen, NL, Alterra. Alterra-rapport 905.

Breen, P.A., Hilborn, R., Maunder, M.N., and Kim, S.W. (2003) Effects of alternative control rules on the conflict between a fishery and a threatened sea lion (Phocarctos hookeri). Canadian Journal of Fisheries and Aquatic Sciences, 60: 527-541.

Broadhurst, M.K. (2000) Modifications to reduce bycatch in prawn trawls: A review and framework for development. Reviews in Fish Biology and Fisheries, 10: 27-60.

Broadhurst, M.K., Suuronen, P., and Hulme, A. (2006). Estimating collateral mortality from towed fishing gear. Fish and Fisheries 7: 180-218.

Buisman, F.C., Wilde, J.W. de, Cappell, R., Borel, G., Giron, Y., and Vibier, F. (2001) Economic aspects of discarding. Agricultural Economics Research Institute (LEI), The Hague. Rapporten aan de Europese Commissie. Juli 2001.

Buisman, F.C., Bakker, T., Bos, E., Kuhlman, T., Poos, J.J. (forthcoming) Effecten van een verbod op discards in de Nederlandse platvisvisserij, LEI report 2011-014, Den Haag.

Bull, L. S. (2007) Reducing seabird bycatch in longline, trawl and gillnet fisheries. Fish and Fisheries, 8: 31-56.

Bult, T.P., and Schelvis-Smit, A.A.M. (2007) Een verkenning van de mogelijkheden van outriggen door vissers uitgevoerd, in het kader van het Advies van de "Task Force Duurzame Noordzeevisserij". IMARES Report C022.07, 34 pp.

Callaway, R., Alsvag, J., de Boois, I., Cotter, J., Ford, A., Hinz, H., Jennings, S., Kröncke, I., Lancaster, J., Piet, G., Prince, P., and Ehrich, S. (2002) Diversity and community structure of epibenthic invertebrates and fish in the North Sea. ICES Journal of Marine Science 59(6): 1199-1214.

Campbell, L. M., and Cornwell, M. L. (2008) Human dimensions of bycatch reduction technology: current assumptions and directions for future research. Endangered Species Research, 5: 325-334.

Camphuysen, C. and Garthe, S. (1997) An evaluation of the distribution and scavenging habits of Northern Fulmars (Fulmarus glacialis) in the North Sea. ICES Journal of Marine Science 54: 654-683.

Camphuysen, C. J. and Garthe, S. (2000) Seabirds and commercial fisheries: population trends of piscivorous seabirds explained? Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. M. J. Kaiser and S. J. de Groot. Oxford, UK, Blackwell Science: 163-184.

Camphuysen, C., Calvo, B., Durinck, J., Ensor, K., Follestad, A., Furness, R., Garthe, S., Leaper, G., Skov, H., Tasker, M., and Winter, C. (1995) Consumption of discards by seabirds in the North Sea. Final report EC DG XIV research contract BIOECO/93/10. NIOZ Rapport 1995 – 5, Netherlands Institute for Sea Research, Texel, 202 + LVI pp.

Catarinio, R. (2010) Evaluating the effect of real-time closures on cod targeting. Fishery Dependent Information Conference, Galway, Ireland, August 23-26, 2010.

Catchpole, T.L. and Gray, T.S. (2010) Reducing discards of fish at sea: a review of European pilot projects. Journal of Environmental Management, 91: 717-723.

Catchpole, T.L. and Revill, A.S. (2008) Gear technology in Nephrops trawl fisheries. Reviews in Fish Biology and Fisheries, 18: 17-31.

Catchpole, T.L., Frid, C.L.J., and Gray, T.S. (2005) Discards in North Sea fisheries: causes, consequences and solutions. Marine Policy, 29: 421-430.

Catchpole, T.L., Frid, C.L.J., and Gray, T.S. (2006) Resolving the discard problem - A case study of the English Nephrops fishery. Marine Policy, 30: 821-831.

Catchpole, T., van Keeken, O., Gray, T., and Piet, G. (2008) The discard problem - A comparative analysis of two fisheries: The English Nephrops fishery and the Dutch beam trawl fishery. Ocean and Coastal Management, 51: 772-778.

Chopin, F, Inoue, Y and Arimoto, T (1996) Development of a catch mortality model. Fisheries Research 25: 377-382.

