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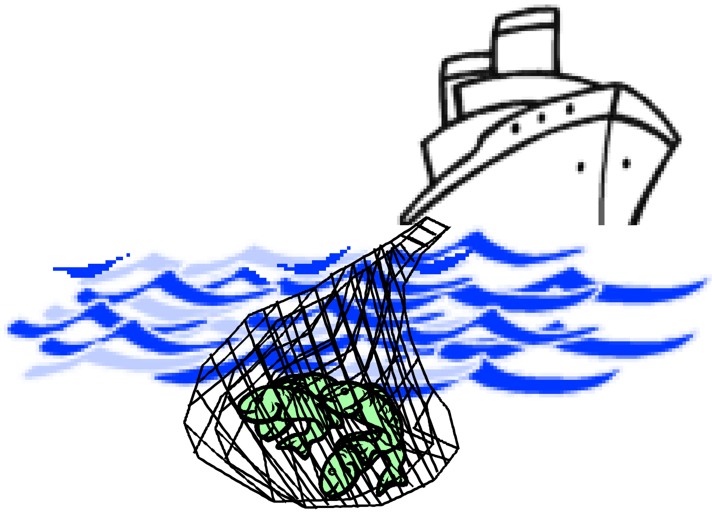

Implementation of fish transport and sailing patterns in NEMO

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ABSTRACT

The national freight transport model in Norway is named NEMO. Until now, transport of fish from the fishing grounds to the landing municipalities has not been included in this model. In a tendering procedure, NTP-Transportanalyser chose SINTEF to implement transport of fish from catching to landing, and the corresponding sailing patterns in NEMO. The implementation is carried out by developing a sub model covering this particular transport. This fishery model handles all transport of fish from the fishing grounds to Norwegian landing municipalities, and describes movements of the fishing fleet.

The developed model covers all catch of wild fish and shellfish, with the exception of river and river systems fishery and foreign vessels. Farmed fish and shellfish, from both land and sea based constructions, are also excluded.

This report describes the structure and main properties of the fishery model. The model has been tested and has proven useful for strategic analysis of fishing harbours. Using the model for assignment of sailing pattern has also been demonstrated.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Transport	Samferdsel
GROUP 2	Model	Modell
SELECTED BY AUTHOR	Freight	Gods
	Fishery	Fiskeri
	Sailing pattern	Fartøybevegelse

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Preface

SINTEF carried out this project on request from NTP-Transportanalyser.

Project manager at SINTEF was Ragnhild Wahl. In addition to Wahl, Solveig Meland and Inger-Anne F. Sætermo constituted the project team, while Eirik Skjetne carried out the quality assurance.

We are indebted to many informants during the project period. In particular we would like to thank Randi Sofie Sletten and Elin Hopland at the Directorate of Fisheries and Ketil Fluksrud at Statistics Norway for providing information and data to the project team. We would also like to thank the many informants in the fishery industry (fishermen, representatives of interest groups, etc.) and representatives in various public administration offices for sharing their trade knowledge and opinions about various aspects of this project.

Trondheim, February 2005

Trond Foss

1 Background and delimitations

1.1 Background

The national freight transport model in Norway is named NEMO. Until now, transport of fish from catching to landing has not been included in the model.

In a tendering procedure, NTP-Transportanalyser chose SINTEF to implement transport of fish from catching to landing, and the corresponding sailing patterns in NEMO. The implementation is carried out by developing a sub model, hereafter named *the fishery model*, in NEMO. The fishery model handles all transport of fish from the fishing grounds to Norwegian landing municipalities, and describe movements of the fishing fleet.

This report describes the work with establishing the fishery model. The main part of the report contains a description of the data sources and methods used. The report also describes results from function tests of the model, represented by two cases and a demonstration of using the model for assignment of vessel movements. Details regarding the model input are put in appendices.

NEMO is composed of four major elements:

1. *Networks*, representing links, zones, transfers, etc. in the infrastructure for road, sea and rail
2. *Cost functions*, representing costs related to freight transport on links and transfers
3. *Annual freight volume matrices* describing transport for 13 different commodity groups between pairs of municipalities on the mainland (domestic transport), between zones on the continental shelf and municipalities on the mainland (offshore transport), and between Norwegian municipalities and abroad zones (transport related to import/export)
4. *Optimization algorithms*, allowing the model to choose the transport solution which minimize total transport costs in the system

A detailed presentation of NEMO is provided by Vold et al (2002) and Madslien and Andersen (2004).

1.2 Delimitations

The fishery model covers all catch of wild fish and shellfish. The following delimitations have been made:

- River and river systems fishery are not included
- Farmed fish and shellfish, both land and sea based constructions, are not included
- Catch registered in the foreign trade statistics is not included[1]. Therefore, catch from foreign vessels and catch delivered directly to non-Norwegian regions is not taken into account.

There are no one-to-one relationships between the landed fish volumes and the consecutive transport volumes from the production facilities to the market. After the fish has been processed and packed, both volumes and product values will have changed. A total implementation of this in NEMO requires a detailed study of the volumes to and from the production facilities, and an elaboration of how to implement this in the model. Harmonization of matrices is also required due to the fact that NEMO matrices are based on transport of production volumes that exceeds consume in one region. This means that only the fish that is not consumed in the landed region

[1] To enable later full integration and simultaneous assignments in NEMO it is important to avoid double-counting volumes

should be considered in a full-integrated NEMO. For these reasons, it was decided to develop the fishery model as a sub model in NEMO.

The land-based domestic network in existing NEMO is based on matrices describing transport between municipalities, as illustrated in the upper box in Figure 1. The fishery model however, is based on matrices describing transport from the fishing grounds to the landing municipalities, as illustrated in the lower box.

	Municipality 1	Municipality 2	Municipality 3	......	Municipality n
Municipality 1					
Municipality 2					
Municipality 3					
⋮					
Municipality n					

	Municipality 1	Municipality 2	Municipality 3	......	Municipality n
Fishing ground 1					
Fishing ground 2					
Fishing ground 3					
⋮					
Fishing ground n					

Figure 1: Model focus

The fishery model covers transport from the fishing ground to the landing municipality only, as illustrated in the lower box in Figure 1.

In this project, actually two variants of the model are established: One describes the distribution of tonnes of fish and corresponds to NEMO. The other describes the sailing patterns (distribution of trips) made by the fishing vessels. This latter model includes all trips – that is, both the transport with fish from the fishing grounds to the delivery harbour and the trips made without fish (from home harbour to the fishing grounds and the return from the delivery harbour to home harbour). The two variants will use the same networks and optimization algorithms, but will have different sets of matrices and cost functions. The unit of the assignment results will differ between the two variants; the first will assign tonnes, while the other will assign trips. Both variants are described in this report.

2 Data sources

2.1 Network

When establishing sea networks for use in strategic models, one of the main challenges is that the vessels will not follow any particular route. Freighters can be assumed to follow defined fairways, but this is not the situation regarding most fishing vessels. Any attempt to establish a traditional network and forcing the vessels to stay on it will result in wrong estimations of travel distance. In the beginning of this project, various solutions regarding construction of a sea network were discussed. In the end it was decided to establish a network with direct links between the fishing grounds and each landing municipality and between the home municipality of the vessels and the fishing grounds. One important reason for this decision was the fact that Statistics Norway had already established a GIS model calculating lengths between the fishing grounds and a set of municipalities based on 1996 statistics from the Directorate of Fisheries. The results from these calculations are already used in official reports (Flugsrud and Rypdal, 1996 and Tornsjø, 2001). The results were made available to us. To establish such a model is very time-consuming and not possible within this project. The estimates from the Statistics Norway model were assumed to be more reliable than any other estimates of distances it would be possible to come up with within the time available in this project. However, the input from Statistics Norway can only be used in networks with direct links. Unfortunately, the estimates from Statistics Norway did not cover all the relations required in the fishery model, so it was necessary to estimate the remaining distances manually.

Another advantage by choosing a network of direct links is that it can be very efficiently established by a simple batch file. This makes it simple to implement and simple to change. The disadvantages of a direct link network are poor plots and poor possibilities of visual presentation of the transport patterns.

An evaluation of the network type is given in section 9.

2.2 OD matrices

Several possible data sources were examined, but in the end it was clear that the statistics produced by the Directorate of Fisheries would constitute our main source of information. This statistics contains information on each landing made by Norwegian vessels and all landing to Norwegian harbours. The figures both describe the characteristics of the catch and characteristics of the vessel that makes the landing. In this project, it was necessary to obtain information on both the catch and the number of trips made by different types of vessels. Usually, one document is filled in per landing, but when there are several buyers or the vessel has been in areas with different quota regulations etc, more than one document are filled in. Thus, there is no one-to-one relationship between the number of documents and the number of trips. In order to calculate these figures correctly and avoid double-counting of tonnes or trips, two separate extracts were made from this statistics.

In addition to the information from the Directorate of Fisheries, we have been in contact with the foreign trade statistics at Statistics Norway and the Directorate of Customs and Excise to clarify the definition of the various catch statistics produced by different organisations. It is important to know exactly what is included and excluded in order to avoid double-counting catch in NEMO.

In order to avoid random fluctuations to influence the results, the estimates were based on average values for 2001 and 2002. During the project period, only preliminary figures for 2003 were available. These preliminary figures will be corrected before the status are changed from preliminary to final - among other things the origin of the catch will be examined, and changes will be done to improve the declaration of fishing grounds. For some of the vessel types this may affect our model input significantly. Hence, it was decided to use average of the final figures for 2001 and 2002 in the model.

When it comes to geographical level of detail, the catch is reported on zone[2] level. Each fishing ground is divided into a set of zones. Maps of the fishing grounds and zones are presented in appendix A. Each zone is the jurisdiction of a country. Hence, a main sector may be composed by zones where several countries have interests. Norway has interests in three categories of zones with the following notation:

- NOR (Norwegian economic zone)
- XSV (protection zone around Svalbard)
- XJM (fisheries zone around Jan Mayen)

The country jurisdiction has not been taken into account in the modelling. All catch by Norwegian vessels landed in Norwegian harbours is included, regardless of origin zone or jurisdiction. The reason for this is that all catch landed in Norway will give load to and put strain on Norwegian infrastructure, and should consequently be taken into account when making plans for fishing harbours.

An important reason for working on main sector level is that the statistics are not very reliable on a more detailed level, in particular for the larger vessels. These vessels often cover several zones on one trip, but the landing documents gives room for only one zone. Hence, it is not recommended to use the statistics on zone level. Furthermore, only a limited number of centroids can be included in NEMO. Thus using the smaller fishing areas for zones in NEMO would exceed this limit.

The Directorate of Fisheries continuously works on improving the quality of the statistics. At present, details about the actual harbour receiving the catch are being implemented. However this work is not completed, so for now it is only possible to point out the place of landing by municipality.

2.3 Costs

The cost functions already implemented in NEMO have formed the basis for the cost functions applied in the fishery model. NEMO contains of 13 commodity groups, where group 1 is general food (including fish that is not fresh or frozen), group 2 is frozen fish, and group 11 is fresh fish. To have consistency, the cost functions in the fishery model should not deviate too much from the corresponding cost functions already implemented in NEMO. The cost functions must be compared and calibrated to avoid unexpected and unreliable choices of transport solutions in future simultaneous network assignments. The existing cost functions were studied carefully and cost terms were adjusted only when better and more relevant information for the particular transport of fish by fishing vessels was found.

Several phone calls and contacts to various producers of vessels, interest groups and industrial bodies etc were made, but it was very difficult to find figures on time-dependent or distance-

[2] Be aware that “zone” in this aspect is not equivalent with the “NEMO zones”, presented in section 6.2.

dependent costs for this particular type of transport. Finally, average estimates[3] of speed, use of fuel, insurance and vessel maintenance were calculated based on combining results from Statistics Norway (Flugsrud and Rypdal, 1996 and Tornsjø, 2001) and the profitability analysis from the Directorate of Fisheries. The assumptions and conclusions have been presented and discussed with fishermen to have their opinion and trade knowledge on discounts on fuel etc.

[3] The costs are in 2002 prices in order to match the OD matrices in the fishery model. It is important to notice that this does not correspond with the time basis for matrices and prices in existing NEMO. Analysing results of simultaneous assignment of all commodity groups should take this into account.

3 Commodity groups

There are numerous species of fish and shellfish. Various principals for categorization of collected data have been discussed, and the following four categories were chosen due to their relatively homogeneous character from a logistical point of view:

a. Pelagic fish (mackerel, herring, sardinellas, anchovy, blue whiting, etc.)
b. Other fish (salmon, trout, tuna, redfishes, halibut, flounders, cod, pollock, catfish, etc.)
c. Prawns
d. Other shellfish and molluscs (krill, crab, lobster, oysters, clams, scallops, squid etc.)

The logistical homogeneity will be reduced when aggregating the groups. A detailed description of the various fish species in each of the four categories is given in appendix B.

As already mentioned, in the existing version of NEMO there are already three commodity groups that involve fish:

- Fresh fish in commodity group 11
- Frozen fish in commodity group 2
- Processed fish in commodity group 1

In order to reflect these principles in the fishery model, it was decided to use similar categories of conservation:

- Fresh fish (fresh, ice-covered, rfw/rsw/sws[4] in tank)
- Frozen fish (frozen, boiled in brine, etc)
- Other (smoked, salted, dried, etc.)

A detailed description of the various ways of conservation belonging to each of these categories is given in appendix C.

The two dimensions of fish category and conservation gives altogether 12 OD matrices. Ideally, for planning of strategic fishery harbours this level of detail would ensure possibilities for landing of all types of fish in the fishery model. However, the existing OD matrices for each commodity group are separated in domestic and international flows. Hence, already 26 matrices are included in the NEMO data bank to describe this transport (Madslien and Andersen, 2004), and it will not be possible to simultaneously assign 12 more matrices. Thus, the matrices are aggregated to reflect the three main categories of conservation.

It is defined three new commodity groups for use in the fishery model:

- Commodity group 14: Fresh fish catch[5] (includes fresh products of pelagic, other fish, prawns, other shellfish and molluscs, numbered a-d above)
- Commodity group 15: Frozen fish catch[6] (includes frozen products of pelagic, other fish, prawns, other shellfish and molluscs, numbered a-d above)
- Commodity group 16: Other fish catch[7] (includes other conservations of pelagic, other fish, prawns, other shellfish and molluscs, numbered a-d above)

One main reason for introducing new commodity groups is that transport of fish from catching to landing cannot be done by land-based modes. In order to allow the pricing out of land-based

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[4] Rfw: refrigerated fresh water, Rsw: refrigerated sea water, Sws: Seawater slush
[5] Norwegian: Fiskefangst fersk
[6] Norwegian: Fiskefangst frosset
[7] Norwegian: Fiskefangst annet

modes for catch of fish, the catch must be defined as separate commodity groups. In the existing NEMO commodity groups 1, 2 and 11 are allowed to use all modes in the model. Thus, when simultaneously assigning all commodity groups, fish catch cannot be excluded from the land-based modes if not defined as separate commodity groups. To allow this commodity to use land-based modes would result in unrealistic mode use. For separate assignments of fish catch, it would be necessary to change cost functions related to commodity group 1, 2 and 11 to make them better reflect the characteristics of fish catch. However, such changes must be removed before assignments of the original commodity groups can be done. By introducing separate commodity groups for fish catch, the problem with land-based modes and mixing of cost functions are avoided.

4 Fishing vessels

Making a consistent and clear categorization of the fleet turned out to be difficult. Even the Directorate of Fisheries uses various groupings dependent on the type of information that is to be presented. Initially, we wanted information reflecting the vessels with various sailing patterns:

- Vessels with ring nets (mainly pelagic fishery), recognised as a dynamic fleet (mostly industrial catch), and characterised by long distances and unpredictable routes due to selling of fish by auctions
- Fresh fish trawlers with trips of 7-10 days length
- Factory trawlers that can have trips of 6 weeks length
- Smacks that will return with the catch on the same day

It was necessary to compromise based on what we initially wanted and what could be established from official statistics. The vessels were therefore categorized by the two dimensions: fishing tool and length of the vessel.

In earlier studies, 28 meters has been used to separate the coastal fishing fleet from the deep sea fishing fleet. It was decided to use 28 meters to separate these two fleets also in the fishery model. For further grouping, the vessels were categorized by the type of tools used to catch the fish. Four tool categories were used:

- Seine
- Trawl
- Conventional
- Other

The two dimensions length and tool category will in theory give 8 combinations describing the trip patterns. However, no vessel of length over 28 meters has reported catch by any other tool than seine, trawl or conventional tools, so in practice there are only 7 combinations present in the data material

Due to capacity restrictions in NEMO, it was necessary to aggregate the information during implementation. The representation of fishing vessels in the model is presented in section 6.1.

5 Overall statistics

5.1 Transport of fish

In total, the data material holds information about catch reported from 56 different fishing grounds. The geographical distribution on fishing grounds of various types of catch can be seen in appendix D. The fish is landed to 213 municipalities. Table 1 presents the distribution of catch by the various categories defined by fish type and conservation method.

Table 1: Average catch quantities per year) per fish type and conservation method*

	Fish type				
Conservation method	Pelagic [tonne]	Other fish [tonne]	Prawn [tonne]	Other shellfish [tonne]	Total [tonne]
Fresh	1 774 315	64 767	49 968	1 159	1 890 208
Frozen	36 697	194 239	5 552	1	236 489
Other	20 486	304 005	92	4 119	328 702
Total	1 831 498	563 011	55 612	5 279	2 455 400

*) Average of 2001 and 2002

As seen in Table 1, the conservation method varies between the fish types. For *Pelagic* fish the main part, about 97%, is landed fresh. Also for *Prawns* the main part (90%) is landed fresh. *Other shellfish* mainly consists of crabs, while *Other fish* is mostly pollock and cod. For these categories the main part of the catch is landed with conservation method “other”, which means that the catch is smoked, salted, dried or similar.

5.2 Freight matrices

This section gives a brief presentation of comparison of freight matrices including fish in the existing NEMO model and the new fishery model.

As mentioned, the NEMO commodity groups 2 and 11 represent frozen and fresh fish respectively, while commodity group 1 consists of other categories of food, including fish which has undergone other kinds of processing. The fishery model introduces three new commodity groups: fresh fish catch (commodity group 14), frozen fish catch (group 15) and other fish catch (group 16). Intuitively, it can be worthwhile to compare the volumes on commodity groups 14 and 15 with the corresponding in the NEMO model, commodity groups 2 and 11. The other food products in NEMO cannot be directly compared to the other fish catch category in the fishery model, and these are therefore left out from this section.

The NEMO fish matrices hold information of about nearly 6.2 million tonnes of fish products shipped <u>from</u> Norwegian municipalities (see Table 2).

Table 2: Volumes (1000 tonnes) from Norwegian municipalities in domestic and foreign trade matrices for existing NEMO commodity groups for fish

	TOTAL			Of this: Internal in zone			Resulting for assignment		
In NEMO	Domestic	Foreign	SUM	Domestic	Foreign	SUM	Domestic	Foreign	SUM
Fresh fish (11)	1 690.190	525.302	2 215.492	478.990	0.000	478.990	1 211.200	525.302	1 736.502
Frozen fish (2)	2 948.967	993.166	3 942.133	578.167	0.000	578.167	2 370.800	993.166	3 363.966
SUM	4 639.157	1 518.468	6 157.625	1 057.157	0.000	1 057.157	3 582.000	1 518.468	5 100.468

Roughly 1/3 of this volume is fresh and 2/3 is frozen fish. Slightly more than 1 million tonnes are excluded from the network assignment in NEMO, as the origin and destination zone is the same. Thus, some 5.1 million tonnes of fresh and frozen fish is assigned to the network in the NEMO model.

The matrices in the fishery model hold information about fish catch transported to Norwegian municipalities from the fishing grounds (see Table 1). The freight matrices in the fishery model are given in units of 1000 tonnes. Volumes in freight matrices are also given in Table 1 in section 5.1).

The volumes for fresh and frozen fish in Table 2 and Table 1 differ considerably. There are several reasons why the volumes in the respective matrices for fresh and frozen fish cannot be expected to be equal:

- The figures in Table 2 include fish from fish farms, whereas the figures in Table 1 comprise wild fish only – no products from fish farms.