Couperus, A.S. (1997) Bycatch of marine mammals and discards in pelagic fisheries (MAMDIS). CFP 94/018 Final report. 21 pp.; RIVO Report C014/97

Couperus, A.S. (2008) Monitoring of incidental catches of cetaceans by Dutch pelagic trawlers in 2007. CVO Report 08.007, 16pp.

Couperus, A.S. (2009) Annual Report of the Netherlands to the European Commission on the implementation of Council Regulation 812/2004 on cetacean bycatch. Results of fishery observations collected during 2008. CVO Report 09.006, 22 pp.

Couperus, A.S. (2010) Annual Report of the Netherlands to the European commission on the implementation of Council Regulation 812/2004 on cetacean bycatch. Results of fishery observations collected during 2009. CVO Report 10.006, 15 pp.

Crowder, L. B., and Murawski, S.A. (1998) Fisheries bycatch: Implications for management. Fisheries, 23: 8-17.

Dalskov, J. and Kindt-Larsen, L. (2009) Fully-documented fishery. Technical University of Denmark, National Institute of Aquatic Resources Report, 49 pp.

Davies, R.W.D. and Rangeley, R. (2010) Banking on cod: Exploring economic incentives for recovering Grand Banks and North Sea cod fisheries. Marine Policy, 34: 92-98.

Davis, M.W. (2002) Key principles for understanding fish bycatch discard mortality. Canadian Journal of Fisheries and Aquatic Sciences 59: 1834-1843.

Densen, W.L.T. van, Quirijns, F.J., and Helmond, A.T.M. van (2008a) Oplossingsrichtingen bij het verminderen van scholdiscards in de 80 mm visserij. IMARES report C064/08, 24pp.

Densen, W.L.T. van, Smit, J., Quirijns, F.J., Oostenbrugge, H. van, and Machiels, M. (2008b) Effecten van een verhoging van de minimummaat (MLS) voor tong. IMARES Report C045/08. 20pp.

Depestele, J., Desender, M., Polet, H., Van Craeynest, K., and Vincx, M. (2009) Mortality of fish discards in beam trawl fisheries. Gent University/ILVO: Oostende, Belgium. Poster. Available at: http://www.vliz.be/imis/imis.php?module=ref&refid=142529

EC (1979) Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. European Commission.

EC (2000) Council Regulation (EC) No 1543/2000 of 29 June 2000 establishing a Community framework for the collection and management of the data needed to conduct the common fisheries policy. Official Journal of the European Communities L 176, pp.1-16.

EC (2001) Commission Regulation (EC) No 1639/2001 of 25 July 2001 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000. Official Journal of the European Communities L 222.

EC (2004) Council Regulation (EC) No 812/2004 of 26.4.2004 laying down measures concerning incidental catches of cetaceans in fisheries and amending Regulation (EC) No 88/98.

EC (2007) A policy to reduce unwanted by-catches and eliminate discards in European fisheries. Communication from the Commission to the Council and the European Parliament. Brussels, 28.3.2007, COM(2007) 136 final.

EC (2008a) Council Regulation (EC) No 199/2008 of 25 February 2008 concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy. Official Journal of the European Union L 60.

EC (2008b) Commission Decision of 6 November 2008 adopting a multiannual Community programme pursuant to Council Regulation (EC) No 199/2008 establishing a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy. (2008/949/EC)

EC (2009) Communication from the Commission Consultation on Fishing Opportunities for 2010. European Commission, Brussels, 12.5.2009, COM(2009) 224 final.

EC (2011) Non-Paper on discards ban for discussion with the stakeholders in Brussels on 3 May 2011. European Commission.

Enever, R., Revill, A.S., and Grant, A. (2009) Discarding in the North Sea and on the historical efficacy of gear-based technical measures in reducing discards. Fisheries Research 95(1): 40-46.

Evans, S.M., Hunter, J.E., Elizal, and Wahju, R.I. (1994) Composition and fate of the catch and bycatch in the Farne Deep (North Sea) Nephrops fishery. ICES Journal of Marine Science, 51(2): 155-168.

Faasse, M.A. (1987) Schatting van het aantal discards van tong (Solea solea L.) per leeftijdsgroep in de boomkorvisserij op de Noordzee. RIVO Intern Rapport.

Ferro, R. S. T., Jones, E. G., Kynoch, R. J., Fryer, R. J., and Buckett, B-E. (2007) Separating species using a horizontal panel in the Scottish North Sea whitefish trawl fishery. – ICES Journal of Marine Science, 64: 1543–1550.Fonteyne, R., 1997. Optimization of a species selective beam trawl (SOBETRA). Final Project Report EU-Project AIR2-CT93-1015.

Frandsen, R. P., Holst, R., and Madsen, N. (2009) Evaluation of three levels of selective devices relevant to management of the Danish Kattegat-Skagerrak Nephrops fishery. Fisheries Research, 97: 243-252.

Garthe, S. and Hüppop, 0. (1998) Possible biases in experiments evaluating the consumption of discards by seabirds in the North Sea. Mar Biol 131:735-741.

Garthe, S., Camphuysen, K.C.J., Furness, R.W. (1996) Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. Marine Ecology Progress Series 136: 1-11.

Gates, K. W. (1991) Waste reduction, water conservation, and recovery of seafood by-products. Marine Technology Society Journal, 25: 44-51.

Graham, N. (2010) Reduction of EU discards – from a prescriptive to results-based approach – can it work in practice? Fishery Dependent Information Conference, Galway, Ireland, August 23-26, 2010.

Graham, N., Ferro, R. S. T., Karp, W. A., and MacMullen, P. (2007) Fishing practice, gear design, and the ecosystem approach - three case studies demonstrating the effect of management strategy on gear selectivity and discards. ICES Journal of Marine Science, 64: 744-750.

Grémillet D., Pichegru L., Kuntz, G., Woakes A.G., Wilkinson S., Crawford R.J.M., and Ryan P.G. (2008) A junk-food hypothesis for gannets feeding on fishery waste. Proc. Roy. Soc. B. 275: 1149-1156.

Hall, S. J., and Mainprize, B. M. (2005) Managing bycatch and discards: how much progress are we making and how can we do better? Fish and Fisheries, 6: 134-155.

Harrington, J. M., Myers, R. A., and Rosenberg, A. A. (2005) Wasted fishery resources: discarded bycatch in the USA. Fish and Fisheries, 6: 350-361.

Helmond, A.T.M. van and Overzee, H.M.J. van (2007) Discard sampling of the Dutch beam trawl fleet in 2006. CVO Report 07.011, 46 pp.

Helmond, A.T.M. van and Overzee, H.M.J. van (2008) Discard sampling of the Dutch beam trawl fleet in 2007. CVO Report 08.008, 44 pp.

Helmond, A.T.M. van and Overzee, H.M.J. van (2009a) Discard sampling of the Dutch Nephrops Fishery in 2007-2008. CVO Report 09.007, 38 pp.

Helmond, A.T.M. van and Overzee, H.M.J. van (2009b) Discard sampling of the Dutch pelagic freezer fishery in 2003-2007. CVO Report 09.001, 60 pp.

Helmond, A.T.M. van and Overzee, H.M.J. van (2010a) Discard sampling of the Dutch beam trawl fleet in 2008. CVO Report 10.001, 45 pp.

Helmond, A.T.M. van and Overzee, H.M.J. van (2010b) Discard sampling of the Dutch pelagic freezer fishery in 2008 and 2009. CVO Report 10.008, 63 pp.

Helmond, A.T.M. van, Steenbergen, J., and Bol, R.A. (2010) Evaluatierapport: sectorbemonstering, december 2009. Internal IMARES Report 10.001, 20pp.

Helmond, A.T.M. van, Steenbergen, J., Bol, R. A., and Uhlmann, S.S. (2011) Internal evaluation of the discards self-sampling programme. Internal IMARES report 11.001, 13pp.

Hoefnagel, E. and Vos, B.I. de (2004) Drijfveren van vissers en duurzaam visserijbeheer. LEI Report 7.04.01.

Hofstede, R. Ter, J.J. Zeeberg, D. De Haan, B. Couperus and I. Mantingh (2004) Incidental catches of pelagic megafauna by the Dutch pelagic fleet in the Mauritanian Exclusive Economic Zone during the years 1999-2003. RIVO Report C032.04, 21 pp.

Hofstede, R. Ter. and M. Dickey-Collas (2006) An investigation of seasonal and annual catches and discards of the Dutch pelagic freezer-trawlers in Mauritania, Northwest Africa. Fisheries Research, 77(2): 184-191.

Holmes, S. (2010) Using fishery-dependent data to inform the development and operation of a co-management initiative to reduce cod mortality and cut discards. Fishery Dependent Information Conference, Galway, Ireland, August 23-26, 2010.