- The conventional NEMO fish matrices hold information about fish which has been processed in one way or another. Depending of type of processing, the weight of the final fish product may be reduced to only a fraction of the live weight of the fish. For example, for Norway haddock, the conversion factor from fillet (without skin and bones) to live weight is 4.77[8], indicating an estimated weight loss of nearly 80%.

- In the estimation of the NEMO matrices, all consumption of a commodity within a zone is assumed to be based on the production of the same commodity within the zone. Freight of a commodity between zones occurs only where the estimated production and consumption of a commodity within a given zone differ in volumes. Any excess production is exported to other zones, while lack of, or too low production, leads to import from other zones. Any zone-internal freight is not assigned in STAN – only freight from and to zones.

- The processing of the catch after it has been delivered, may lead to a shift in category. E.g. fresh catch in the fishery model may be forwarded as frozen fish products in NEMO. As long as the current NEMO matrices do not supply information about the total volumes of fish within NEMO (fresh, frozen and other categories), it is not possible to make a useful comparison of volumes between the two models.

5.3 Vessel transport pattern

It have been constructed matrices describing the vessels' round trip from their home municipality to the fishing ground, from the fishing ground to the landing municipality, and the return from the landing municipality to their home municipality. As mentioned, catch is registered from 55 different fishing grounds to 213 various municipalities. These landings are made by vessels from 251 various home municipalities.

Table 3 shows the number of estimated landings by vessel characteristics of length and tool.

[8] Fiskeridirektoratet: Norske omregningsfaktorer, versjon IV, gjeldende fra 1/11-2003.

Table 3: Average number of estimated landings) per length and tool category*

Vessel category	Seine	Trawl	Conventional	Other	Total
	Tool category				
Length under 28m	6 912	23 005	182 487	29	212 432
Length over 28m	2 854	8 396	2 477	-	13 727
Total	9 766	31 401	184 964	29	226 158

*) Average of 2001 and 2002

As shown, most landings are made by the smaller vessels with trawl or conventional tools. The number of landings made by these two categories alone constitutes about 91% of all landings. However, there are large differences in the quantities delivered by the smaller and the larger vessels. Table 4 shows the number of tonnes delivered per category of vessel.

Table 4: Average number of tonnes) per length and tool category*

Vessel category	Seine	Trawl	Conventional	Other	Total
	Tool category				
Length under 28m	308 942	31 093	262 346	27	602 409
Length over 28m	765 045	1 011 030	76 916	-	1 852 991
Total	1 073 987	1 042 123	339 262	27	2 455 400

*) Average of 2001 and 2002

According to Table 4, the main part of the catch is delivered by the larger vessels with seine and trawl. A comparison between the two previous tables indicates that the larger vessels will deliver significantly more tonnes per landing than the smaller vessels. The size of an average landing for each length category is calculated and presented in Table 5.

Table 5: Average number of tonnes) per landing*

	Tool category				
Vessel category	Seine [tonnes/landing]	Trawl [tonnes/landing]	Conventional [tonnes/landing]	Other [tonnes/landing]	Total [tonnes/landing]
Length under 28m	45	1	1	1	3
Length over 28m	268	120	31	-	135

As shown in Table 5, the larger vessels with seine or trawl deliver by far the most tonnage per landing.

6 Network

Due to limited remaining capacity in the data bank in existing version of NEMO, a new data bank with extended capacity had to be established. An overview of the main data bank characteristics is presented in Table 6.

Table 6: The NEMO data bank, new capacity and estimated requirements

	Existing NEMO			Estimated new requirements			
Data item	Status	Max	Free capacity	Fishery part of the model	Model Total	New NEMO version extended to	Max in license 6
Centroids	502	530	28	55	557	600	1 200
Conventional nodes	4 308	5 469	1 161	150	4 458	5 000	6 000
Links	15 957	17 000	1 043	3 450	19 407	24 000	24 000
Transfers	10 605	20 500	9 895	316	10 921	24 000	24 000

6.1 Mode

Fishing vessels are allowed to use the harbours and links defined in the NEMO short sea network, where this has been defined. The short sea network mode is named **s.** For additional network needed in the fishery model, a new network mode **t** has been defined. Using only the s mode would not allow us to exclude other commodity groups access to the fishery part of the network, which is necessary in order to produce realistic model assignments. The t mode was introduced in order to control that only fishing vessels were able to use the network.

The t mode is linked to the short sea network in harbours or at the closest short sea node (see section 6.5).

6.2 Fishing grounds (zones)

Fishing grounds are indexed with a 4-digits code in the statistics. The first two digits state in which main area the fish has been caught (named fishing grounds in section 2.2). The last two digits represent a further division of the grounds (named zones in section 2.2). In the model, the fishing grounds are represented by the first two digits only.

There are a total of 98 fishing grounds on a two-digit level, whereof only 55 are being used by the catch landed in Norwegian harbours by Norwegian fishing vessels. Each of these main fishing areas (and a few more for practical reasons) was defined as a zone in NEMO. 61 fishing zones are defined, with centroid numbers 2400 – 2481, the two last digits corresponding to the main fishing area number. For each of the 61 fishing zones, a corresponding node was defined. These nodes are numbered 24000 – 24081, with the two last digits corresponding to the main fishing area number. Appendix E gives an overview of the numbering of each fishing ground, centroids and nodes.

6.3 Fishing harbours (nodes)

Localisation of landing harbour is reported on a municipal level. Thus, municipalities are being used as the zone level in the model. This corresponds to the structure of the existing NEMO. Some new harbours had to be defined in NEMO:

- 92 new harbours were defined in zones where there was no harbour defined in the existing NEMO network
- 2 new harbours were defined in zones with too few available transfers in the defined harbour (Kristiansand and Bergen)
- Node numbers for the new harbours are 22301 – 22394

6.4 Links

A total of 3 069 new links have been added to the NEMO data bank. All links which will be used by vessels with catch (links from fishing zones to delivery zone) are defined by link type 931, while the remaining links, primarily to be used by empty vessels sailing from delivery harbour to home harbour or from home harbour to fishing zones, are defined by link type 930. Table 7 presents an overview of the links added to the NEMO data bank.

Table 7: Link description

Link description	mode	link type	function set	N. of links
Connector out of fishing zone	t	931	31	61
Link from fishing area to delivery harbour	t	931	31	1 253
Connector from new delivery harbour to delivery zone	t	931	33	79
Connector from delivery zone to new delivery harbour	t	930	32	79
Links between new harbours and short sea network	t	930	30	180
Connectors from home harbour to home zone	t	930	32	14
Connectors from home zone to home harbour	t	930	32	14
Link from home harbour to fishing area	t	930	30	1 328
Connector into fishing zone	t	930	30	61
TOTAL				3 069

A graphical plot of the new links of mode t, link type 931, is presented in Figure 2.

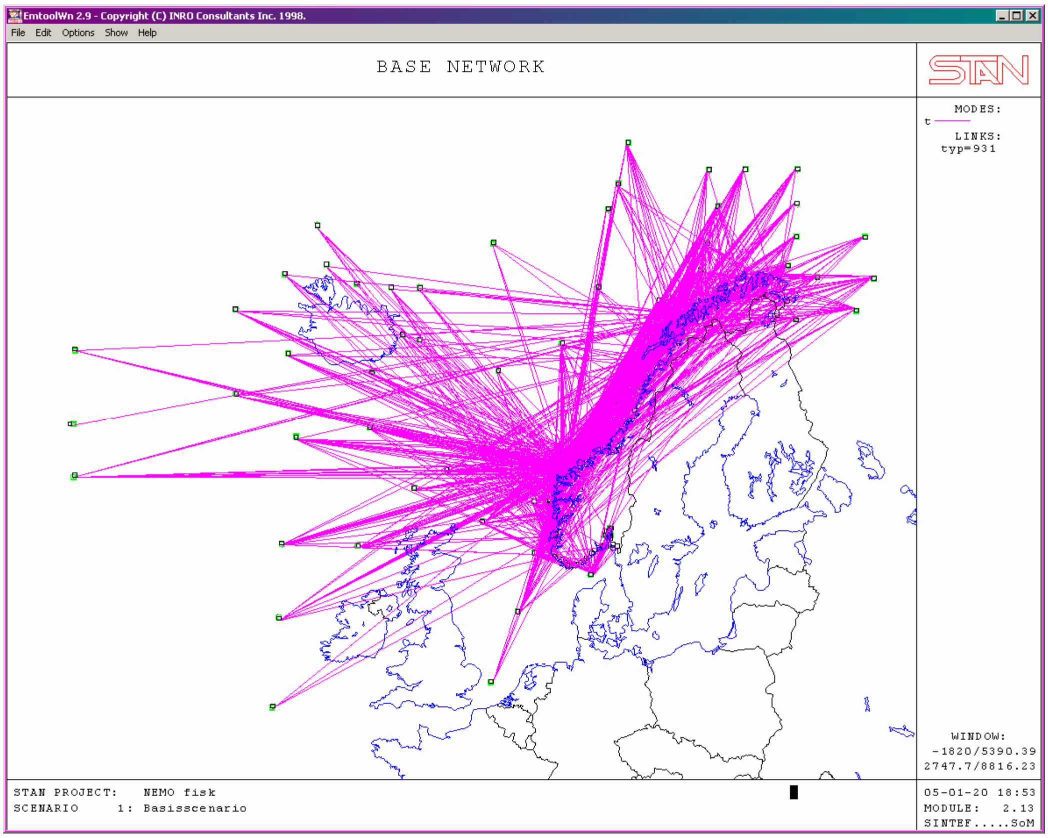

Figure 2: New links of mode t, link type 931, defined in NEMO

As illustrated in Figure 2, the new parts of the network are not well suited for illustrating the total picture, with all pairs of fishing zone and delivery zone in the same plot. If one reduces the number of relations, the picture gets less blurred, as shown in Figure 3.

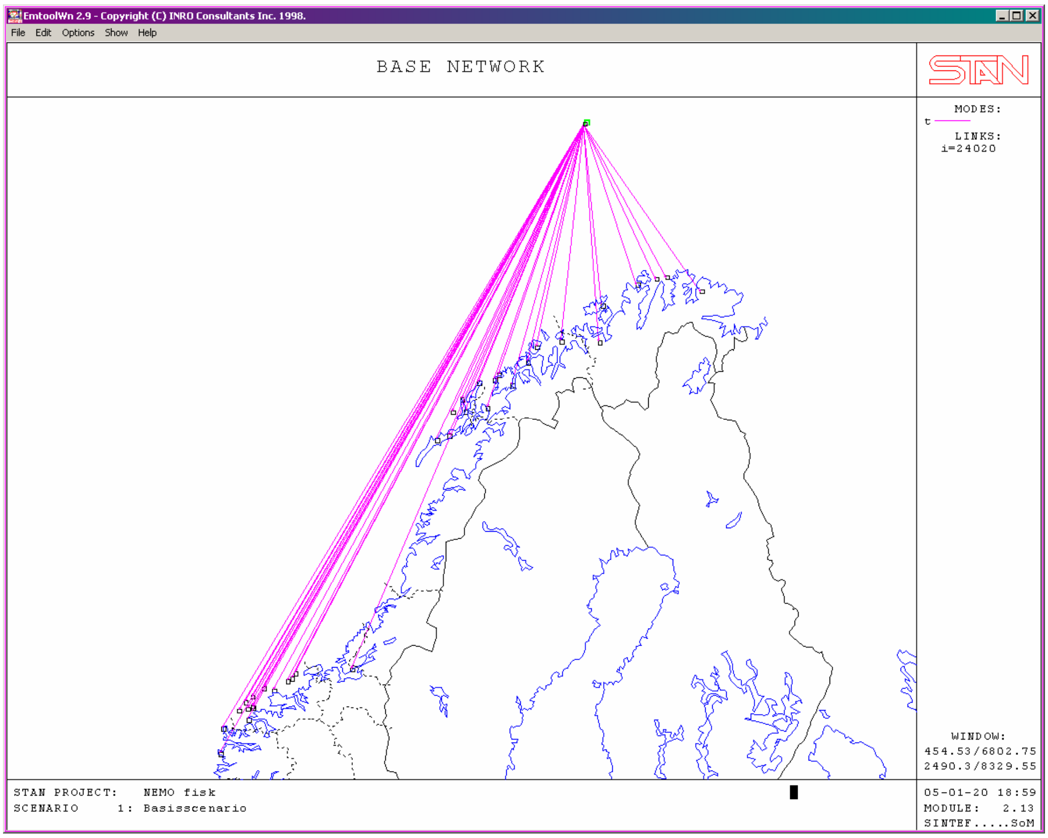

Figure 3: New links of mode t, link type 931, from NEMO fishing zone 24020, (Bjørnøya)

Link length

As mentioned in section 2.1, sailing distances (link length) for many of the OD relations used in the model have been estimated by Statistics Norway. A GIS based model has been used for this purpose. Some of the fishing grounds cover zones in both coastal and deep sea areas, and for some of these, Statistics Norway had estimated separate link lengths from the freight centre of gravity in both coastal and deep sea area of each fishing ground. However, only one length per fishing ground can be implemented in the fishery model. This has been solved by using the average link length for links with two length estimates.

The distance estimates from Statistics Norway did not cover all relevant pairs of fishing zone and delivery zone. Out of 1591 relations in the freight matrices, distances were still missing for 831. These lacking distances have been estimated manually by SINTEF, using the freight centre of gravity in each fishing ground as basis.

In addition to the combinations of fishing zone and delivery zone, the model should also include all combinations of home harbour to fishing ground (trips with empty vessels). A total of 1374 relations used for trips from home harbour to fishing ground were lacking distance. These distances have been set to the nearest known distances gained from the GIS based method or the manual estimation.

Table 8 presents an overview of the different link length estimation.

Table 8: Link length estimation

Number of links	Distance estimated by	Estimation method	Distance quality
760	Statistics Norway	GIS based method based on real OD relations from each location within each main fishing ground	Good
831	SINTEF	Manual estimation based on one point representing centre of gravity within each fishing ground	Medium
485	SINTEF	Automatic estimation by using known distances[9] to neighbour harbours	Medium
584	SINTEF	Automatic estimation by using known distances[8] to further away neighbour harbours	Medium / poor
305	SINTEF	Manual estimation by using the nearest known distance[10]	Poor

As indicated in Table 8, the quality of distance estimates varies a lot. Statistics Norway provides the best estimates, while the manual and automatic estimations made by SINTEF represent lower quality due to a less sophisticated estimation method and less detailed available input data. The last row in Table 8 represents the poorest quality on distance estimates. These are distances which cannot be defined by any of the manual estimations (second row) or by using any of the defined neighbour harbours (third and fourth row).

Link speed

Average speed is 14.8 km/h for coastal vessels (<28m) and 20.4 km/h for deep sea vessels (>28m).

[9] "Known distance" are distances gained from the GIS based method or the manual estimation method.
[10] This method is used for the distances which cannot be estimated by any of the other methods. The nearest harbour with a known distance can be located far away from the destination harbour.

Link speed on the short sea network (mode s) is 18.5 km/h. Due to the allowance for fish transport to use this network as well, the same link speed has been chosen for mode t. The speed is later adjusted by a correction factor in the cost functions on links (see section 7).

6.5 Transfers

Transfers between the fishery (t) and short sea (s) networks have been defined for all existing and new harbours. A total of 2 181 transfers have been defined between the two modes, of which 1 121 accommodate shift from the fishery to the short sea network, and the remaining 1 060 transfers allow shifts from short sea to fishery links.

Transfers had to be defined differently for the already existing harbours, and for the harbours which had to be defined especially for the fishery model. Figure 4 and Figure 5 show the main principles for the definition of transfers in the two situations respectively, with the movements and transfers allowed between the sea modes s and t in the model. There are no costs related to the transfers.

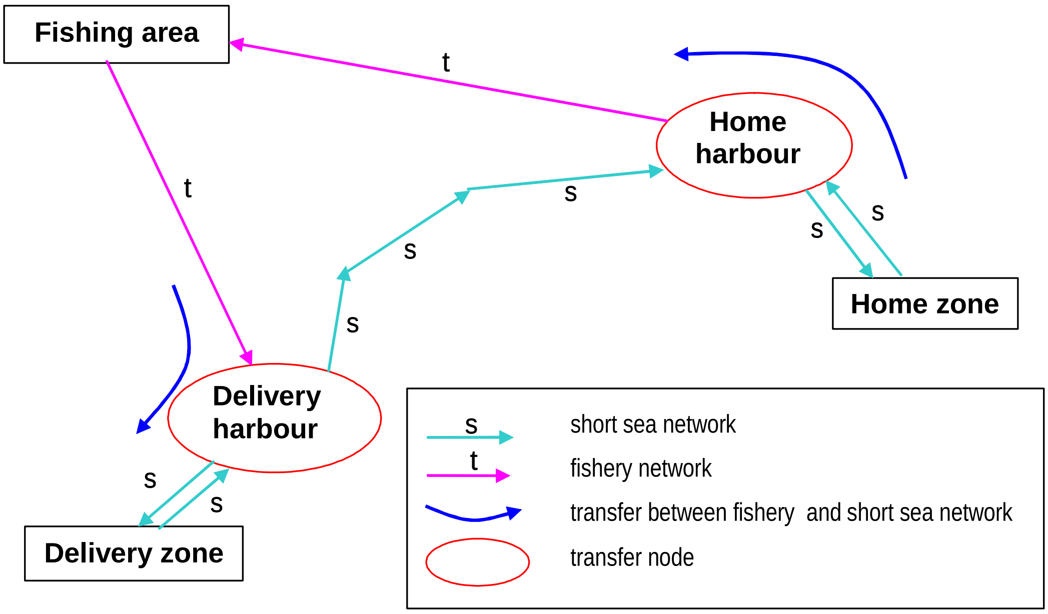

Figure 4: Fishing and short sea network connections at existing harbours

At existing harbours (Figure 4), transfers in both directions have been defined in the harbour. At new harbours (Figure 5), transfers in both directions have been defined in the nearest node in the short sea network. At these harbours links for connecting the harbours to the zone centroids (named “Home zone” and “Delivery zone” in the figure) have been defined.

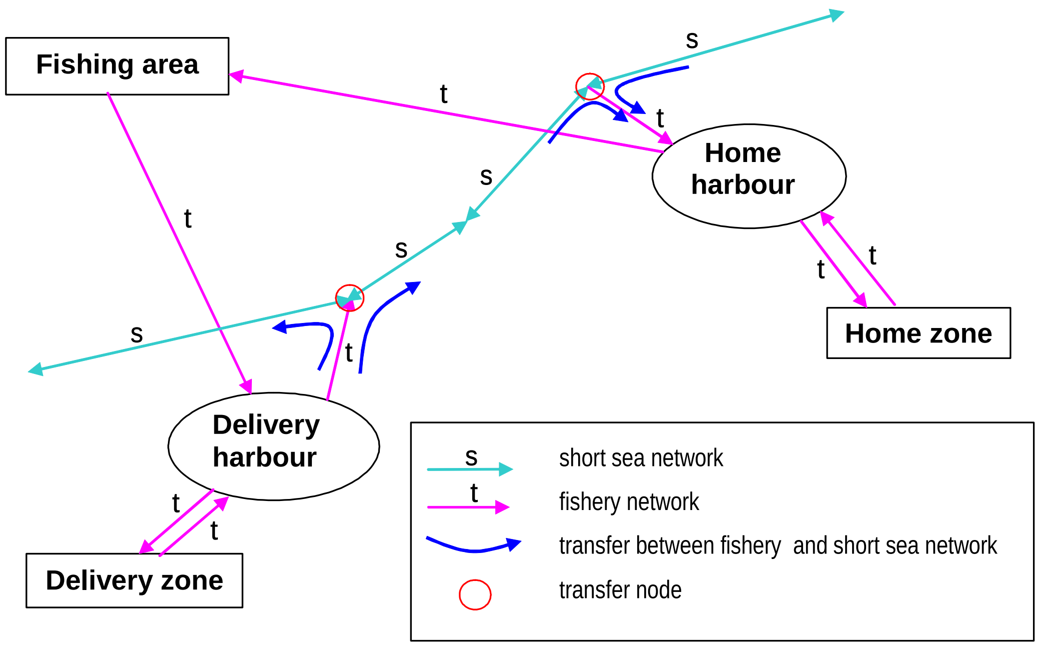

Figure 5: Fishing and short sea network connections at new harbours

7 Cost functions

As mentioned, the basis for the cost functions for the new links was the already existing cost functions in NEMO. The most relevant functions for the transport covered in the fishery model were the costs related to mode s and commodity groups 1 (food), 2 (frozen fish) and group 11 (fresh fish). A general description of cost functions and their parameters in NEMO is presented in Madslien and Andersen, 2004. The following presentation includes changes and considerations concerning the specific elements in the functions and the parameter values. A total presentation of the cost functions (including both function sets and parameter values) is given in appendix G.