Holmes, S.J., Campbell, N., Aires, C., Fernandes, P.G., Catarino, R., Bailey, N., and Barratt, K. (2009) Using VMS and Fishery Data in a Real Time Closure Scheme as a Contribution to Reducing Cod Mortality and Discards. ICES CM 2009/M:13.

Howell, E. A., Kobayashi, D. R., Parker, D. M., Balazs, G. H., and Polovina, J. J. (2008) TurtleWatch: a tool to aid in the bycatch reduction of loggerhead turtles Caretta caretta in the Hawaii-based pelagic longline fishery. Endangered Species Research, 5: 267-278.

Huppop, 0. and Wurm, S. (2000) Effects of winter fishery activities on resting numbers, food and body condition of large gulls Larus argentatus and L. marinus in the south-eastern North Sea. Marine Ecology Progess Series 194: 241-247.

ICES (2008) Report of the Sutdy Group for Bycatch of Protected Species (SGBYC), 29-31 Januray 2008, ICES, Copenhagen, Denmark. ICES CM 2008/ACOM 48: 88pp.

ICES (2004) Report of the Working Group on Elasmobranch Fishes (WGEF). ICES CM 2004/G:11, 114pp.
Kaiser, M.J. and Groot, S.J. de (2000). Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. Oxford, Blackwell Science.
Keeken, O.A. van, and M.A. Pastoors (2004) Discard sampling of the Dutch beam trawl fleet in 2003. CVO Report 04.024, 55 pp.
Keeken, O.A. van and M.A. Pastoors (2005). Discard sampling of the Dutch beam trawl fleet in 2004. CVO Report 05.006, 56 pp.
Keeken, O.A. van (2006) Discard sampling of the Dutch beam trawl fleet in 2005. CVO Report C061.06, 54 pp.
Keeken, O.A. Van, J.J. Poos, and M.A. Pastoors (2004) Discard sampling of the Dutch beam trawl fleet in 2002. CVO Report 04.010, 32 pp.
Keeken, O.A. van, Quirijns, F.J., Grift, R.E. (2004). Discards in de Nederlandse twinrigvisserij. RIVO Rapport C011/04. N. I. v. V. Onderzoek. IJmuiden, Nederlands Instituut voor Visserij Onderzoek: 57.
Kelleher, K. (2005) Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper. Rome, FAO. No. 470: 131 p.
Krag, L.A., Holst, R., and Madsen, N. (2009a) The vertical separation of fish in the aft end of a demersal trawl. ICES J. Mar. Sci. 66, 772-777.
Krag, L.A., Madsen, N., and Karlsen, J.D. (2009b) A study of fish behaviour in the extension of a demersal trawl using a multi-compartment separator frame and SIT camera system. Fisheries Research 98, 62-66.
Lancaster, J., and Frid, C. L. J. (2002) The fate of discarded juvenile brown shrimps (Crangon crangon) in the Solway Firth UK fishery. Fisheries Research, 58: 95-107.
Leeuwen, P.I. van (1984) De overlevingskansen van schol- en tongdiscards in de Nederlandse vloot. (Een samenvatting van overlevingsexperimenten met en zonder vangstverwerker uit de periode 1972-1982). RIVO Intern Rapport ZE 84-09.
Leopold, M.F. and Dankers, N. (1997) Natuur in zoute wateren. Achtergronddocument 2c. Natuurverkenning '97. Alterra report.
Leopold, M.F. (2002) Eiders Somateria mollissima scavenging behind a lugworm boat, J. Sea Res (47) 1: 75-82
Madsen, N. (2007) Selectivity of fishing gears used in the Baltic Sea cod fishery. Reviews in Fish Biology and Fisheries, 17: 517-544.
Madsen, N. and Valentinsson, D. I. (2010) Use of selective devices in trawls to support recovery of the Kattegat cod stock: a review of experiments and experience. ICES Journal of Marine Science, 67: 2042–2050.
Marlen, B. van (2000) Technical modifications to reduce the bycatches and impacts of bottom-fishing gears. In: Kaiser, MJ, De Groot, SJ (eds) Effects of fishing on non-target species and habitats. Blackwell Science, 2000.
Marlen, B. van (2003) Improving the selectivity of beam trawls in The Netherlands: the effect of large mesh top panels on the catch rates of sole, plaice, cod and whiting, Fisheries Research 63 (2): 155-168
Marlen, B. van, Lange, K., Wardle, C.S., Glass, C.W., and Ashcroft, B. (1994) Intermediate results in EC-project TE-3-613 "Improved species and size selectivity of midwater trawls" (SELMITRA), ICES CM 1994/B:13.
Marlen, B. van, de Haan, D., Revill, A.S., Dahm, K.E., Wienbeck, H., Purps, M., Coenjaerts, J., and Polet, H. (2001) Bycatch reduction devices in the European Crangon fisheries, ICES CM 2001/R:10.
Marlen, B. van, Bergman, M.J.N., Groenewold, S., and Fonds, M. (2005) New approaches to the reduction of non-target mortality in beam trawling, Fisheries Research 72 (2–3): 333-345.
Marlen, B. van, Grift, R.E., Keeken, O.A. van, Ybema, M.S., Hal, R. van (2006) Performance of pulse trawling compared to conventional beam trawling. IMARES Report C014/06, pp. 60.