7.1 Link cost

It is necessary to adjust the speed-dependent costs on links. As mentioned in section 6.4 weighted average link speed for fishing vessels is 18.2 km/h. The weighting is based on the total calls for each vessel category. The corresponding link speed in the network is 18.5 km/h, and a correction factor in the link cost function is therefore introduced.

The relevant element in the cost functions is related to the calculation of travel time on the link[11]:

length / (ul1 * ul2)

Where

ul1: Factor that adjusts the speed at the link (is multiplied by ul2). Default value=1
ul2: Speed at the link [km/hour]

Both ul1 and ul2 are specified directly on each link. Because fish catch is allowed to use both network mode s and t, the specification for network mode t uses the same parameter values as for mode s. Thus, the correction factor is added to the same element in the cost function for both modes. This gives the resulting cost function element:

length / (ul1 * ul2 * 18.2/18.5)

It can be argued that the effect of the correction factor is negligible. However, it has been introduced in order to establish the structure and allow for potential larger adjustments in the future.

7.2 Vehicle[12] cost

Four cost parameters on vehicles are relevant:

- uv1: Distance dependent operative cost (NOK/tonnekm)
- uv2: Time dependent operative cost (NOK/tonne and hour)
- uv3a: Handling cost in the centroid (NOK/tonne)
- uv3b: Time used for loading/unloading in a centroid (hour)

uv3a and **uv3b** have not been adjusted in the fishery model. The same parameter values as for mode s have been used.

[11] The various cost functions are defined by different elements. Thus, the cost function element presented here represents one of the “building stones” in the cost functions.
[12] Vehicle is the NEMO nomenclature for all kinds of vehicles, vessels, rails, etc. In the fishery model, vehicles will be the NEMO term for fishing vessels.

Distance-dependent costs on vehicles

In the estimation of this parameter value, costs of fuel, maintenance of the vessel and vessel insurance have been taken into account.

Statistics Norway provided a worksheet giving input parameters for their calculations of emission (Flugsrud, K. and K. Rypdal (1996)). Among these parameters were estimates on average speed for different types and sizes of vessels on their way from the fishing grounds to the landing municipalities, and also estimates on corresponding fuel use. From this a weighted average speed and resulting fuel use were calculated for vessels under and over 28 meters respectively (column “Fuel consumption” in Table 9).

Statistics from the Directorate of Fisheries formed the basis for calculation of average landing sizes in tonnes (column “Average landing” in Table 9). In addition, fishermen have been contacted to get a realistic estimate (including common discounts) of costs per litre of fuel. The resulting estimations of costs per tonne-km related to fuel use are shown in column “Fuel costs” in Table 9.

Table 9: Input for estimation of costs per year related to fuel use

Vessel category	Fuel consumption [l/km]	Average landing [tonnes]	Fuel costs [NOK/tonnekm]
Length under 28m	1.38	3	0.09
Length over 28m	6.42	135	0.04

The Directorate of Fisheries produces a profitability analysis each year. From this it is possible to extract key figures on cost elements like fuel, maintenance and insurance for various categories of vessels. The available figures and calculated weighted average cost for maintenance and insurance have been used to get an estimate of the costs. For use in conversion from total cost to cost per tonnekm, weighted average cost for fuel has also been calculated based on this statistics. These input data are shown in *Table* 10.

Table 10: Input for estimation of costs per year related to maintenance and insurance of vessel and fuel

Vessel category	Maintenance [NOK]	Insurance [NOK]	Fuel [NOK]
Length under 28m	144 850	33 930	73 703
Length over 28m	1 964 665	340 512	1 881 899

By comparing the figures for fuel costs (column “Fuel” in *Table* 10) with the estimates based on figures from the Statistics Norway (Table 9), an estimate of maintenance and insurance costs per tonnekm can be obtained. The various cost elements are summarized in Table 11.

Table 11: Estimated cost elements

Vessel category	Fuel [NOK/tonnekm]	Maintenance [NOK /tonnekm]	Insurance [NOK /tonnekm]	Total [NOK /tonnekm]
Length under 28m	0.086	0.172	0.040	0.300
Length over 28m	0.043	0.045	0.008	0.096

The overall weighted total (based on information of population in the profitability statistics) is 0.265 NOK/tonnekm. The corresponding values in the existing cost functions for commodity group 1, 2 and 11 in NEMO are:

- 0.069 NOK /tonne for food
- 0.063 NOK /tonne for frozen fish
- 0.063 NOK /tonne for fresh fish

Different cost parameters for the three commodity groups can be explained by the heterogeneity of the commodity groups. “Food” is a very wide group and includes all kinds of food except frozen or fresh fish. It is therefore expected that cost parameters for food differ from the cost parameters for fish. In the fishery model, the category “other conservation” is assumed to have much in common with fresh and frozen fish, so it was decided to use the same cost parameter for all three commodity groups 14, 15 and 16. Thus, the cost parameter **uv1** is set to 0,265 for commodity group 14, 15 and 16.

Time-dependent costs on vehicles
A similar argumentation has been used for the time-dependent operative costs on vehicles. We do not have data for recalculating the costs, but we argue that the time-dependent cost should be similar for all three commodity groups in the fishery model. Thus, we have chosen the value for commodity group 2 and 11 (frozen and fresh fish) to be used for the commodity groups 14, 15 and 16. The cost parameter **uv2** is therefore set to 13.8 NOK/tonnekm).

Costs on vehicles with catch versus empty vehicles
Costs on vehicles are related to costs per tonnekm. This cost unit is not relevant for trips with empty vehicles, due to the lack of tonnes. NEMO is primarily developed for assigning freight transport, thus the existing NEMO does not include empty vehicle movements. However, we are asked to do an assignment of trips made by empty vessels. There is a lack of input data which separates costs on empty vessels and vessels with catch. Thus, average costs per tonnekm representing an average of empty trips and trips with catch, has been applied.

8 Function test

The model has been tested on two situations:

- Scenario 0: Current situation
- Scenario 1: Reduction in number of fishing harbours

According to requests from NTP-Transportanalyser, the function test of the fishery model also includes sailing patterns.

A limited numbers of plots are presented in this section. Additional plots are presented in appendix G (scenario 0) and appendix H (scenario 1).

8.1 Scenario 0: Current situation

The current situation uses the base network, which includes all harbours and links implemented in the fishery model. Table 12 shows the tonnekilometres assigned to the network for each of the three commodity groups.

Table 12: Total tonnekm assigned to modal links for each category of fish catch

Mode	Fresh fish catch	Frozen fish catch	Other fish catch	Total
l	.0	.0	.0	.0
s	630.5	54.3	45.0	729.8
t	1 048 652.0	171 920.6	50 744.3	1 271 316.0
Total	1 049 282.0	171 974.9	50 789.3	1 272 046.0

Figure 6 presents a plot of assignment of total amount of fresh fish (commodity group 14) on the base network.

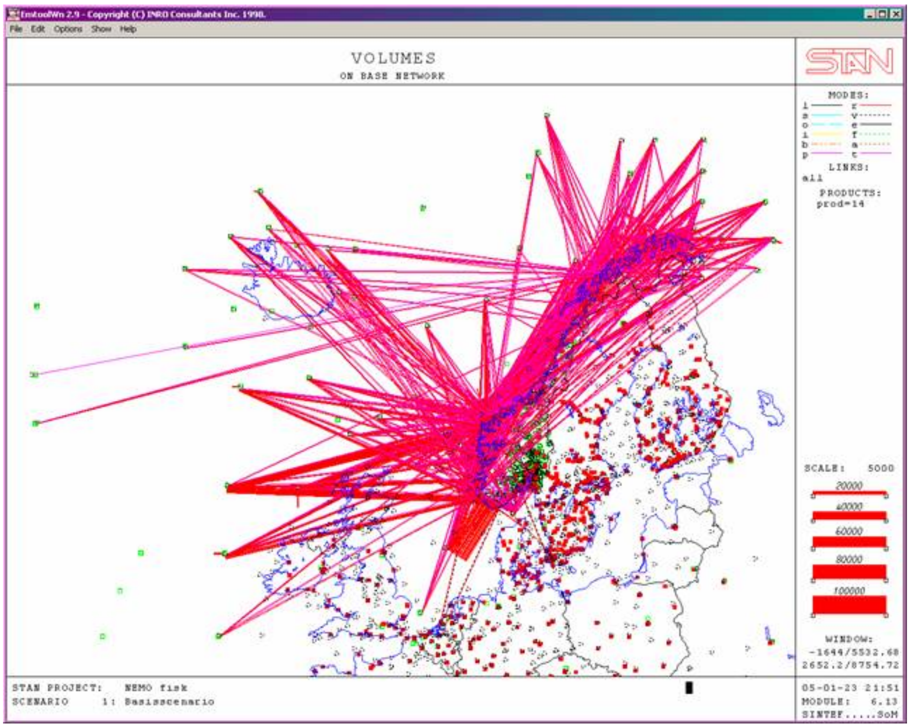

Figure 6: Assignment of fresh catch fish on base network

Due to the direct link network, visual presentation of total assignments like the one in Figure 6, is somewhat confusing. However, the figure shows that many links are used in the assignment, and that the single most important links regarding landing of fresh fish (measured in volumes) are related to the southern part of Norway.

Figure 7 presents an easier readable plot of assignment of all catch fish from one single fishing ground, Bjørnøya. The figure shows that fish catch from Bjørnøya is landed in many municipalities along the Norwegian coast.

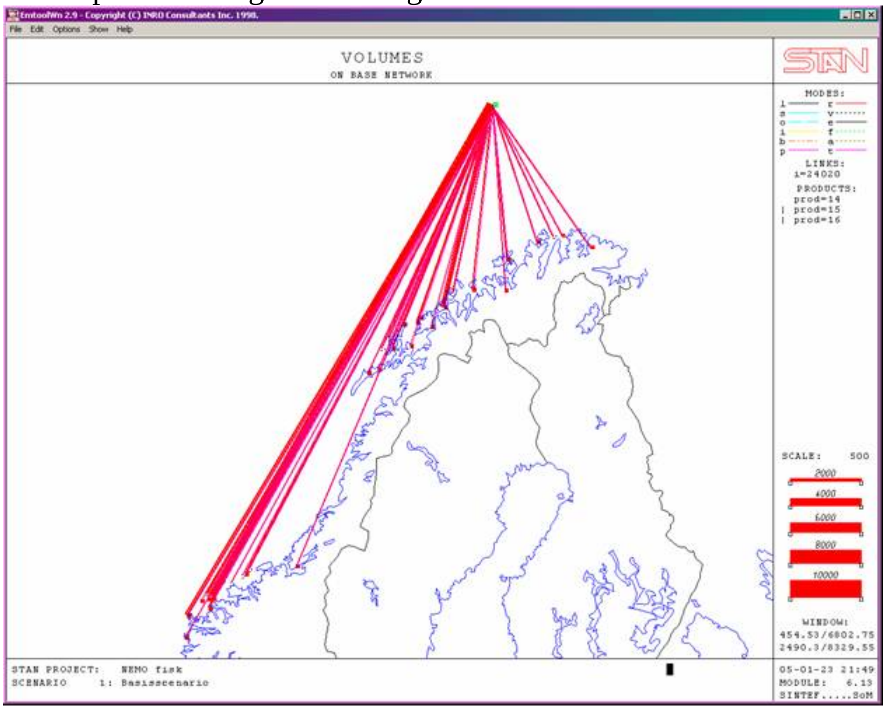

Figure 7: Assignment of all catch fish from Bjørnøya on base network

The fishery model can also be used for illustrating differences in volumes. Figure 8 illustrates the differences in volumes of fresh fish catch and frozen fish catch, commodity group 14 and 15 respectively, from one single fishing ground, Egersundsbanken.

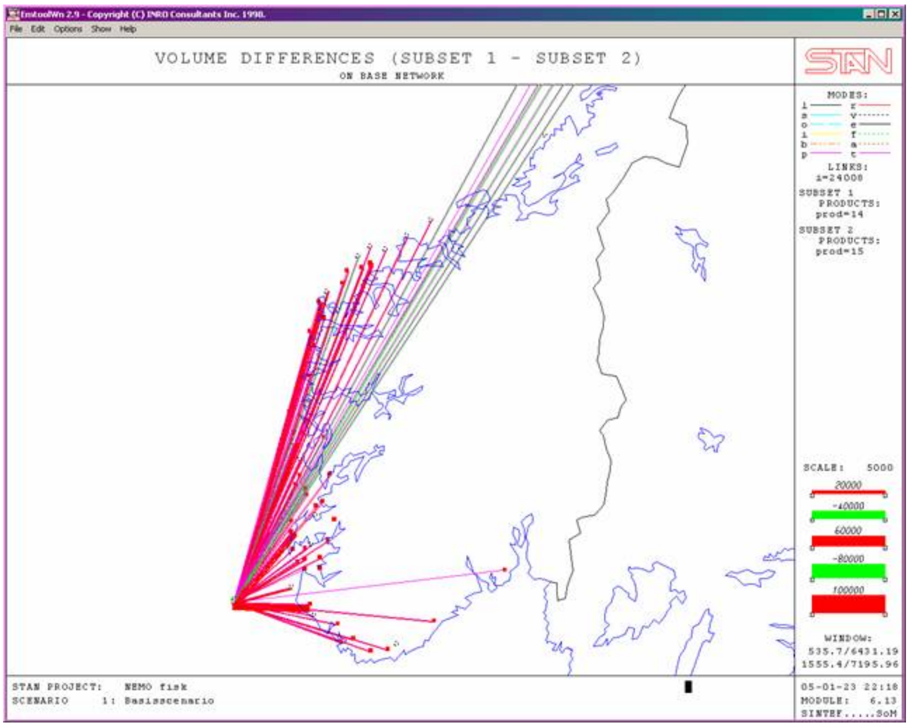

Figure 8: Assignment of the difference in fresh catch fish and frozen catch fish from Egersundsbanken on base network

The red lines indicate majority of fresh fish, while the green lines indicate majority of frozen fish. The figure shows that fresh fish is landed in the nearby harbours to a larger extend than frozen fish. This is an expected result, due to the fact that time-dependent costs on fresh fish exceed the respective costs on frozen fish.

As mentioned in section 5.2, the volumes of fish products in the existing NEMO matrices do not necessarily match the volumes of the new fish catch matrices. This is illustrated in Figure 9, showing the volumes of fresh fish catch delivered into the municipality of Eigersund from the fishing grounds, and the volumes of fresh fish products shipped from the same zone.

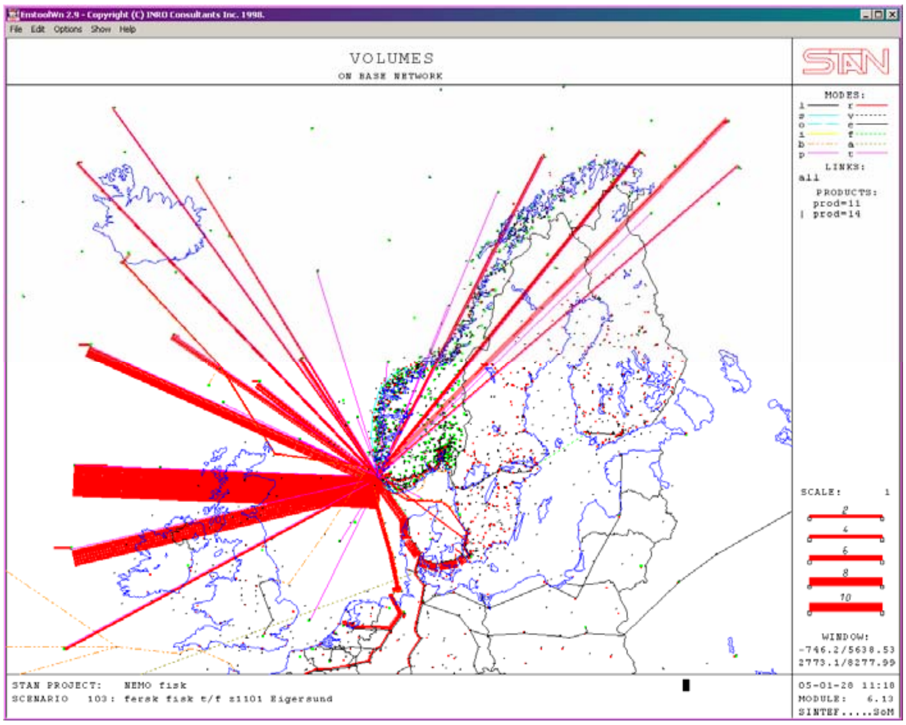

Figure 9: Assignment of fresh catch fish delivered to and fresh fish products shipped from Eigersund, zone 1101

8.2 Scenario 1: Reduction in number of fishing harbours

Catch is delivered to 213 zones located in 17 of the 19 counties in Norway (Table 13).

Table 13: Total annual catch (kg) delivered per county

County	N of delivery zones	Fish category				Total
		Pelagic	Other fish	Prawns	Other shellfish	
1 Østfold	4	940 069	308 011	832 269	47 261	2 127 611
2 Akershus	3	23 915	22 693	60	2	46 669
3 Oslo	1	15 121	72 762	24 701	179	112 762
6 Buskerud	4	0	2 020	0	0	2 020
7 Vestfold	5	31 735	373 630	363 858	27 717	796 941
8 Telemark	2	321 679	331 363	420 847	2 964	1 076 853
9 Aust-Agder	4	17 765	344 454	537 195	8 682	908 096
10 Vest-Agder	7	5 985 127	1 822 446	2 005 607	22 730	9 835 910
11 Rogaland	19	494 932 694	5 253 686	2 672 808	372 638	503 231 826
12 Hordaland	23	112 608 023	2 095 274	122 454	191 233	115 016 984
14 Sogn og Fjordane	13	346 166 140	27 792 672	103 317	234 215	374 296 344
15 Møre og Romsdal	32	445 082 512	168 699 699	4 672 814	66 473	618 521 499
16 Sør-Trøndelag	15	10 288 271	4 152 909	88 684	3 145 878	17 675 742
17 Nord-Trøndelag	9	1 826 299	6 196 170	4 677	333 850	8 360 995
18 Nordland	35	181 302 858	144 084 517	2 032 175	250	327 419 800
19 Troms	20	117 048 730	95 877 461	38 105 866	14 671	251 046 728
20 Finnmark	17	114 893 499	95 705 967	3 091 900	423 348	214 114 713
	213	1 831 484 437	553 135 734	55 079 232	4 892 090	2 444 591 493

In the case study defined in this project, the harbours in municipalities with less than 100 tonnes of total catch delivered per year, are removed. However, if this applies to all zones in a county, the largest zone in this county, measured in total catch delivered, is kept, in order to accommodate a minimum level of landing facilities within the area.

The 80 zones listed in Appendix F all have an annual average of total delivered catch of less than 100 tonnes. None of the zones in the counties of Akershus and Buskerud received more than 100 tonnes of catch per year. With a strict 100 tonne-limit, these two counties would be left without a delivery zone. To avoid this, the municipalities of Vestby in Akershus (45.647 tonnes) and Hurum in Buskerud (1.140 tonnes) were kept. The 80 zones removed represent 0,048% of total catch, and are relatively large for shellfish.

Table 14 provides the total tonnage per county which will have to be re-directed to a different landing harbour in the case study.

Table 14: Total annual catch (kg) delivered to zones with less than 100 tonnes catch delivered per year, per county

County	N of delivery zones < 100 tonnes	Fish category: Pelagic	Other fish	Prawns	Other shellfish	Total
1 Østfold	2	424	6 946	0	10	7 379
2 Akershus	2	0	962	60	0	1 022
3 Oslo	0	0	0	0	0	0
6 Buskerud	3	0	880	0	0	880
7 Vestfold	2	0	1 102	0	0	1 102
8 Telemark	0	0	0	0	0	0
9 Aust-Agder	0	0	0	0	0	0
10 Vest-Agder	1	0	7 316	0	0	7 316
11 Rogaland	10	11 841	52 646	24 013	26 089	114 588
12 Hordaland	13	185 945	109 939	17 860	65 338	379 080
14 Sogn og Fjordane	7	31 390	24 281	12 238	4 784	72 693
15 Møre og Romsdal	11	0	45 279	47	661	45 987
16 Sør-Trøndelag	7	42 622	104 779	0	0	147 400
17 Nord-Trøndelag	7	0	200 326	0	0	200 326
18 Nordland	10	0	42 138	0	250	42 387
19 Troms	5	0	83 306	16 653	0	99 959
20 Finnmark	0	0	0	0	0	0
SUM, < 100 tonnes	80	272 220	679 899	70 870	97 130	1 120 118
% of total within category		*0,016 %*	*0,125 %*	*0,127 %*	*1,840 %*	*0,048 %*

Table 15 presents the total amount of tonnekilometres resulting from an assignment where the smaller harbours are removed.

Table 15: Total tonnekm assigned to modal links for each category of fish catch[13]

Mode	Fresh fish catch	Frozen fish catch	Other fish catch	Total
l	5.9	.1	12.1	18.0
s	643.9	54.5	72.6	771.0
t	1 048 653.0	171 920.0	50 747.0	1 271 321.0
Total	1 049 303.0	171 974.6	50 831.6	1 272 110.0

The difference in tonnekilometres between the current situation with many small harbours and scenario 1 where these are removed is shown in Table 16. The figures show that for most products

[13] Total tonnekm assigned in Table 12 and Table 15 should be identical. However, differences in the tables is caused by rounding errors in the model.

the amount of tonnekilometres will increase when harbours are removed. This is as expected, because the vessels will no longer be allowed to use the direct link. For one product however; frozen fish catch, the transport made by the fishing vessels (mode t) will decrease. This means that when smaller harbours are removed, the fishermen will land the frozen fish to a harbour with shorter distance from the fishing grounds. This corresponds to the observation from section 8.1 that fresh fish is landed in the nearby harbours to a larger extend than frozen fish.

Table 16: Total tonnekm assigned to modal links for each category of fish catch. Difference between sc.0 and sc.1

Mode	Fresh fish catch	Frozen fish catch	Other fish catch	Total
l	5.9	.1	12.1	18.0
s	13.4	.2	27.6	41.2
t	1.0	-.6	2.7	5.0
Total	21.0	-.3	42.3	64.0

Table 17 shows the amount of fish that is assigned to modal transfers – that is, the amount of fish that will use more than one modal network. In scenario 0, the vessels are allowed to travel directly to the landing municipality. The only change of network that will take place is related to vessels that are directed towards landing municipalities already included in NEMO. These vessels will enter the short sea shipping network (s) to reach the final destination. In scenario 1, the smaller harbours are removed; hence the vessels may not be allowed to use the harbour closest to their final destination and may choose to use the short sea shipping network (s) or the road network (l) to reach the destination. The comparison of the two scenarios show that removal of the smallest harbours will result in a transfer of about 1 230 tonnes of fish from sea transport to road transport, and about 430 tonnes of fish will be redirected from the direct link in the fishery network to the short sea shipping network.

Table 17: Total amount of fish [1000 tonnes] assigned to modal transfers: Sum for all categories of fish catch (scenario 0, scenario 1 and change)

	Scenario 0					Scenario 1					Scenario 1 - Scenario 0			
From	To Mode				From	To Mode				From	To Mode			
Mode	l	s	t	Total	Mode	l	s	t	Total	Mode	l	s	t	Total
l	.00	.00	.00	.00	l	.00	.00	.00	.00	l	.00	.00	.00	.00
s	.00	.00	.00	.00	s	1.12	.00	.00	1.12	s	1.12	.00	.00	1.12
t	.00	2 048.83	.00	2 048.83	t	.00	2 049.26	.00	2 049.26	t	.00	0.43	.00	0.43
Total	.00	2 048.83	.00	2 048.83	Total	1.12	2 049.26	.00	2 050.38	Total	1.12	0.43	.00	1.55

Figure 10 illustrates difference in volumes when comparing volumes of all catch fish from Egersundsbanken in scenario 0 and 1.

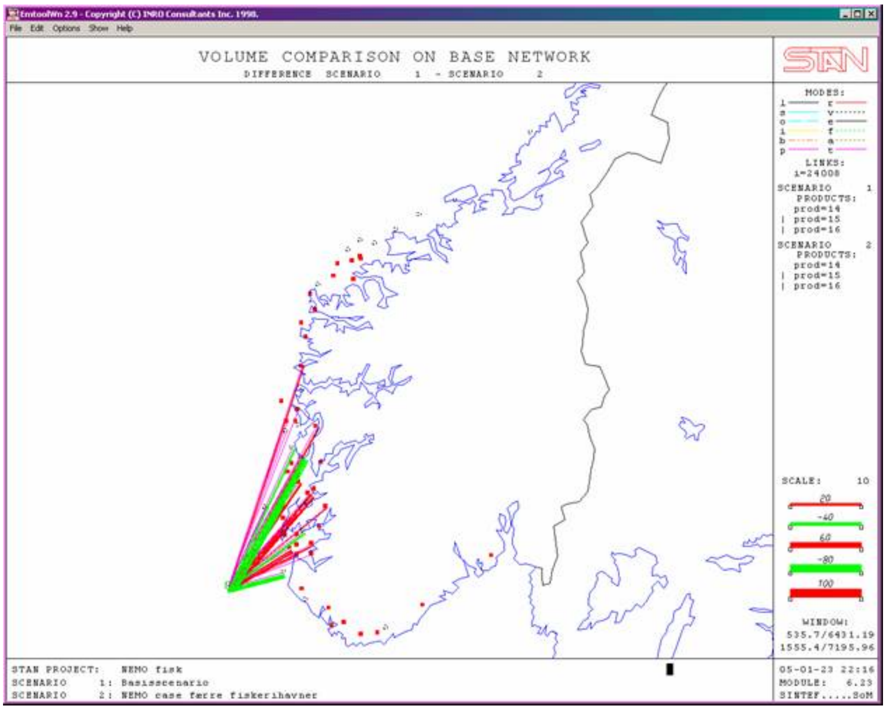

Figure 10: Comparison of scenario 0 and 1, all catch fish from Egersundsbanken

Red lines indicate reduced volumes when removing harbours under 100 tonnes, while green lines indicate increased volumes. As can be seen, scenario 1 implies a concentration of volumes to a limited number of harbours, as expected. A closer study of the effect in one single harbour (Ølen) is presented in Figure 11. Here an analysis of assigned paths is used to create the graphical result.

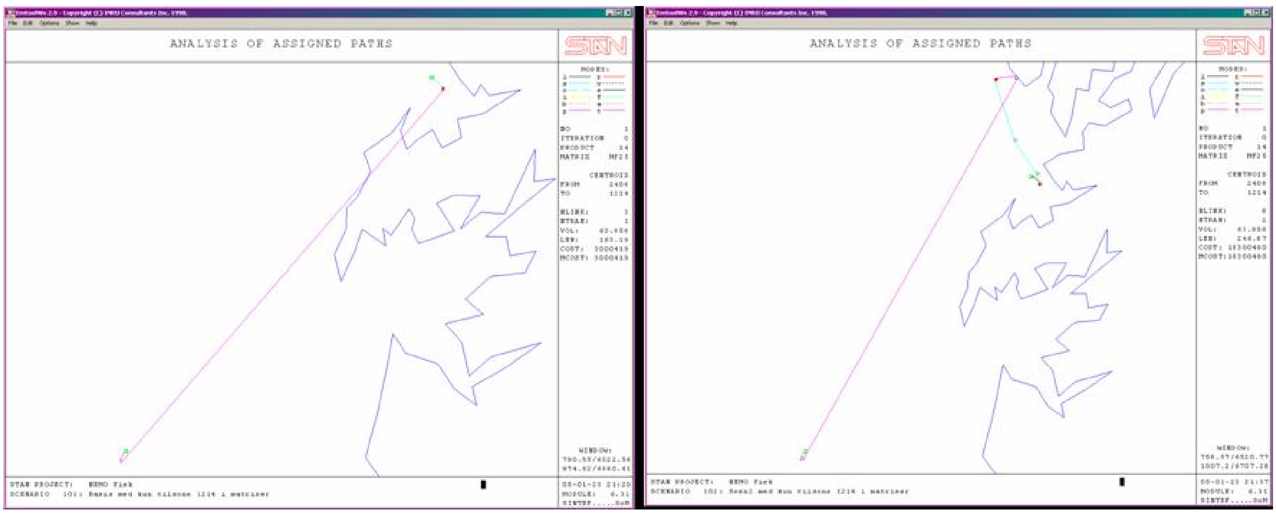

Figure 11: Comparison of assigned paths in scenario 0 and 1, fresh catch fish from Egersundsbanken to Ølen

The left part of Figure 11 shows assignment in the basis scenario (scenario 0). The blue line indicates that the transport is using the s mode for connecting to the zone. When removing the harbour in Ølen in scenario 1, one gets the assignment shown in the right part of Figure 11. Here one can see that the fresh catch fish is using another harbour than in Ølen. However, due to fixed matrices, the fish has to be assigned all the way to Ølen – even though this harbour does not exist in the network. Thus, after connecting to the new harbour (where the pink line meets the red dot), the volumes are assigned on modes s and l (lorry) to get to its final destination.

The same assignment in volumes is presented in Figure 12. Here green lines illustrate reduced volumes in scenario 1 and red lines increased volumes in scenario 1.

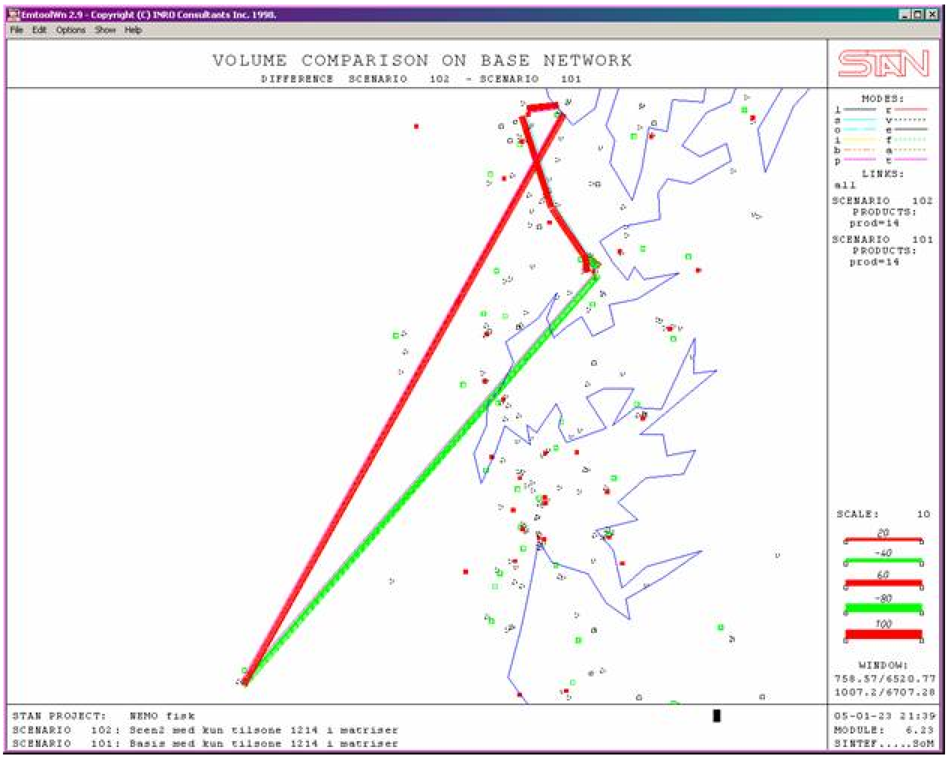

Figure 12: Comparison of scenario 0 and 1, fresh catch fish from Egersundsbanken to Ølen

8.3 Sailing pattern

Average tonnage per vessel is estimated to 10.9 tonnes. This is based on average number of tonnes (Table 4) and estimated landings (Table 3) per length and tool category.

The matrix comprises a total of 678 474 vessel movements. 7 % of these were movements with unknown origin or destination, and a further 18 % were zone internal movements. Thus, only 75 % of the matrix could be assigned. The assignment is shown in Figure 13.

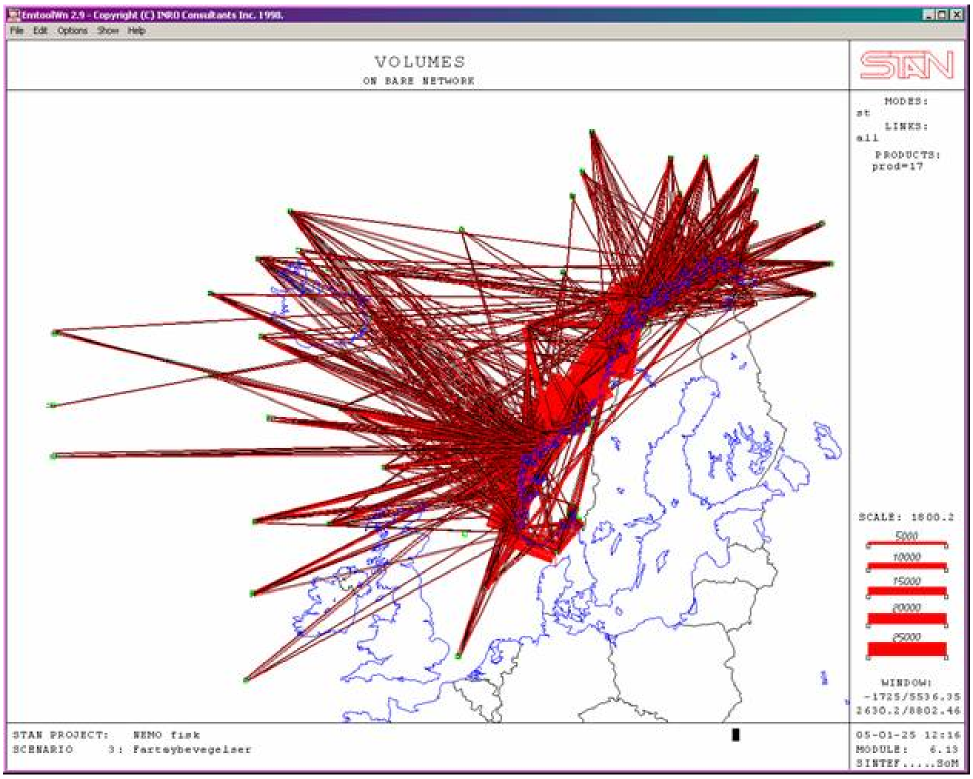

Figure 13: Assignment of matrices describing sailing patterns

According to Figure 13, a major amount of the movements are carried out along the Norwegian coast. The majority of trips along the coast are related to transport between landing and home harbour.

The assignment results for sailing patterns suffer under two conditions: The sailing distances for links from home harbour to fishing ground are not of a satisfying quality[14]. Furthermore, cost functions with average values for vessels with and without catch on board do not reflect the true cost situation for the vessels[15]. Together, these two conditions contribute to a series of sailing paths which are not logical.

[14] This problem is addressed in Table 8: Link length estimation.
[15] See section 7.2, Vehicle cost

9 Evaluation and concluding remarks

9.1 Evaluation of the fishery model

Basis matrices
Both freight and trip matrices are based on information provided by the department of statistics at the Directorate of Fisheries. We found this source to the best and most complete regarding information about volumes and trips related to fish transport. The statistics is made from information in notes provided by the fishermen at each landing, and the information describes the trip, the catch and the vessel. We consider the quality of the OD matrices describing the flows in tonnes to be of good quality. In order to obtain estimates of the number of trips, a specially designed extract of the statistics had to be made. Usually, one document is filled in per landing, but when there are several buyers or the vessel has been in areas with different quota regulations etc, more than one document are filled in. For these reasons, some uncertainty is introduced to the estimation of the number of trips. However, there is no official statistics that will result in a better estimate so we decided to establish also the OD matrices describing the trips on the statistics from the Directorate of Fisheries.

Network
A direct link network was chosen in the present fishery model. This allowed us to utilise distance estimates available from Statistics Norway, and use efficient input procedure of links in the model. The direct link network is appropriate for the required analyses, but inclusions of further relations should be considered. In the present network, we have included all links that are in use either for transporting the fish from catching to landing, or for transporting the vessels from home harbour to fishing ground. All the other possible zone relations have not been included in the network, due to the time and cost limits on this project. Supplementing the network with these "missing links" is easy if distance estimates are available. We therefore suggest that cooperation with Statistics Norway for establishing reliable link length estimates on the whole fishery network is considered. This also includes updated distance estimates on present links.

Another network alternative is representing the t mode on a spider-network. A spider-network makes re-routing of fish transport easier and more realistic than by using direct links. In addition, a spider-network allows a more elegant graphical result presentation. Thus establishing a spider network could be considered in order to improve the model. It is however necessary to gain reliable distance estimates on also in this case.

Full model integration
Simultaneous assignment of all commodity groups is possible. Thus the fishery model can be run together with the existing NEMO. The sub model is however not fully integrated in NEMO, and the fishery model matrices are not harmonized with the existing NEMO matrices. If this should be done, it is necessary to conduct a further study to reveal what happens in the harbours, and how it affects the quantities of fish and shellfish that will need further transport to reach the market. Such further model development can be relevant for strategic planning issues. It is however important to test the model on relevant planning aspect before concluding with limitation and possible needs for further development.

Cost functions
Cost parameters have been updated or corrected according to available information. To our knowledge, we have utilised the most relevant available information for this. For some aspects,

we did not have the necessary information to make such corrections. In those cases, we have used the already implemented cost parameters.

Transfer costs have not been corrected, due to the fact that transfers between modes are not relevant in the fishery model with the exception of transfers between mode t and s. If a full model integration should be developed, it will be necessary to correct transfer costs based on a detailed study of the cost structure in transfers.

As mentioned, costs on vessels are related to costs per tonnekm, and there is a lack of input data which separates costs on empty vessels and vessels with catch. Therefore average costs per tonnekm have been used for representing an average of empty trips and trips with catch. This is a weakness with the model. A separate cost study should be performed to obtain necessary input data for these cost functions and parameters, allowing an increase of the model reliability.

Model results
The assignment of the base matrices on the present network will only reflect the information from the underlying statistics and recreate today’s situation. It is not really possible to assess the quality of the model from this type of assignment – it will be limited by the quality of the official statistics as discussed earlier in this report. From this assignment one can show that the model is functioning technically, and verify that the input is implemented correctly.

9.2 Future utilisation of satellite-based vessel monitoring systems

Satellite-based vessel monitoring systems for fishery management was introduced in Norway in year 2000. All Norwegian vessels of length 24 m or more must have satellite-based tracking equipment installed. Satellite tracking is meant for managing the fisheries – not only in Norway, but also in the countries we cooperate with regarding fisheries.

Satellite monitoring and control implies that communication equipment installed on the vessel regularly sends signals containing information about the geographical position, the course and speed to the vessel’s flag authority message central (FMC). The Norwegian FMC is located at the Directorate of Fisheries. The equipment sends signals once per hour, and in addition a signal is sent when the vessel either enters or leaves zones under other countries’ jurisdiction.

So far, the information from the satellite tracking is mostly used for monitoring and control. However, they have also been used for special analysis when oil companies ask for documentation of activities related to fisheries in various areas.