Marlen, B. van (2007) NEphrops and CEtacean Species Selection Information and TechnologY (NECESSITY). Sixth Framework Programme, Priority 8.1, Policy-oriented research (SSP) SSP8-CT-2003-501605, p. 62.

Marlen, B. van, Helmond, A.T.M. van, Pasterkamp, T.L., and Bol, R. (2008) Study of the effect of a By catch Reduction Panel in a twin trawl on reducing plaice discards. IMARES Report C106/08 pp. 19

Millas, R.B. and Fryer, R.J. (1999) Estimating the size-selection curves of towed gears, traps, nets and hooks. Review in Fish Biology and Fisheries 9: 89-116.

Miller, D.C.M., Helmond, A.T.M. van, and Poos, J.J. (2010) Kennisvraag H-AKV-139: Fully documented fisheries - Draft Advice. IMARES Report number C178/10.

Morizur, Y., Berrow, S.D., Tregenzac, N.J.C., Couperus, A.S., and Pouvreau, S. (1999) Incidental catches of marine-mammals in pelagic trawlfisheries of the northeast Atlantic, Fisheries Research (41) 297-307

Morizur, Y., Tregenza, N., Heessen, H., Berrow, S., Pouvreau, S. (1996) Bycatch and discarding in pelagic trawlfisheries (BIOECO). Final report – Contract EC DG XIV-C-1 Study BIOECO /93/017, 122pp.

Nielsen, J.R. (2008) Final Consolidated EFIMAS Project Report (SSP8-CT-2003-502516). EFIMAS Project covering and summarising 20 special subject and task final reports under the project. Final Report to the EU Commission, 2008, 112pp.

Pascoe, S. (1997) Bycatch management and the economics of discarding. FAO Fisheries Technical Paper. No. 370. Rome, FAO. 137 pp.

Pastoors, M. A. and Röckmann, C. (2009) Dekstudies underpinning the Dutch vision on the reform of the Common Fisheries Policy. IMARES Report C077/09, 79 pp.

Pastoors, M. A., Rijnsdorp, A. D., and Beek, F. A. van (2000) Effects of a partially closed area in the North Sea ("plaice box") on stock development of plaice. ICES Journal of Marine Science, 57: 1014-1022.

Poos J.J., Bogaards, J.A., Quirijns, F.J., Gillis, D.M., and Rijnsdorp, A.D. (2010) Individual quotas, fishing effort allocation, and over-quota discarding in mixed fisheries. ICES Journal of Marine Science (67) Issue2 pp. 323-333.

Price, A. B. and Rulifson, R. A. (2004) Use of traditional ecological knowledge to reduce striped bass bycatch in the Currituck Sound white perch gill-net fishery. North American Journal of Fisheries Management, 24: 785-792.

Quirijns, F.J. and Hintzen, N. (2007) Effect van de maaswijdte op de vangstsamenstelling in de boomkorvisserij. Report Number: C122/07.

Quirijns, F.J., Rijnsdorp, A.D., and Grift, R.E. (2006) Analyses of changes in spatial distribution of the beam trawl fleet and their effects on the plaice and sole stock, 1990-2005. RIVO report C075/06, 27pp.

Report Number: C122/07 Revill, A.S. and Holst, R. (2004) Reducing discards of North Sea brown shrimp (C. crangon) by trawl modification. Fisheries Research, 68: 113-122.

Ridgway, I.D., Taylor, A.C., Atkinson, R.J.A., Chang, E.S., and Neill, D.M. (2006) Impact of capture method and trawl duration on the health status of the Norway lobster, Nephrops norvegicus. Journal of Experimental Marine Biology and Ecology 339: 135-147.