When modelling the transport patterns of the fishing fleet, the data from satellite tracking is very interesting and would constitute a valuable input. However, there is no official statistics published based on this material available today. In the future, most likely the landing documents will be electronic. When this is implemented, the information in these documents can be linked to the data from satellite tracking. This will both give us valuable new information and enable us to make quality checks of already existing information. In addition to the more technical challenges included in linking of these data sets it is also necessary to check out the legal aspects concerning the publication of information from satellite tracking: The tracking data gives very detailed information about each vessel and it is necessary to aggregate the information in order to be allowed to publish it.

The group at the Directorate of Fisheries produces statistics from satellite tracking for internal use. For this internal statistics, they use fishing tool to categorize the vessels. If this will form the basis on which they will publish the data in the future, this might be a very useful and comprehensive material to be used for calibration of the fishery model.

9.3 Concluding remarks

A fishery model is developed and implemented as a sub model in NEMO. We have made a thorough job checking data availability and discussing various categorization and definitions with experts. During the model development we have emphasized flexibility, so adjustments and updates of the input should not be too time-consuming. All input data are organised in a database and the network is created using batch files.

The model has been tested and has proven useful for strategic analysis of fishing harbours. Using the model for assignment of sailing pattern has also been demonstrated.

10 References

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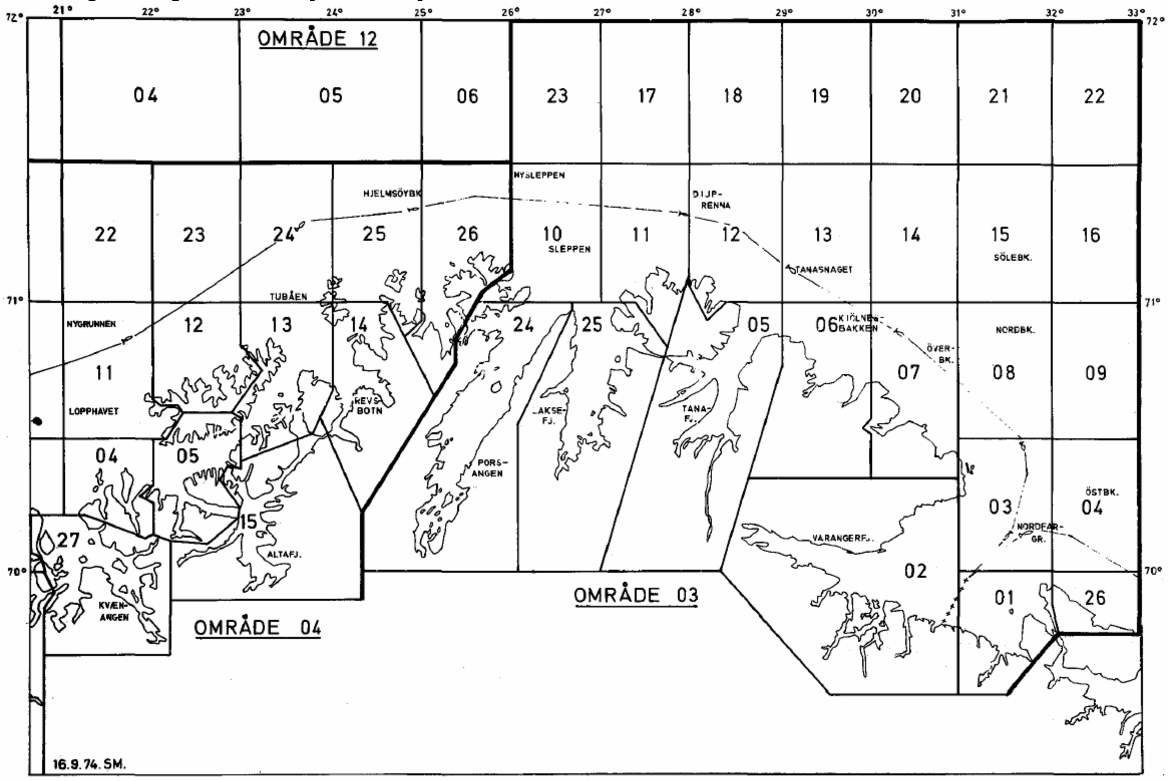
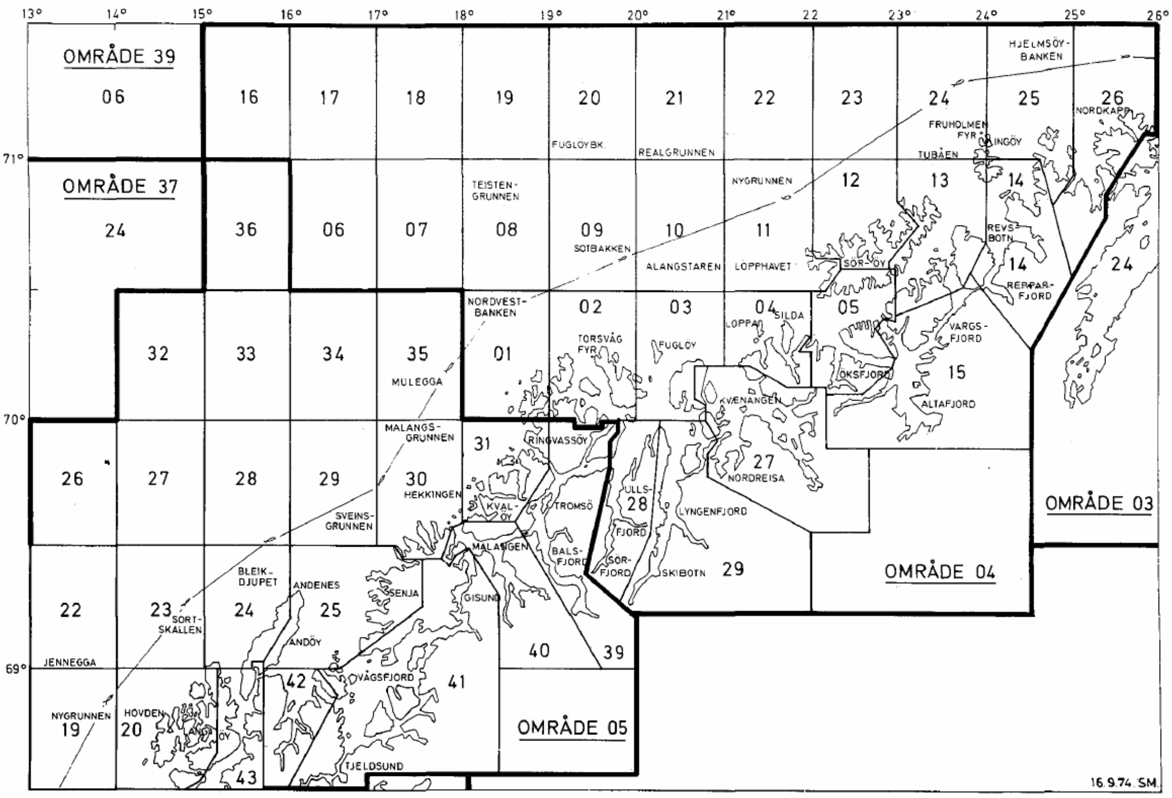
Appendix A: Maps of fishing grounds

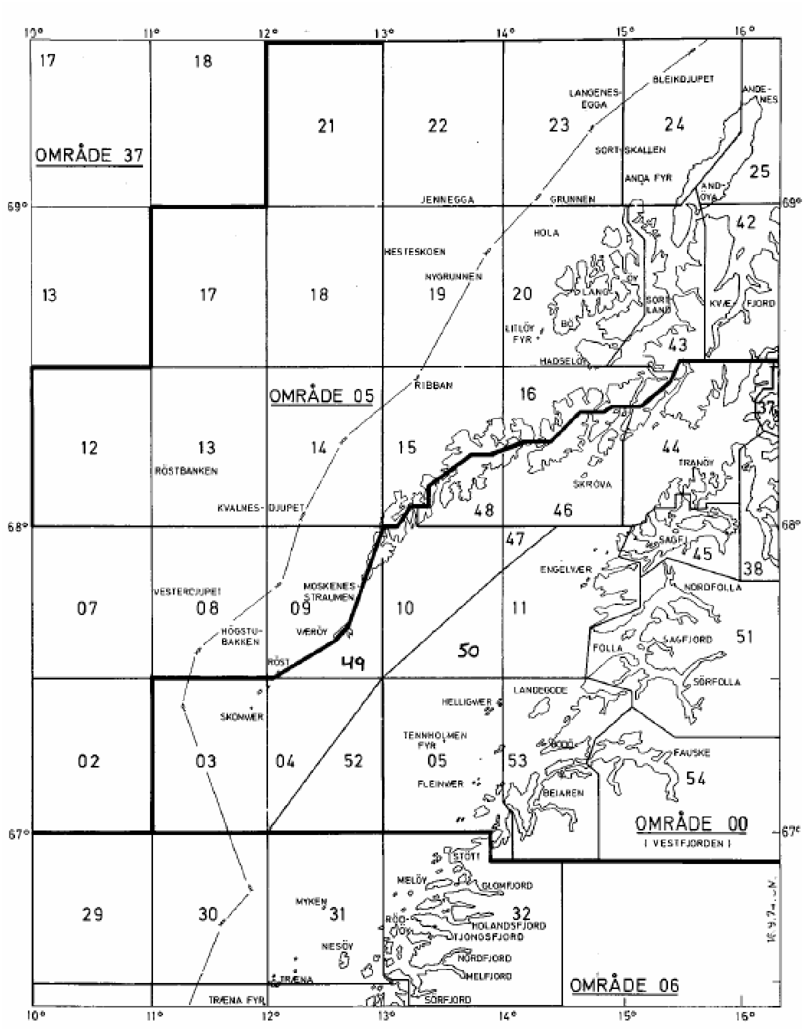
All maps are provided by Skantrykk AS.



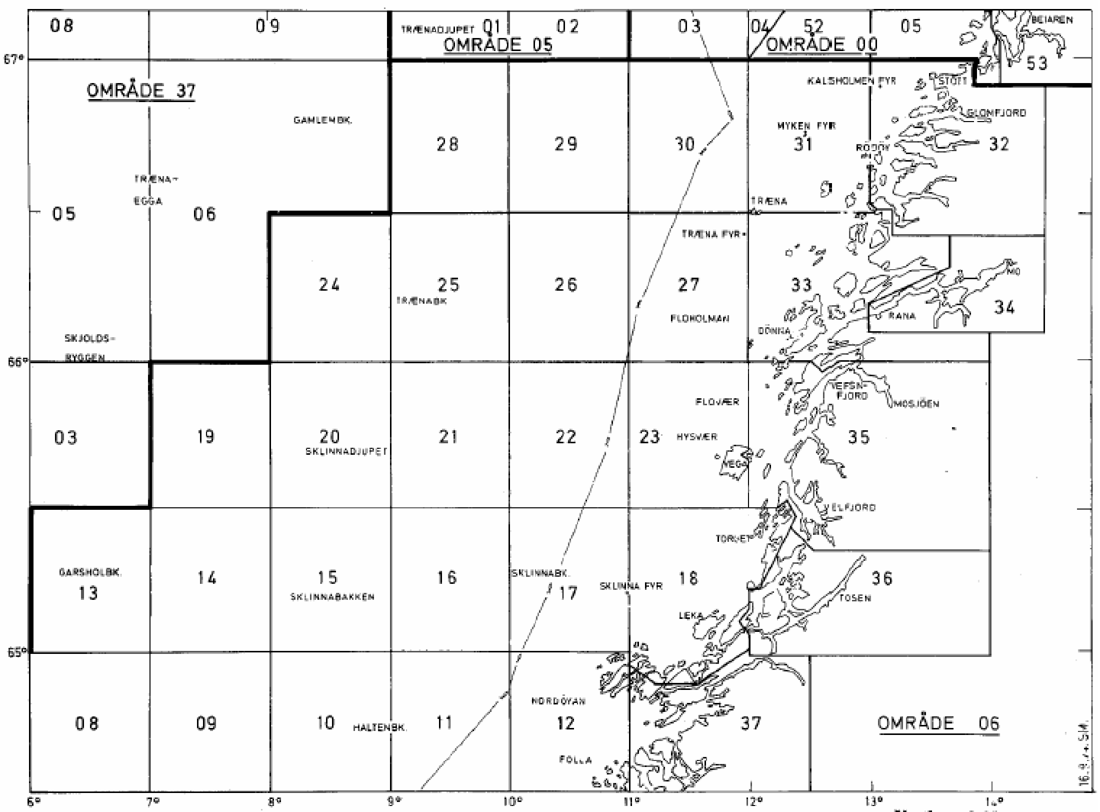
Kystkart 9: Finnmark



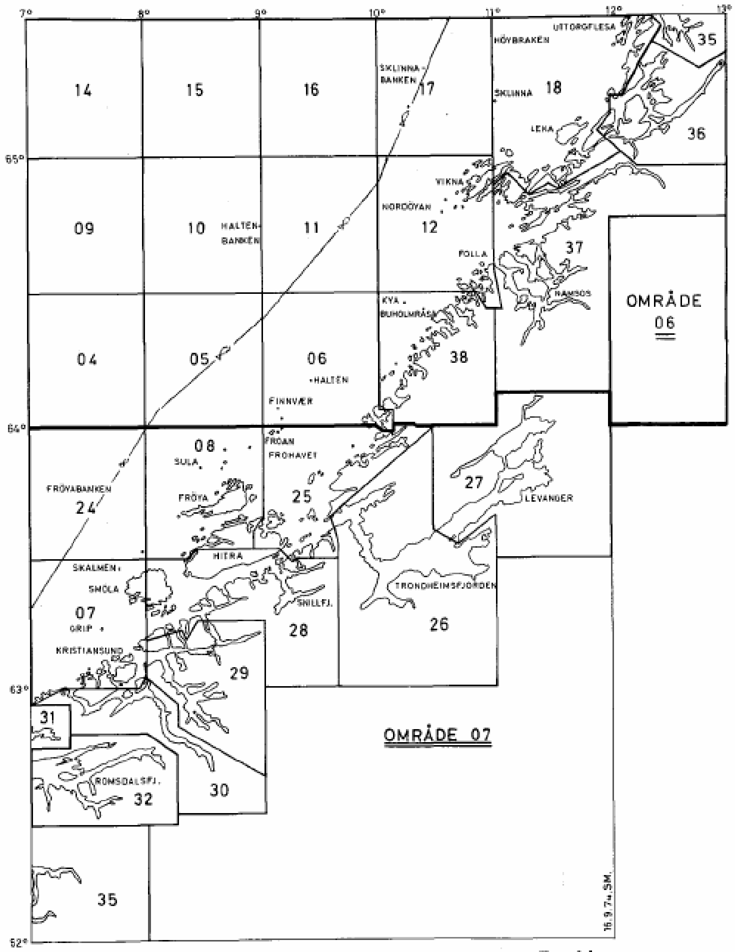
Kystkart 8: Troms



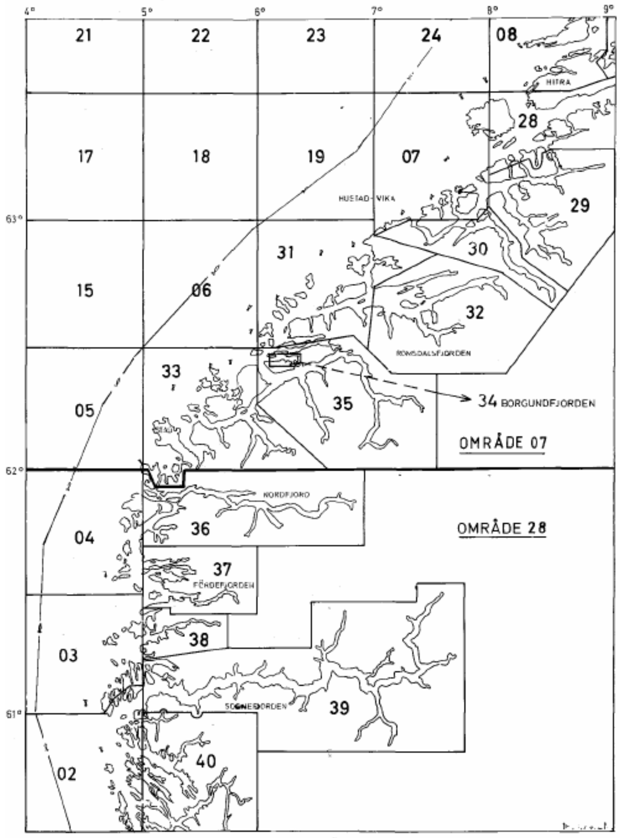
Kystkart 7: Vesterålen/Lofoten/Vestfjorden



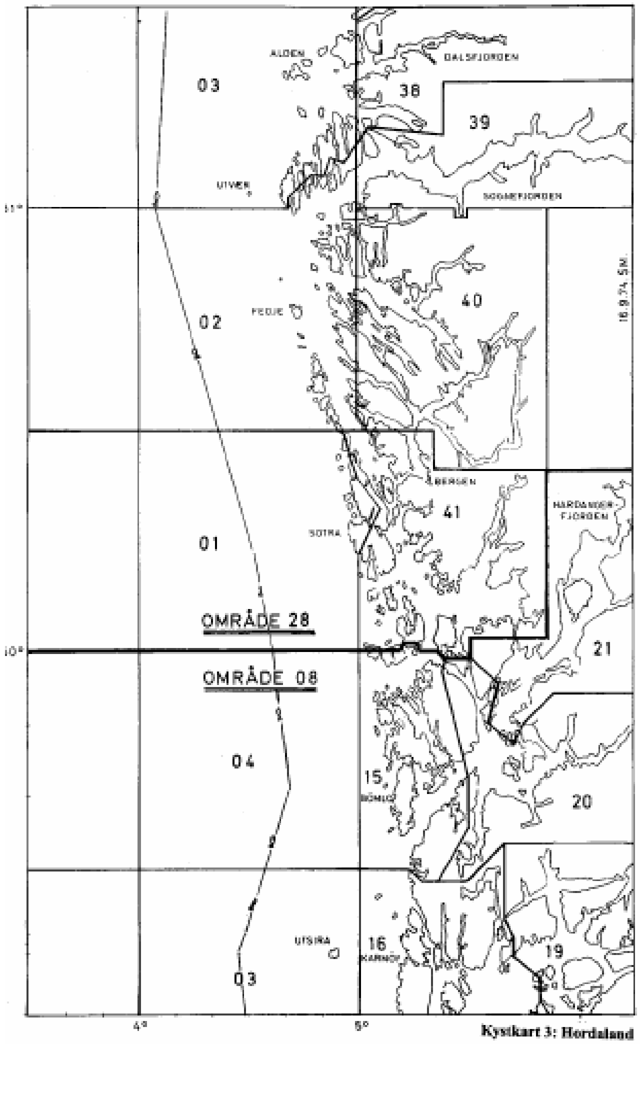
Kystkart 6: Nordland



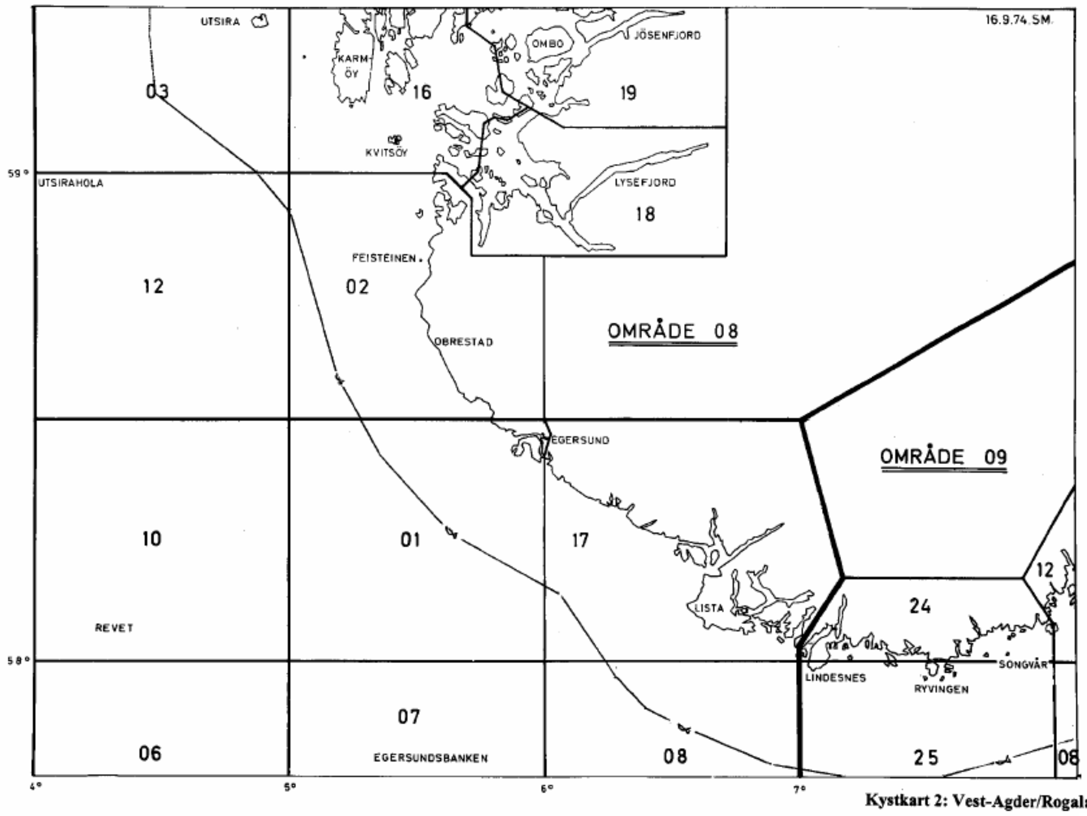
Kystkart 5: Trøndelag



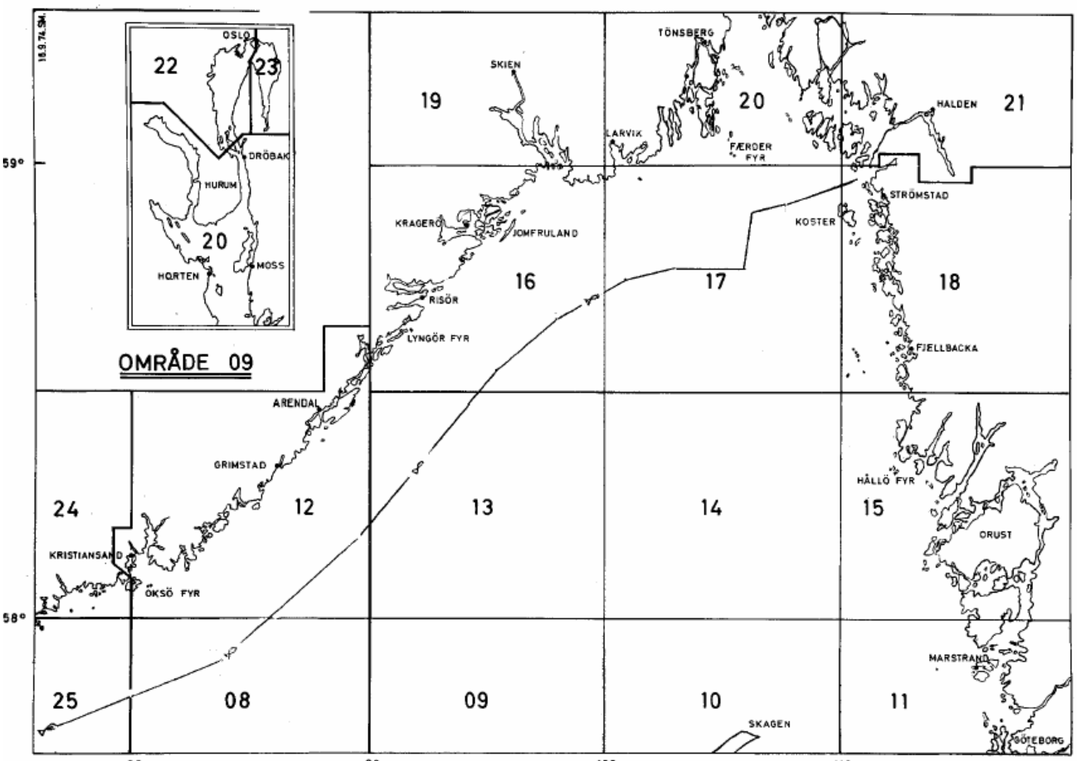
Kystkart 4: Sogn og Fjordane/Møre og Romsdal



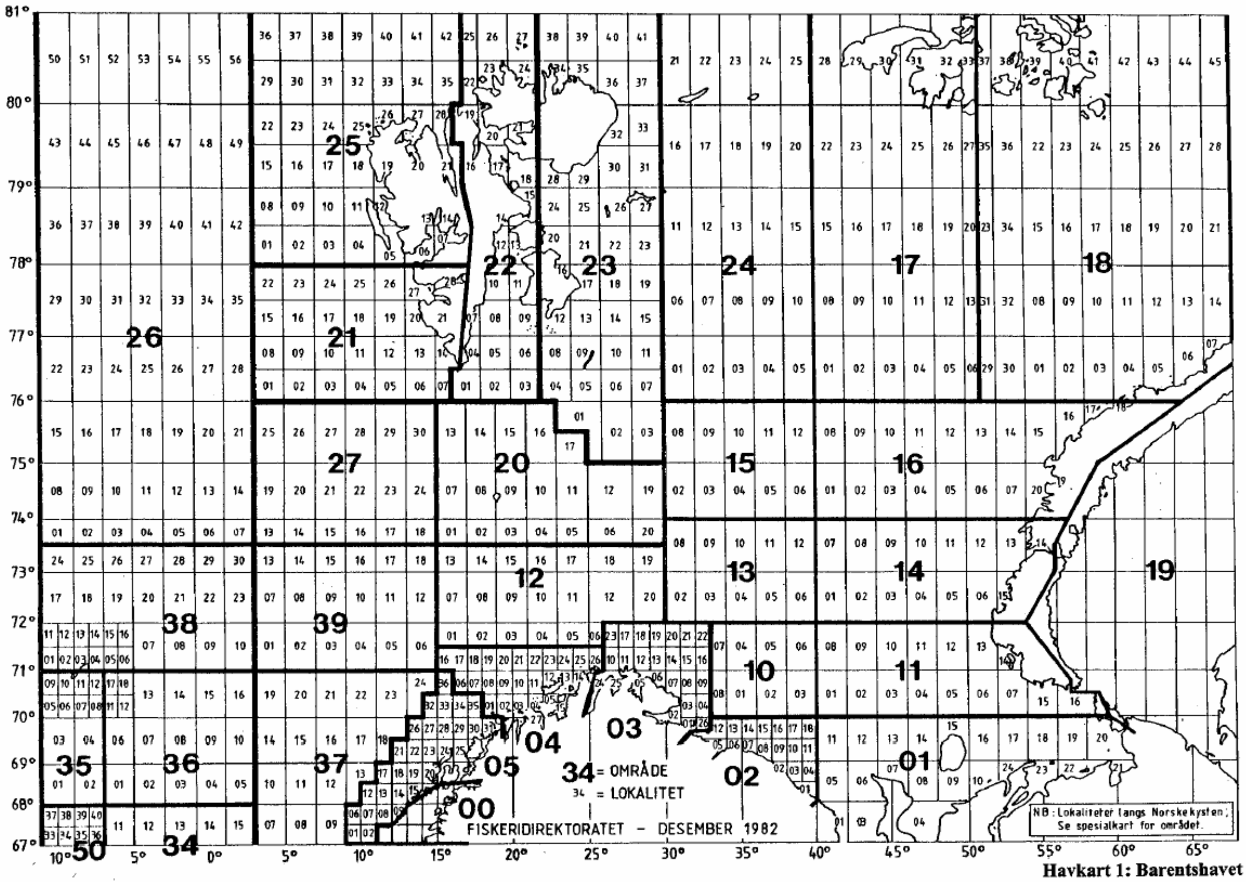
Kystkart 3: Hordaland



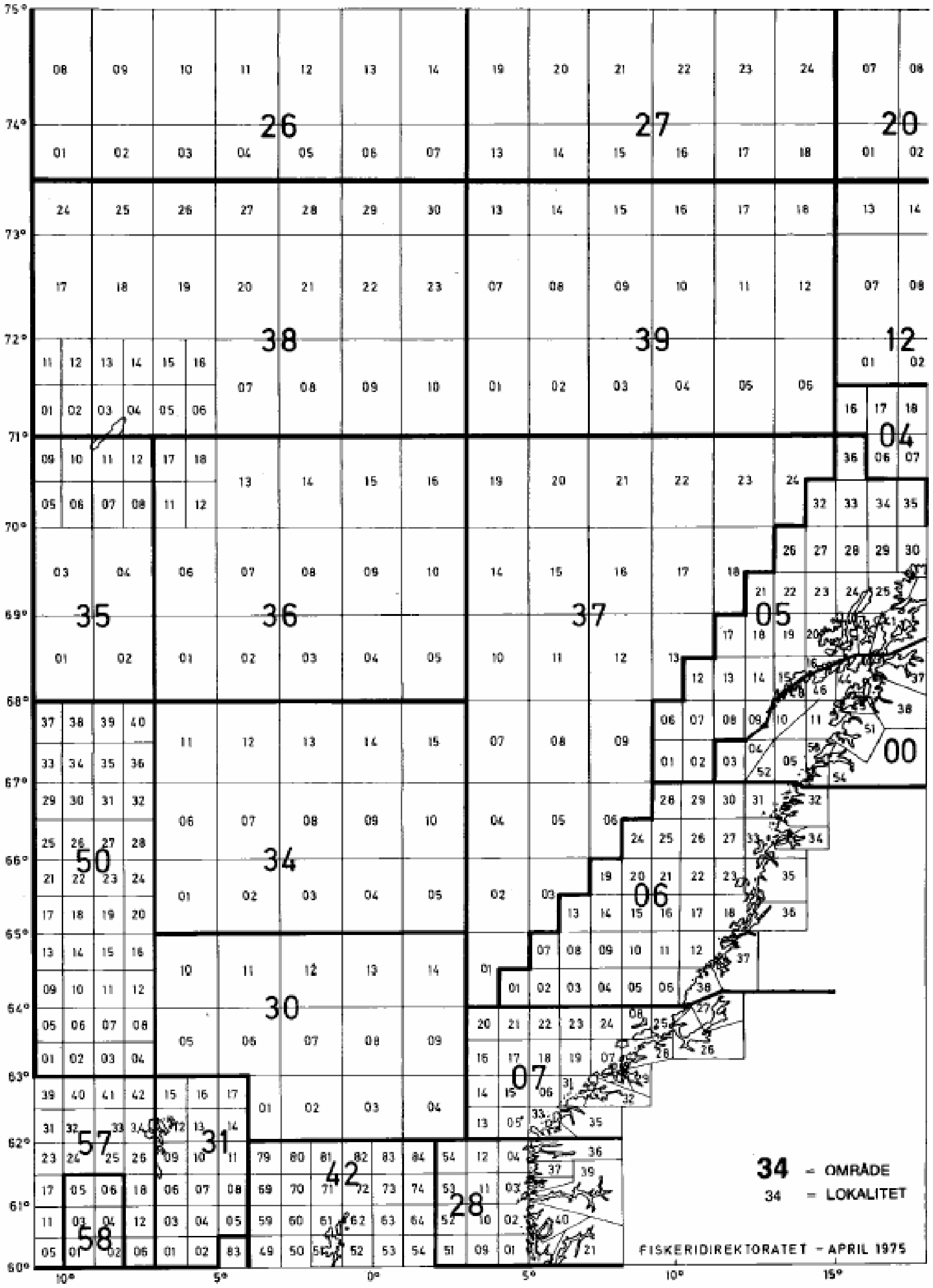
Kystkart 2: Vest-Agder/Rogaland



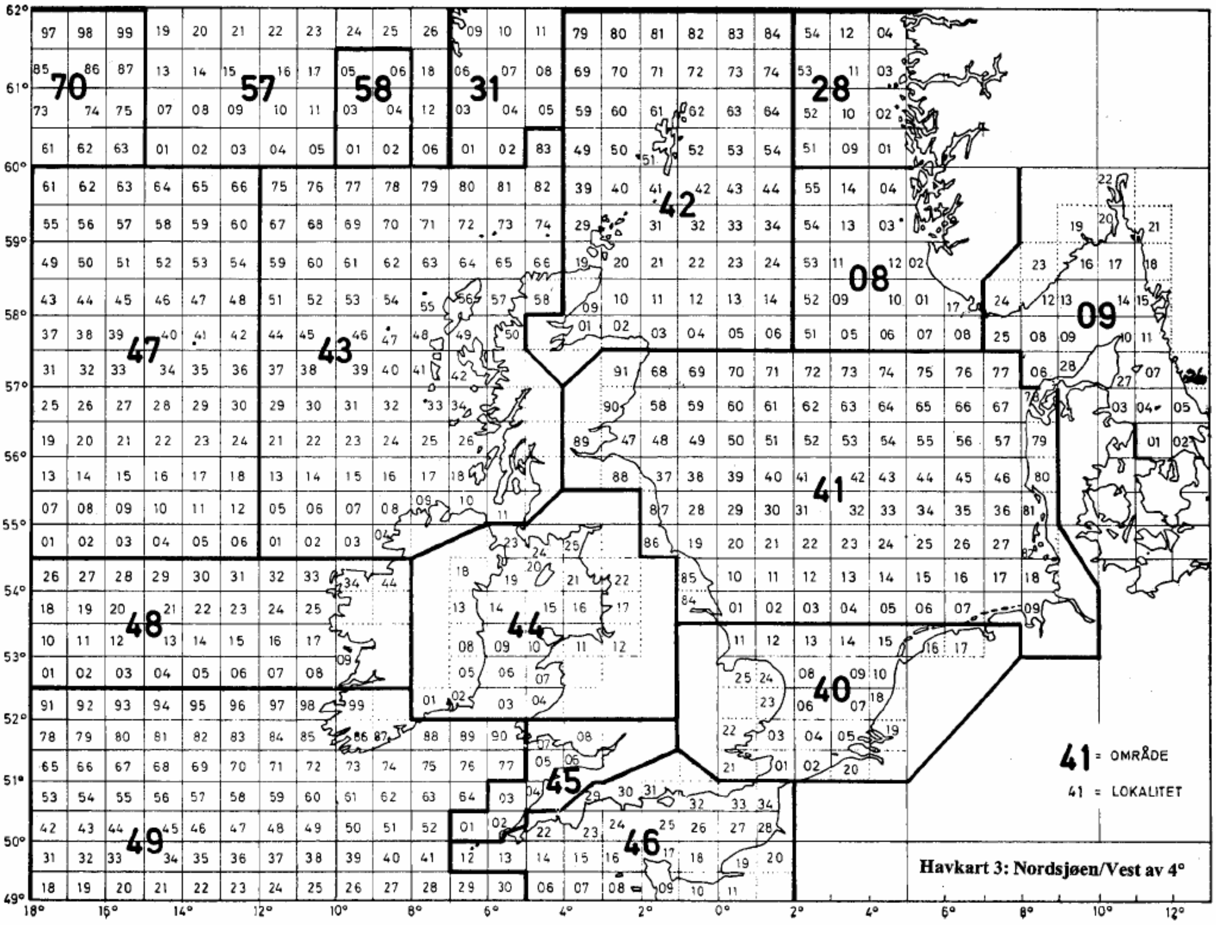
Kystkart 1: Skagerrakkysten



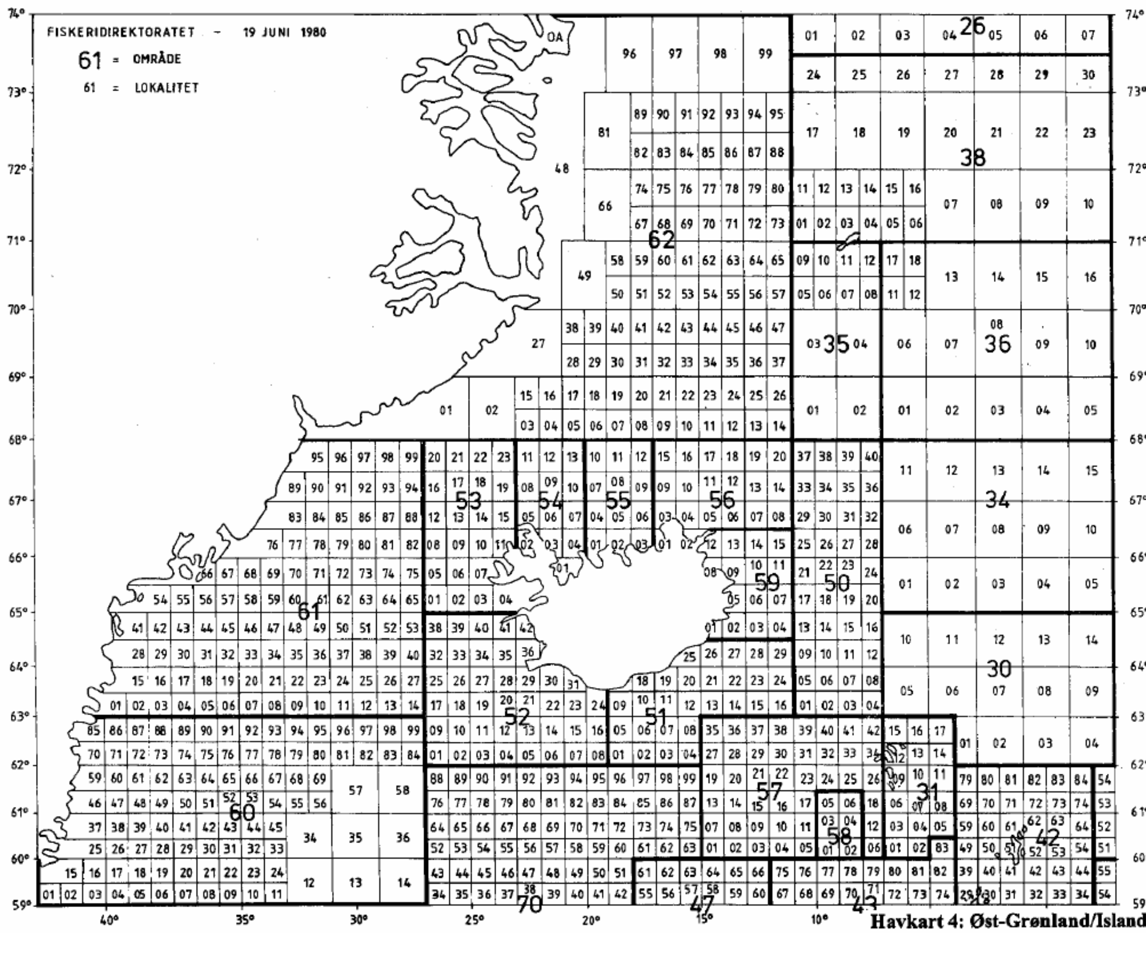
Havkart 1: Barentshavet



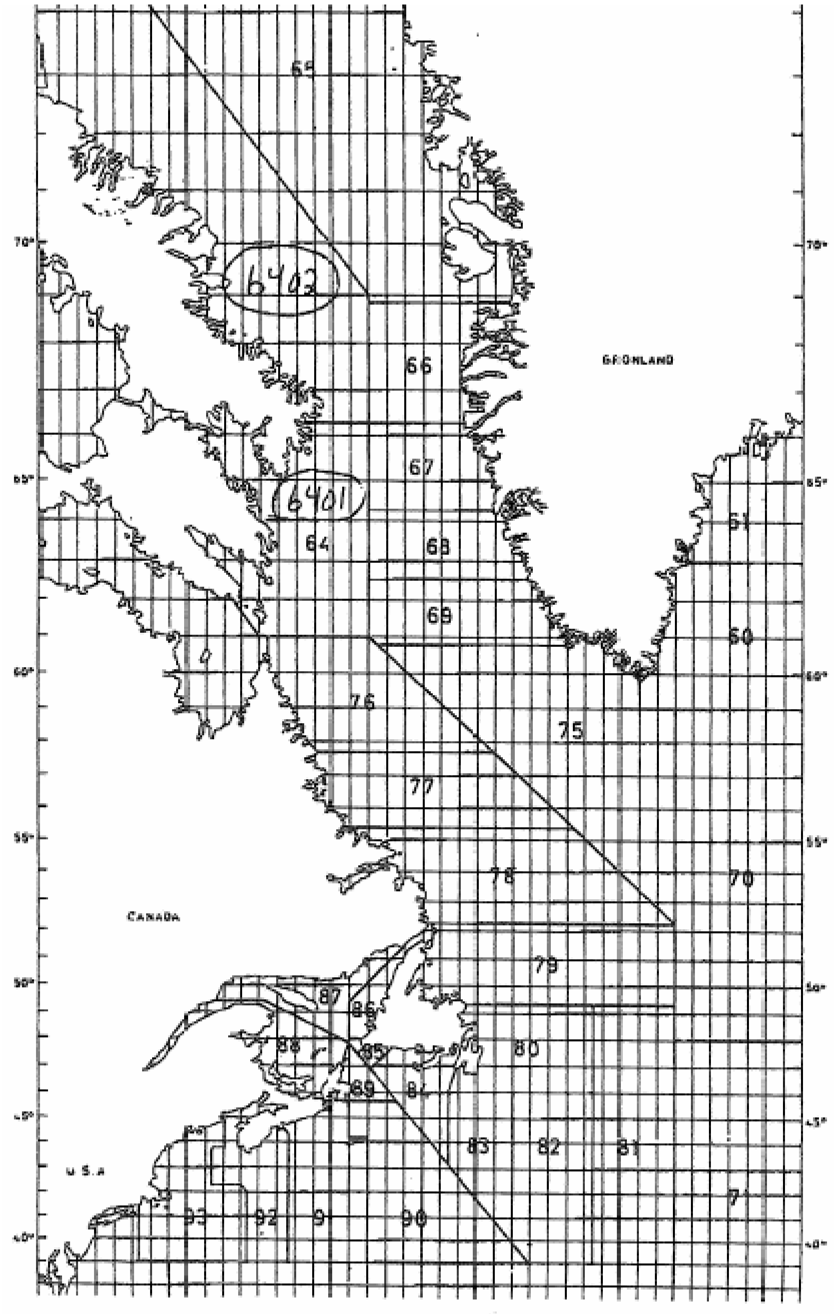
Havkart 2: Norskehavet



Havkart 3: Nordsjøen/Vest av 4°



Havkart 4: Øst-Grønland/Island/Jan Mayen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Appendix B: Fish categories