Rijnsdorp, A.D. and Beek, F.A. van (1991) The effects of the plaice box on the reduction in discarding and on the level of recruitment of North Sea sole. ICES C.M. 1991/G:47

Rijnsdorp, A.D., Piet, G.J., and Poos, J.J. (2001) Effort allocation of the Dutch beam trawl fleet in response to a temporarily closed area in the North Sea. ICES CM 2001/N:01, 1-17.

Rochet, M.-J. and Trenkel, V. (2005) Factors for the variability of discards: assumptions and field evidence. Canadian Journal of Fisheries and Aquatic Sciences, 62: 224-235.

Rotherham, D. (2010) Integrating different sources of data to reduce uncertainty in the assessment and management of fisheries resources following an environmental impact. Fishery Dependent Information Conference, Galway, Ireland, August 23-26, 2010.

Slooten, E., Taylor, B., and Fletcher, D. (2000) Taking account of uncertainty in the management of animal populations: Is Hectors Dolphin at risk from bycatch? Conservation Biology, 14: 1264-1270.

Steenbergen, J., Machiels, M., and Leijzer, T. (2011) Reducing discards in shrimp fisheries with the letter box. IMARES report C023/11, 37pp.

Stenhouse, I. J. and Montevecchi, W. A. (1999). Indirect effects of the availability of capelin and fishery discards: gull predation on breeding storm-petrels. Marine Ecology-Progress Series 184: 303-307.

Stobutzki, I. C., Jones, P., et al. (2003). A comparison of fish bycatch communities between areas open and closed to prawn trawling in an Australian tropical fishery. ICES Journal of Marine Science 60: 951-966.

Stratoudakis, Y. (1999) Recommendations for improving the estimation of the number of seabirds potentially sustained by fisheries discards. Marine Ecology Progress Series 176: 307-309.

Tasker, M. L., Camphuysen, C. J. K., Cooper, J., Garthe, S., Montevecchi, W. A., and Blaber, S. J. M. (2000) The impacts of fishing on marine birds. Ices Journal of Marine Science, 57: 531-547.

Thurstan, R.H., and Roberts, C.M. (2010) Ecological Meltdown in the Firth of Clyde, Scotland: Two Centuries of Change in a Coastal Marine Ecosystem. PLoS One, 5.

Tulp, I. (2009) Onderzoeksagenda 'duurzame garnalenvisserij'. IMARES Report C102/09.

Tulp, I., Leijzer, T., and Helmond, A.T.M. van (2010) Overzicht Wadvisserij Deelproject A. Bijvangst garnalenvisserij. Eindrapportage. IMARES Report C102.10, 37 pp.

Veen, J.F. de, and Rodenburg, W.F. (1971) Discarding in the Dutch sole fisheries in 1969 and 1970. ICES C.M. 1971/B:11

Veen, J.F. de, Huwae, P.H.M., and Lavaleye, M.S.S. (1975) On discarding in the sole fishery and preliminary observations on survival rates of discarded plaice and sole in 1975. ICES C.M. 1975/F:28 Demersal Fish (N) Committee, Ref. Statistics Committee

Verweij, M.C. and Densen, W.L.T. van (2010) Differences in causal reasoning about resource dynamics and consequences for the participatory debate on North Sea fisheries. Marine Policy.

Vlasveld, P. (1977) Een onderzoek naar de sterfte van platvisdiscards (in het bijzonder die van schol). RIVO Intern Verslag.

Vos, B.I. de and Tatenhove, J.P.M. van (2011) Trust relationships between fishers and government: New challenges for the co-management arrangements in the Dutch flatfish industry. Marine Policy, 35, 218-225.

Votier, S., Furness, R., Bearhop, S., Crane, J., Caldow, R., Catry, P., Ensor, K., Hamer, K., Hudson, A., Kalmbach, E., Klomp, N., Pfeiffer, S., Phillips, R., Prieto, I., and Thompson, D. 2004. Changes in fisheries discard rates and seabird communities. Nature 427(6976): 727-730.

Walters, C. (2000) Impacts of dispersal, ecological interactions, and fishing effort dynamics on efficacy of marine protected areas: how large should protected areas be? Bulletin of Marine Science, 66, 745-757.

Whitfield J. (2008) Does 'junk food' threaten marine predators in northern seas?. Science 322: 1786-1787.

Wijk, M.O. van, Ruiter, C. de, Smit, M.H., and Taal, C, (1999) Visserij in Cijfers 1999. LEI report 1.00.11, 51 pp.

Winger, P.D., Eayrs, S., and Glass, C.W. 2010. Fish behaviour near bottom trawls. In: Behavior of Marine Fishes - Capture Processes and Conservation Challenges, P. He (ed.). Wiley-Blackwell. 392 p.

WWF (2009) The Scottish Conservation Credits Scheme – Moving fisheries management towards conservation. WWF Scotland, December 2009.

Zeeberg, J.J., Corten, A,, and Graaf, E. de (2006). Bycatch and release of pelagic megafauna in industrial trawler fisheries off Northwest Africa. Fisheries Research 78(2-3): 186-195.

Zhou, S. J. (2008) Fishery bycatch and discards: a positive perspective from ecosystem-based fishery management. Fish and Fisheries, 9: 308-315.

Acknowledgements

This report could not have been written without the help of the following IMARES and LEI colleagues: Frans van Beek, Rob van Bemmelen, Ingeborg de Boois, Sophie Brasseur, Erik Buisman, Bram Couperus, Edwin van Helmond, Mardik Leopold, Bob van Marlen, Hans van Oostenbrugge, Martin Pastoors, Jan Jaap Poos, Josien Steenbergen, and Ingrid Tulp. We thank Paula den Hartog, Inger Wilms and Henk Offringa for valuable comments on earlier versions of this report.

Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

Justification

Rapport C068/11
Project Number: 4308.101.011

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved:	Dr. David Miller Onderzoeker	Ir. Edwin van Helmond Onderzoeker
Signature:		
Date:	17-06-11	16-06-'11

Approved:	Dr. Tammo Bult Afdelingshoofd Visserij
Signature:	
Date:	21/6

Appendix A. IMARES and LEI project overview

No	Project name	CATEGORY	Description	Output
1	Discards in de NL Twinrigvisserij	04_Magnitude	Data collection & description	Keeken and Quirijns 2004
2	Discards in de NL Kreeftvisserij	04_Magnitude	Data collection & description	Annual CVO report (e.g. Helmond and Overzee 2009a)
3	WOT Monitoring discards in DCF I: Wadden Sea and North Sea	04_Magnitude	Estimating volumes and composition of discards in selected metiers (e.g. TBB and OTM)	Keeken et al. 2004; Keeken and Pastoors 2004, 2005; Keeken 2006; Helmond and Overzee 2007, 2008, 2009a, 2009b, 2010a, 2010b
4	WOT Monitoring discards in DCF II: Shrimp fisheries	04_Magnitude	Estimating volumes and composition of discards in shrimp fisheries	IMARES report C097/08
5	WOT Monitoring discards in DCF III: Self-sampling	04_Magnitude	Estimating volumes and composition of discards in sea fisheries, samples collected by fishers	Helmond and Overzee 2010a
6	WOT Bijvangst zeezoogdieren	04_Magnitude	Data collection on bycatch of marine megafauna (sharks, seals, whales (dolphins)	Annual CVO report (e.g. Couperus 2010)
7	MAMDIS	04_Magnitude	Monitoring bycatch of dolphins and discards in pelagic fisheries	Couperus 1997
8	Bijvangst Zeezoogdieren	04_Magnitude	Monitoring bycatch of dolphins in NL pelagic fishery	RIVO report C030/95
9	BioEco	04_Magnitude	Monitoring of bycatch of dolphins by pelagic trawlers	Morizur et al. 1996, 1999
10	Discards Mauritanie	04_Magnitude	Monitoring bycatch of dolphins in NL fisheries	Zeeberg et al. 2006
11	Self-sampling of discards	04_Magnitude	Fishers collect discards data by means of simple protocol provided by IMARES	Various (confidential) reportings
12	Kamervraag discards in NL Visserij	04_Magnitude	Overview discards percentages and composition in Dutch Fisheries. Literature study	IMARES report C101/07
13	VIP Outrig	04_Magnitude	Comparison discards between outrig and beam trawl	IMARES report in prep.
14	EFIMAS	04_Magnitude	Retrospective discard quantity estimation and reconstruction (1975-2000)	Nielsen 2008