Fish category	Subgroups	Fish type - Norwegian	Fish type - English	Fish type - Latin
Pelagic	Pelagisk fisk	Sild	Atlantic herring	Clupea harengus
		Norsk vårgytende sild		
		Trondheimsfjordsild		
		Mussa		
		Nordsjøsild		
		Skagerraksild		
		Sild vest av 4 graden		
		Fjordsild		
		Annen sardin	Sardinellas	Sardinella spp
		Atlantic menhaden	Atlantic menhaden	Brevoortia tyrannus
		Sardinella	European pilchard	Sardina pilchardus
		Brisling	European sprat	Sprattus sprattus
		Havbrisling		
		Kystbrisling		
		Ansjos	European anchovy	Engraulis encrasicolus
			Bairds slickhead (smooth-head)	Alepocephalus bairdii
		Annen sildefisk	Clupeoids	Clupeoidei
		Lodde	Capelin	Mallotus villosus
		Barentshavslodde		
		Island/Ø Grønl./Jan M		
		Polartorsk	Polar cod	Boreogadus saida
		Øyepål	Norway pout	Trisopterus esmarkii
		Kolmule	Blue whiting	Micromesistius poutassou
		Taggmakrell (hestmakrell)	Atlantic horse mackerel	Trachurus trachurus
			Leerfish	Lichia amia
		Annen taggmakrell	Jack and horsemackerel	Trachurus spp
		Tobis og annen sil	Sandeels (= Sandlances)	Ammodytes spp
		Spansk makrell	Chub mackerel	Scomber japonicus
		Makrell	Atlantic mackerel	Scomber scombrus
		Annen makrell	Mackerels	Scombridae
Shrimp	Skalldyr og bløtdyr	Reke (dypvanns)	Northern prawn	Pandalus borealis
		Reke av Penaeusslekten	Penaeus shrimps	Penaeus spp
		Reke av Pandalusslekten	Pink (= Pandalid) shrimps	Pandalus spp
		Reke av Palaemonidaeslekten	Palaemonid shrimps	Palaemonidae
		Strandreke	Common prawn	Palaemon serratus
		Reke av Crangonidaeslekten	Crangonid shrimps	Crangonidae
		Hestereke	Common shrimp	Crangon crangon
Other shellfish and molluscs	Skalldyr og bløtdyr	Krill	Norwegian krill	Euphausiidae
		Raudåte		Calanus finmarchicus
		Langust	Palinurid spiny lobster	Palinurus spp
		Krabbe	Edible crab	Cancer pagurus
		Hankrabbe		
		Hunkrabbe		
		Svømmekrabber	Swim crab	Portunus spp
		Kongekrabbe	King crab	Paralithodes camtscatica
		Trollkrabbe	Stone king crab	Lithodes maja

Fish category	Subgroups	Fish type - Norwegian	Fish type - English	Fish type - Latin
		Annen krabbe	Marine crabs	Reptantia
		Sjøkreps	Norway lobster	Nephrops norvegicus
		Hummer	European lobster	Homarus gammarus
		Amerikansk hummer	American lobster	Homarus americanus
		Andre krepsdyr	Marine crustaceans	Crustacea
		Østers	European flat oyster	Ostrea edulis
		Annen Cupped oysters	Cupped oysters	Crassostrea spp
		Kuskjell	Ocean Quahog	Cyprina islandica
		Sandskjell	Soft clam	Mya arenaria
		Kamskjell	Common scallop	Pecten maximus
		Harpeskjell	Queen scallop	Chlamys opercularis
		Blåskjell	Blue mussel	Mytilus edulis
		Oskjell	Horse mussel	Modiolus spp
			Surf clam	Spisula solidissima
		Haneskjell	Islandic scallop	Chlamys islandica
		Hjerteskjell	Common cockle	Cardium edule
		Albuskjell	Lipmets	Patellidae
		Annen skjell	Scallops	Pectinidae
		Blekksprut	Common squid	Loglio spp
			Longfinned squid	Loglio pealei
			Shortfin (Northern) squid	Illex illecebrosus
		Akkar	European flying squid	Todarodes sagittatus sagittat
			Octopuses	Octopodidae
		Annen blekksprut	Squids	Loliginidae, Ommastrephidae
			Cuttlefishes	Sephiidae, Sepiolidae
		Kråkebolle	Sea urchins	Echinoidea
		Andre pigghuder	Echinoderms	Echinodermata
		Strandsnegle	Periwinkles	Littorinidae
		Annet bløtdyr	Marine molluscs	Mollusca
Other fish	Annen og uspesifisert fisk	Villaks	Atlantic salmon	Salmo salar
		Coho laks	Coho salmon	Oncorhynchus kisutch
		Sjøørret	Sea trout	Salmo trutta
		Regnbueørret	Rainbow trout	Oncorhynchus mykiss/ Salmo gairdneri
		Annen ørret	Trouts	Salmo spp
		Røye	Arctic char	Salvelinus alpinus
		Annen røye	Chars	Salvelinus spp
		Harr	Grayling	Thymallus arcticus
		Annen laksefisk	Salmonoids	Salmonoidei
		Horngjel	Garfish	Belone belone
		Makrellgjedde	Atlantic saury	Scomberesox saurus
			Bluefish	Pomatomus saltratix
		Annen marulk		Beloniformes
		Mora	Moras	Moridae
		Skjellbrosme	Greater forkbeard	Phycis blennoides
			Forkbeard	Phycis phycis
		Navagotorsk	Wachna cod	Eleginus navaga
		Skjeggtorsk	Pouting	Trisopterus luscus
		Isgalt	Roughhead grenadier	Macrourus berglax
		Skolest	Roundnose grenadier	Coryphaenoides rupestris
		Annen torskefisk	Gadiformes	Gadiformes
		Stingsild	Sticklebacks	Gasterosteus spp
		Trompetfisk	Slender snipefish	Macroramphosus scolopax

Fish category	Subgroups	Fish type - Norwegian	Fish type - English	Fish type - Latin
		Annen multe	Mullets	Mugilidae
		Stripefisker	Silverside smelts	Atherinidae
			Dusky grouper	Epinephelus guaza
		Vrakfisk	Wreckfish	Polyprion americanus
		Havabbor	Seabass	Dicentrarchus labrax
		Stripet havabbor	Striped bass	Morone saxatilis
		Grunt	Grunts, sweetlips, etc.	Haemulidae (Pomadasyidae)
		Ørnefisk	Meagre	Argyrosomus regius
		Flekkpagell	Red seabream	Pagellus bogaraveo
		Rødpagell	Common pandora	Pagellus erythrinus
			Axillary seabream	Pagellus acarne
			Largeeye dentex	Dentex macrophthalmus
			Common dentex	Dentex dentex
			Dentex	Dentex spp
			Gilthead seabream	Sparus aurata
		Oksøyefisk	Bogue	Boops boops
		Annen havkaruss	Porgies, seabreams etc.	Sparidae
		Mulle	Surmullet	Mullus surmuletus
			Red mullet	Mullus barbatus
		Fjesing	Greater weever	Trachinus draco
		Sølvbrasme	Atlantic pomfret	Brama brama
			Picarels	Spicara spp
		Berggylt	Ballan wrasse	Labrus bergylta
		Annen leppefisk	Wrasses, hogfish	Labridae
		Bergnebb	Gold-sinny wrasse	Ctenolabrus rupestris
		Grøngylt	Corkwing wrasse	Crenilabrus melops
		Blåstål	Cuckoo wrasse	Labrus bimaculatus
		Rødnebb	Cuckoo wrasse	Labrus bimaculatus
		Annen piggfinnefisk		Perciformes
		Slirefisk	Silver scabbardfish	Lepidopus caudatus
		Dolkfisk/trådstjert	Black scabbardfish	Aphanopus carbo
		Ryggstripet pelamide	Atlantic bonito	Sarda sarda
		Atl. spansk makrell	Atlantic spanish mackerel	Scomberomorus maculatus
		Auxid	Frigate and bullet tunas	Auxis thazard,A. rochei
		Tunnin	Atlantic black skipjack	Euthynnus alletteratus
		Bukstripet pelamide	Skipjack tuna	Katsuwonus pelamis
		Makrellstørje	Northern bluefin tuna	Thunnus thynnus
		Albakor	Albacore	Thunnus alalunga
			Yellowfin tuna	Thunnus albacares
			Bigeye tuna	Thunnus obesus
		Seilfisk	Atlantic sailfish	Istiophorus albicans
			Atlantic blue marlin	Makaira nigricans
			Atlantic white marlin	Tetrapturus albidus
		Sverdfisk	Swordfish	Xiphias gladius
		Annen tunfisk	Tunas	Thunnini
		Kutling	Gobies	Gobiidae
		Annen marin fisk	Marine fishes	Osteichthyes
		Uspesifisert fisk	Unidentified	Indeterminus
		Laksestørje	Opah	Lampris guttatus
			Common (blue) warehou	Seriolella brama
			Silver warehou	Seriollella punctata
			Giant stargazer, monkfish	Kathetostoma giganteum
			Frostfish	Lepidopus caudatus
			Kingfish, yellowtail	Seriola lalandi
			Black oreo	Allocyttus niger

Fish category	Subgroups	Fish type - Norwegian	Fish type - English	Fish type - Latin
			Oreo dories nei.	Oreosomatidae spp.
			Hoki	Macruronus novaezelandiae
			Hake	Merluccius australis
			Hakes nei.	Merluccius spp.
			Ling	Genypterus blacodes
	Diverse dypvannsarter	Håbrann	Porbeagle	Lamna nasus
		Brugde	Basking shark	Cetorhinus maximus
		Makrellhai	Shortfin mako	Isurus oxyhinchus
		Blåhai	Blueshark	Prionace glauca
			Blackmouth catshark	Galeus melastomus
			Small-spotted catshark	Scyliorhinus canicula
			Deep-water catsharks	Apristurus spp.
			False catshark	Pseudotriakis microdon
			Crest-tail catsharks nei.	Galeus spp.
			Catcharks, nursehounds nei	Scyliorhinus spp.
		Håkjerring	Greenland shark	Somniosus microcephalus
		Pigghå	Picked(= Spiny)dogfish	Squalus acanthias
			Dogfish sharks	Squalidae
		Annen hå	Dogfishes and hounds	Squalidae Scyliorhinidae
		Islandshå	Black dogfish	Centroscyllium fabriciil
			Little sleeper shark	Somnius rostratus
			Kitefin shark	Dalatias licha
			Bramble shark	Echinorhinus brucus
			Dogfishes nei.	Squalidae
		Havengler	Angelshark, sand devil	Squatinidae
		Brunhå	Shark gulper, leafscale	Centrophorus squamosus
		Dypvannshå	Portugese dogfish	Squamosus
		Gråhå	Squale savate	Deania calceus
		Bunnhå	Longnose velvet dogfish	Centroscymnus crepidater
		Stor svarthå	Canternsharks nei.	Etmopterus spp.
		Annen hai	Sharks	Selachimorpha (Pleurotremata)
		Storskate	Blue skate	Raja batis
		Piggskate	Thornback ray	Raja clavata
		Flekkskate	Spotted ray	Raja montagui
		Nebbskate	Shagreen ray	Raja fullonica
		Gjøkskate	Cuckoo ray	Raja naevus
		Spisskate	Longnose skate	Raja oxyrinchus
			Little skate	Raja erinacea
			Barndoor skate	Raja laevis
			Winter skate	Raja ocellata
			Thorny skate/ Starry ray	Raja radiata
			Smooth skate	Raja senta
			Spinytail skate	Raja spinicauda
			Blonde ray	Raja brachyura
			Sandy ray	Raja circularis
			Round ray	Raja fyllae
			Small-eyed ray	Raja microocellata
			Undulate ray	Raja undulata
			White skate	Raja alba
		Skate, uspesifisert	Skates	Raja spp.
		Ørneskate	Eagle rays	Myliobatidae
		Elrokke	Torpededos	Torpedo spp
		Annen skate og rokke	Skates and rays, nei.	Rajiformes
		Havmus	Rabbit fish (ratfish)	Chimaera monstrosa

Fish category	Subgroups	Fish type - Norwegian	Fish type - English	Fish type - Latin
			Ratfishes nei.	Hydrolagus spp.
			Knife-nosed chimaeras	Rhinochimaera spp.
			Longnose chimaeras	Harriotta spp.
		Brun havmus	Ratfishes nei.	Hydrolagus spp.
	Flatfisk og bunnfisk	Strømsild/Vassild	Argentines	Argentina spp
		Ål	European eel	Anguilla anguilla
		Havål	European conger	Conger conger
		Annen ål	Congers, eels	Congridae
		Beryx, alfonsinos	Alfonsinos	Beryx spp
		Orange roughy	Orange Roughy	Hoplostethus atlanticus
		Sanktpetersfisk	John dory	Zeus faber
		Gråsteinbit	Atlantic wolffish (= Catfish)	Anarhichas lupus
		Flekksteinbit	Spotted wolffish (= Catfish)	Anarhichas minor
		Blåsteinbit	Northern wolffish (Blue sea-cat)	Anarhichas denticulatus (latifrons)
		Steinbiter	Wolffishes (= Catfishes)	Anarhichas spp
		Ålekvabbe	Eelpout	Zoearces viviparus
		Annen slimfisk		Blennoidei
		Uer uspes.	Atlantic redfishes	Sebastes spp
		Uer (vanlig)	Golden redfish	Sebastes marinus
		Snabeluer	Beaked redfish	Sebastes mentella
		Lusuer	Scorpionfish	Sebastes viviparus
		Blåkjeft	Bluemouth	Helicolerus dactylopterus
		Knurr uspes.	Gurnards, searobins	Triglidae
		Knurr	Grey gurnard	Eutrigla (= Trigla) gurnardus
		Tverrstripet knurr	Red gurnard	Aspitrigla (= Trigla) cuculus
		Rognkjeks (felles)	Lumpfish (=Lumpsucker)	Cyclopterus lumpus
		Rognkall (han)	Lumpfish (= Lumpsucker)	Cyclopterus lumpus
		Rognkjeks (hun)	Lumpfish (= Lumpsucker)	Cyclopterus lumpus
		Annen ulkefisk		Cottoidei
		Kveite	Atlantic halibut	Hippoglossus hippoglossus
		Rødspette	European plaice	Pleuronectes platessa
		Blåkveite	Greenland halibut	Reinhardtius hippoglossoides
		Smørflyndre	Witch flounder	Glyptocephalus cynoglossus
		Gapeflyndre	Amer. plaice	Hippoglossoides platessoides
			Yellowtail flounder	Limanda ferruginea
		Sandflyndre	Common dab	Limanda limanda
		Lomre	Lemon sole	Microstomus kitt
		Skrubbe	European flounder	Platichthys flesus
			Winter flounder	Pseudopleuronects americanus
		Annen flyndre	Right eye flounders	Pleuronectoidei
		Tunge	Common sole	Solea vulgaris
		Sandtunge	Sand sole	Solea lascaris
			Wedge sole (Senegal)	Dicologoglossa cuneata
		Annen tunge	Soles	Soleidae
		Glassvar	Megrim	Lepidorhombus whiffiagonis
		Slettvar	Brill	Scophthalmus rhombus
			Windowpane flounder	Scophthalmus aquosus
		Piggvar	Turbot	Psetta maxima
			Summer flounder	Paralichthys dentatus
		Annen var	Left eye flounders	Bothidae
		Annen flatfisk	Flatfishes	Pleuronectiformes
		Breiflabb	Angler (= Monk)	Lophius piscatorius
			American angler	Lophius americanus
		Andre av breiflabbfamilien	Anglerfishes	Lophiidae

Fish category	Subgroups	Fish type - Norwegian	Fish type - English	Fish type - Latin
	Torsk og torskeartet fisk	Brosme	Tusk(= Cusk)	Brosme brosme
		Torsk	Atlantic cod	Gadus morhua
		Skrei		
		Norsk arktisk torsk		
		Kysttorsk		
		Annen torsk		
		Lange	Ling	Molva molva
		Blålange	Blue ling	Molva dypterygia
		Hyse	Haddock	Melanogrammus aeglefinus
		Norsk arktisk hyse		
		Kysthyse		
		Nordsjøhyse		
		Annen hyse		
		Rød lysing	Red hake	Urophycis chuss
		Hvit lysing	White hake	Urophycis tenuis
		Sei	Saithe (= Pollock)	Pollachius virens
		Lyr	Pollack	Pollachius pollachius
		Hvitting	Whiting	Merlangius merlangus
		Lysing	European hake	Merluccius merluccius
			Silver hake	Merluccius bilinearis

Appendix C: Conservation categories

Conservation category	Code	Norwegian description	Comments
Frozen	5	Frossen	
	6	Frossen saltkokt	
	7	Frossen sjøkokt	
Fresh	2	Fersk/ukonservert	
	3	Fersk saltkokt	
	4	Fersk sjøkokt	
	9	Iset	
	10	Rfw (refrigerated fresh water)	
	11	Rsw (refrigerated sea water)	
	18	Rsw + is	Rsw (refrigerated sea water) i tank
	19	Rsw + ozon	Rsw (refrigerated sea water) i tank
	20	Rfw + ozon	Rfw (refrigerated fresh water) i tank.
	21	Rfw + is	Rfw (refrigerated fresh water) i tank.
	22	Rfw + syre	Rfw (refrigerated fresh water) i tank.
	23	Rfw + syre + is	Rfw (refrigerated fresh water) i tank.
	24	Rfw + syre + ozon	Rfw (refrigerated fresh water) i tank.
	25	Sws	Seawater slush (saltvanns is-sørpe) i tank (notbåter uten Rsw)
	26	Rfw + FishForm	Konserv.middel for industrifisk og fiske-produkter.
	27	Rfw + "Soft Eddik"	Konserv.middel av fiskeråstoff for produksjon av fiskemel til dyrefor (SoftAcid Aqua E).
	28	Rsw + "Soft Eddik"	Konserv.middel av fiskeråstoff for produksjon av fiskemel til dyrefor (SoftAcid Aqua E).
	29	Rsw + FishForm	Konserv.middel for industrifisk og fiske-produkter.
Other	0	Uspesifisert	
	1	Ensilert	
	8	Gravet	
	12	Røkt	
	13	Saltet	
	14	Saltet og tørket (klippfisk)	
	15	Speket	
	16	Sukkersaltet	
	17	Tørket	
	99	Uspesifisert	