No	Project	CATEGORY	Description	Output
15	Reisverslagen oude discardsbemonsteringen	04_Magnitude	Reports of observer trips in earlier years	Not digitally available
16	BADMINTON	04_Magnitude/05_Effects	Exploratory analysis of discard data on a pan-European basis, identify indicators, describe management implications	Report in prep.; Manuscript in prep. (submitted)
17	Discards als vogelvoer	05_Effects	Objectives: How many bird species live off discards, when and where do they feed on them?	Leopold and Dankers 1997; Bemmelen 2010
18	Scavenging eiders	05_Effects	Scavenging eiders behind a lugworm boat	Leopold 2002
19	Ministudie: Diets of Terns	05_Effects	Study of diet of terns	NA
20	WKEID (discard indicators)	05_Effects/ 06_Solutions	ICES Workshop on ecosystem indicators of discarding	Workshop report in prep.
21	Economic aspects of discarding	05_Effects/ 06_Solutions	Objectives: establish incentives to discard, determine the value of discards, describe perception by fishers, best practices of management	Buisman et al. 2001
22	KBA Discardban	05_Effects/ 06_Solutions	Cost-benefit analysis of a potential discard ban	Buisman et al. forthcoming
23	Incentives van vissers	06_Solutions	sociological research into the perceptions and motivations of fishers	Hoefnagel and Vos 2004
24	KBA Discards	06_Solutions	Solutions for discarding problem in the demersal 80mm fishery	Densen et al. 2008a
25	Maaswijdteproject	06_Solutions	How does mesh size (70, 80 and 90 mm) affect plaice discards and sole landings	Quirijns and Hintzen 2007
26	Effecten MLS voor tong	06_Solutions	Does increasing minimum landing size for sole reduce plaice discarding?	Densen et al. 2008b
27	Less Fuel and Discards	06_Solutions	vessel UK158 and a net manufacturer (from DK) develop a new twinrig gear for nephrops. Objective: less fuel and discards (LFD).	IMARES report, in prep.
28	SELMITRA	06_Solutions	To separate species assemblages by means of gear modifications (e.g. separator panels)	Marlen et al. 1994

No	Project	CATEGORY	Description	Output
29	various gear technology projects related to beam trawl	06_Solutions	- SOBETRA (1990-1996)TE.2.559 (FAR, 1990-1996) - IMPACT; RONDUS; REDUCE (1996-2000); - RECOVERY (2002-2005 cod bycatch); - NECESSITY (2004-2007, discards in Nephrops fisheries); - BESTEK6b (2004-2005, bycatch of harbour seals in fyke nets and beam trawls); - PULSKOR (1996-ongoing, bycatch and discard reduction by using electric pulses, impact on benthos, fuel consumption); - DEGREE (2006-2009, impact and design of fishing gear); - LOT3 (2008-2010, investigating the efficacy of alternative fishing egars than beam trawls in catching sole and plaice); - VDTN/PVIS (2008-2009).	Fonteyne 1997; Marlen 2003; Marlen et al. 2005, 2006
30	Twinrig: Twinrig BRP	06_Solutions	Examine and test Bycatch Reduction Devices in otter trawls	Marlen et al. 2008
31	Various VIP projects related to gear technology I	06_Solutions	To study the and minimize flow resistance: Hydrorig (2008-2010); OUTRIGGEN (2008-2009); SUMWING (2008-2009)	
32	Various VIP projects related to gear technology II	06_Solutions	VIP VDTN (2010-2012); VIP PRAKTIJKNETWERK DISCARDS (2010-2012)	
33	RESCUE, DISCRAN	06_Solutions	Discards reduction in shrimp fisheries	Marlen et al. 2001
34	Garnalen MSC	06_Solutions	Pilots for reducing discard mortality in shrimp fisheries	IMARES report C116/08
35	Netinnovatie Brievenbus	06_Solutions	reducing discards in shrimp fisheries by net adjustment	Steenbergen et al. 2011
36	Fisheries innovation conference Rdam	06_Solutions	Conference with fishers presenting innovations, amongst others for discards reductions	presentations (http://www.fisheriesinnovationplatform.com/conferences/conferences_rotterdam_2009)
37	SUSUSE	06_Solutions	Model spatial distribution and overquota discarding in the TBB 80 mm fleet	Poos et al. 2010
38	EFIMAS	04 Magnitude	Estimate historic discarding by combining landings, discards observations and scientific surveys	Aarts and Poos 2009
39	Survival of discards	05_Effects		Veen et al. 1975; Van Beek et al. 1989, 1990
40	Fishing Closures	06_Solutions	Evaluation of the Plaice Box	Beare et al. 2010
41	Puntzakanalyse	06_Solutions	Effects of distribution shift of the demersal fleet on plaice discards	Quirijns et al. 2006