Appendix D: Geographical distribution of the catch

Fishing ground		N. of landings	Fish category				Total [tonnes/yr
			Pelagic [tonnes/yr]	Other fish [tonnes/yr	Shrimps [tonnes/yr	Other shellfish [tonnes/yr	
0	VESTFJORDEN (LOFOTEN)	69 919	395 403	52 130	73	3	447 609
1	KANINBANKEN - Sørøstlige Barentshav	22	592	1 349	0	0	1 941
2	MURMANSKKYSTEN	82	17 152	622	0	0	17 774
3	ØST-FINNMARK	40 773	157 241	68 134	615	423	226 414
4	VEST - FINNMARK	77 508	87 284	92 901	409	0	180 594
5	RØSTBANKEN TIL MALANGSGRUNNEN	97 111	2 538	136 343	89	15	138 985
6	HELGELANDSBANKEN	63 695	23 094	29 825	217	820	53 956
7	STOREGGA-FRØYABANKEN - Møre	127 101	87 679	39 545	62	3 040	130 325
8	EGERSUNDBANKEN - Nordsjøen	52 084	154 872	13 766	3 753	525	172 916
9	SKAGERRAK	42 870	3 237	2 388	3 275	101	9 001
10	SKOLPENBANKEN - Barentshavet	64	9 777	1 387	2	0	11 166
11	GÅSEBANKEN	64	36 973	617	31	0	37 621
12	NORDKAPPBANKEN / TROMSØFLAKET	1 022	3 608	26 100	11	0	29 720
13	THOR IVERSENS BANK - Barentshavet	228	19 945	1 588	4 904	0	26 437
14	BRITVINFELTET	51	41 872	0	131	0	42 002
15	SENTRALBANKEN - Nordøstlige Barentshav	182	0	15	13 986	0	14 000
20	BJØRNØYA - Barentshavet	319	0	13 140	186	0	13 326
21	VEST SPITSBERGEN Vernesonen ved Svalbard	37	0	537	420	0	958
22	STORFJORD/HINLOPENSTREDET - Vest Spitsbergen	24	0	511	637	0	1 149
23	HOPEN - Spitsbergen Øst/Vernesonen	164	0	627	5 332	0	5 959
24	STORBANKEN - Barentshavet	153	0	858	12 916	0	13 774
25	NORD - VEST SPITSBERGEN / VEST SPITSBERGEN	59	0	48	3 945	0	3 993
27	SØRVEST AV SPITSBERGEN	4	0	72	0	0	72
28	VIKINGBANKEN - Nordsjøen	19 301	135 284	18 947	18	349	154 599
30	SØRLIGE NORSKEHAV	266	45 260	748	0	0	46 008
31	ØST AV FÆRØYANE	160	19 903	2 392	0	0	22 295
34	SENTRALE NORSKEHAV	51	10 761	235	0	0	10 995
35	SØR AV JAN MAYEN	16	0	33	1 043	0	1 075
37	ØSTLIGE NORSKEHAV	199	10 126	8 269	0	0	18 395
38	NORDVESTLIGE NORSKEHAV	4	396	0	48	0	444
39	VEST AV TROMSØFLAKET	6	304	137	0	0	441
40	SØRLIGE NORDSJØEN	18	1 817	0	0	0	1 817
41	SENTRALE NORDSJØEN+D1905	1 117	166 522	847	2	2	167 373
42	SHETLAND	1 125	26 064	30 326	14	1	56 405
43	VEST AV SKOTTLAND/HEBRIDENE	277	105 162	3 000	0	0	108 161
47	ROCKALL	151	102 663	1 641	0	0	104 305
48	VEST AV IRLAND	55	51 091	579	0	0	51 670
49	SØRVEST AV IRLAND	9	5 575	26	0	0	5601
50	SØRVESTLIGE NORSKEHAV	8	0	283	0	0	283
51	SØRØST AV ISLAND	6	0	123	0	0	123
52	SØRVEST AV ISLAND	16	0	434	0	0	434
53	NORDVEST AV ISLAND - Danskestredet/Østgrønland	23	11726	0	0	0	11 726
54	NORD AV HORN, ISLAND	5	1 650	0	0	0	1 650
55	NORD AV ISLAND	1	0	53	0	0	53
56	NORDØST AV ISLAND	18	11 693	0	0	0	11 693

Fishing ground		N. of landings	Fish category Pelagic [tonnes/yr]	Other fish [tonnes/yr	Shrimps [tonnes/yr	Other shellfish [tonnes/yr	Total [tonnes/yr
57	VEST AV FÆRØYANE	133	12 062	2 135	0	0	14 197
58	FÆRØYBANKEN	53	1 998	1 048	0	0	3 045
59	ØST AV ISLAND	10	8 102	0	0	0	8 102
60	SKJOLDUNGEN/REYKJANESRYGGEN	34	0	4 386	62	0	4 447
61	DANMARKSTREDET - Østgrønland	73	0	1 827	673	0	2 499
62	GAMMELOCK - ØSTGRØNLAND ØST	61	24 609	0	0	0	24 609
68	FYLLAS BANK	6	0	1 367	0	0	1 367
70	REYKJANESRYGGEN	69	37 463	1 619	0	0	39 082
80	NORDLEGE GRAND BANK	1	0	0	0	0	0
81	FLEMISH CAP	16	0	31	2 760	0	2 791
99		1	0	21	0	0	21
Totalt		596 812	1 831 498	563 011	55 612	5 279	2 455 400

Appendix E: NEMO fishery zones

Main fishing grounds		NEMO zone	NEMO node at zone
00	VESTFJORDEN (LOFOTEN)	2400	24000
01	KANINBANKEN - Sørøstlige Barentshav	2401	24001
02	MURMANSKKYSTEN	2402	24002
03	ØST-FINNMARK	2403	24003
04	VEST - FINNMARK	2404	24004
05	RØSTBANKEN TIL MALANGSGRUNNEN	2405	24005
06	HELGELANDSBANKEN	2406	24006
07	STOREGGA-FRØYABANKEN - Møre	2407	24007
08	EGERSUNDBANKEN - Nordsjøen	2408	24008
09	SKAGERRAK	2409	24009
10	SKOLPENBANKEN - Barentshavet	2410	24010
11	GÅSEBANKEN	2411	24011
12	NORDKAPPBANKEN / TROMSØFLAKET - Barentshavet	2412	24012
13	THOR IVERSENS BANK - Barentshavet	2413	24013
14	BRITVINFELTET	2414	24014
15	SENTRALBANKEN - Nordøstlige Barentshav	2415	24015
20	BJØRNØYA - Barentshavet	2420	24020
21	VEST SPITSBERGEN Vernesonen ved Svalbard	2421	24021
22	STORFJORD/HINLOPENSTREDET - Vest Spitsbergen	2422	24022
23	HOPEN - Spitsbergen Øst/Vernesonen	2423	24023
24	STORBANKEN - Barentshavet	2424	24024
25	NORD - VEST SPITSBERGEN / VEST SPITSBERGEN - nord om 78gr N	2425	24025
27	SØRVEST AV SPITSBERGEN	2427	24027
28	VIKINGBANKEN - Nordsjøen	2428	24028
30	SØRLIGE NORSKEHAV	2430	24030
31	ØST AV FÆRØYANE	2431	24031
34	SENTRALE NORSKEHAV	2434	24034
35	SØR AV JAN MAYEN	2435	24035
37	ØSTLIGE NORSKEHAV	2437	24037
38	NORDVESTLIGE NORSKEHAV	2438	24038
39	VEST AV TROMSØFLAKET	2439	24039
40	SØRLIGE NORDSJØEN	2440	24040
41	SENTRALE NORDSJØEN+D1905	2441	24041
42	SHETLAND	2442	24042
43	VEST AV SKOTTLAND/HEBRIDENE	2443	24043
47	ROCKALL	2447	24047
48	VEST AV IRLAND	2448	24048
49	SØRVEST AV IRLAND	2449	24049
50	SØRVESTLIGE NORSKEHAV	2450	24050
51	SØRØST AV ISLAND	2451	24051
52	SØRVEST AV ISLAND	2452	24052
53	NORDVEST AV ISLAND - Danskestredet/Østgrønland	2453	24053
54	NORD AV HORN, ISLAND	2454	24054
55	NORD AV ISLAND	2455	24055
56	NORDØST AV ISLAND	2456	24056
57	VEST AV FÆRØYANE	2457	24057
58	FÆRØYBANKEN	2458	24058
59	ØST AV ISLAND	2459	24059
60	SKJOLDUNGEN/REYKJANESRYGGEN - Irmigerhavet/Nordlige Atlanterhav	2460	24060
61	DANMARKSTREDET - Østgrønland	2461	24061
62	GAMMELOCK - ØSTGRØNLAND ØST	2462	24062

Main fishing grounds		NEMO zone	NEMO node at zone
68	FYLLAS BANK	2468	24068
70	REYKJANESRYGGEN	2470	24070
80	NORDLEGE GRAND BANK	2480	24080
81	FLEMISH CAP	2481	24081

Appendix F: Delivery zones with less than 100 tonnes catch delivered per year

Zone(Municipality)		County	Pelagic	Other fish	Prawns	Other shellfish	Grand Total
1852	Tjeldsund	18		60			60
1449	Stryn	14		65			65
627	Røyken	6		72			72
602	Drammen	6		139			139
1151	Utsira	11			159		159
1129	Forsand	11		167			167
219	Bærum	2		127	60		187
1443	Eid	14		193			193
1816	Vevelstad	18		206			206
1815	Vega	18				250	250
1426	Luster	14				258	258
1432	Førde	14				282	282
704	Tønsberg	7		330			330
1524	Norddal	15		131		272	403
101	Halden	1		413			413
1812	Sømna	18		472			472
1854	Ballangen	18		492			492
1233	Ulvik	12		530			530
1429	Fjaler	14		56	101	438	594
1529	Skodje	15		617		25	642
1714	Stjørdal	17		645			645
626	Lier	6		670			670
1849	Hamarøy	18		695			695
713	Sande	7		773			773
215	Frogn	2		834			834
1134	Suldal	11		845			845
1853	Evenes	18		989			989
1154	Vindafjord	11		1 016			1 016
1526	Stordal	15		1 372			1 372
1919	Gratangen	19		1 402			1 402
1663	Malvik	16		1 422			1 422
1535	Vestnes	15		1 196	47	211	1 455
1751	Nærøy	17		1 712			1 712
1211	Etne	12	1 750				1 750
1828	Nesna	18		1 796			1 796
1102	Sandnes	11		1 649	54	208	1 911
1528	Sykkylven	15		1 918			1 918
1926	Dyrøy	19		2 147			2 147
1613	Snillfjord	16		2 318			2 318
1638	Orkdal	16		2 650			2 650
1571	Halsa	15		2 671			2 671
1260	Radøy	12				2 819	2 819
1924	Målselv	19		2 870			2 870
1111	Rennesøy	11		2 416	568	9	2 993
1539	Rauma	15		3 132		108	3 240
1566	Surnadal	15		4 533			4 533
1145	Bokn	11		1 285	4 142		5 427
104	Moss	1	424	6 533		10	6 967
1256	Meland	12		6 047		1 022	7 069
1560	Tingvoll	15		7 168			7 168
1029	Lindesnes	10		7 316			7 316
1748	Fosnes	17		7 482			7 482

Zone(Municipality)		County	Pelagic	Other fish	Prawns	Other shellfish	Grand Total
1519	Volda	15		7 485		40	7 525
1657	Skaun	16		8 807			8 807
1130	Strand	11		3 551	2 183	3 639	9 374
1725	Namdalseid	17		11 091			11 091
1833	Rana	18		14 432			14 432
1624	Rissa	16		14 791			14 791
1523	Ørskog	15		15 059		5	15 064
1913	Skånland	19			16 653		16 653
1265	Fedje	12		19 096		31	19 127
1811	Bindal	18		22 997			22 997
1263	Lindås	12	425	23 177	347	1 052	25 001
1264	Austrheim	12		25 459	140	265	25 864
1729	Inderøy	17		26 207			26 207
1413	Hyllestad	14	31 390	1 415			32 804
1242	Samnanger	12	10 953	21 997		68	33 017
1411	Gulen	14		22 553	12 138	3 806	38 497
1216	Sveio	12	2 741	1 303	15 430	20 501	39 975
1124	Sola	11		2 909	16 906	21 734	41 549
1223	Tysnes	12	15 803	9 729		22 934	48 466
1141	Finnøy	11	11 841	38 810		499	51 149
1243	Os	12	50 027	246	1 355		51 627
1703	Namsos	17		54 484			54 484
1622	Agdenes	16	42 622	15 333			57 954
1612	Hemne	16		59 459			59 459
1246	Fjell	12	40 389	2 356	588	16 646	59 979
1214	Ølen	12	63 858				63 858
1915	Bjarkøy	19		76 888			76 888
1749	Flatanger	17		98 705			98 705
SUM, < 100 tonnes			296 134	702 770	70 870	97 132	1 166 906
% of TOTAL			*0,016 %*	*0,125 %*	*0,127 %*	*1,840 %*	*0,048 %*

Appendix G: Cost functions and parameter values in the fishery model

Detailed description of the variables is given in the STAN User’s manual, release 6.

modes

l	'lastebil	'	1	1	1.000	.059	.075	1.000
r	'jernbane	'	1	2	1.000	.070	.200	1.000
s	'kystfart	'	1	5	1.000	.038	.000	1.000
v	'sjøfart Europa	'	2	1	1.000	.038	6.472	1.000
o	'oversjøisk	'	5	5	1.000	.038	.000	1.000
e	'jernbaneferge	'	1	1	1.000	.038	6.472	1.000
i	'indre vannveier	'	7	7	1.000	.038	.000	1.000
f	'ferge	'	2	3	1.000	.038	6.472	1.000
b	'bulk-nett	'	4	8	1.000	.038	6.472	1.000
a	'flyfrakt	'	2	9	1.000	.045	.000	1.000
p	'rørnettverk	'	1	6	1.000	.000	.000	1.000
t	'fiskeri	'	1	6	1.000	.380	.000	1.000

products

p= 1	descr='mat inkl bearb fisk '	662823.0	340909.0	.410
p= 2	descr='frossen fisk '	662823.0	340909.0	.480
p= 3	descr='termovarer '	662823.0	340909.0	8.400
p= 4	descr='transpmidl/maskiner '	662823.0	340909.0	4.400
p= 5	descr='div. stykkgods '	672923.0	340909.0	.460
p= 6	descr='tommer og trelast '	101010.0	101010.0	.050
p= 7	descr='kull,koks, sand etc '	101010.0	101010.0	.030
p= 8	descr='kjemiske produkter '	111111.0	101010.0	.070
p= 9	descr='malmer/metall '	101010.0	101010.0	.220
p=10	descr='flytende bulk '	121212.0	101010.0	.050
p=11	descr='fersk fisk '	662823.0	340909.0	28.300
p=12	descr='gass '	121212.0	101010.0	.050
p=13	descr='flyvare '	672923.0	340909.0	2.050
p=14	descr='Fiskefangst fersk '	662823.0	340909.0	28.300
p=15	descr='Fiskefangst frosset '	662823.0	340909.0	.480
p=16	descr='Fiskefangst annet '	662823.0	340909.0	.410
p=17	descr='Fiskefartoy '	662823.0	340909.0	.000

vehicles for relevant combinations of product and mode

p= 1	m=s	.010	.000	.010	.069	10.580	537.370
p= 1	m=t	.010	.000	.010	.265	13.800	537.370
p= 2	m=s	.010	.000	.010	.063	13.800	537.200
p= 2	m=t	.010	.000	.010	.265	13.800	537.200
p=11	m=s	.010	.000	.010	.063	13.800	537.200
p=11	m=t	.010	.000	.010	.265	13.800	537.200
p=14	m=s	10.900	.000	10.900	.265	13.800	537.370
p=14	m=t	10.900	.000	10.900	.265	13.800	537.200
p=15	m=s	10.900	.000	10.900	.265	13.800	537.370
p=15	m=t	10.900	.000	10.900	.265	13.800	537.200
p=16	m=s	10.900	.000	10.900	.265	13.800	537.370
p=16	m=t	10.900	.000	10.900	.265	13.800	537.370
p=17	m=s	10.900	.000	10.900	.265	13.800	537.370
p=17	m=t	10.900	.000	10.900	.265	13.800	537.370

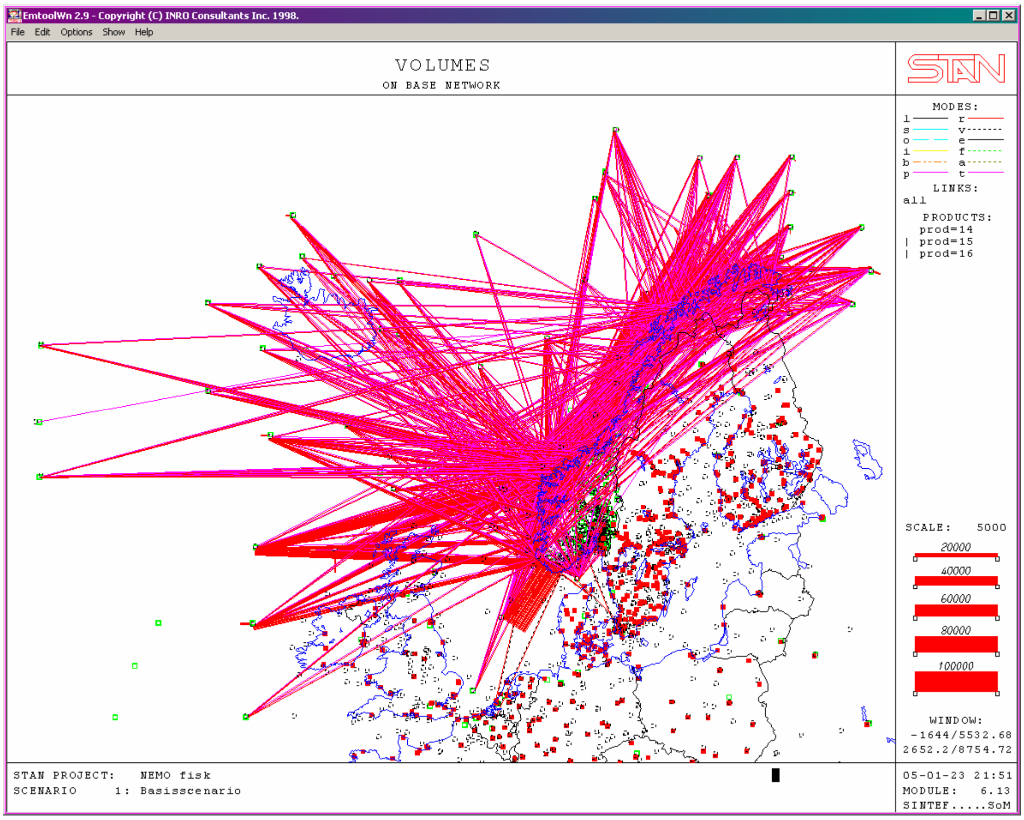
link function sets for the t mode

```
a   301    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    302    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    303    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    301    8:299    9:299   10:299   11:299   12:299   13:299   14:299
    302    8:299    9:299   10:299   11:299   12:299   13:299   14:299
    303    8:299    9:299   10:299   11:299   12:299   13:299   14:299
    301   15:299   16:299   17:112
    302   15:299   16:299   17:290
    303   15:299   16:299   17:290
a   311    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    312    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    313    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    311    8:299    9:299   10:299   11:299   12:299   13:299   14:111
    312    8:299    9:299   10:299   11:299   12:299   13:299   14:121
    313    8:299    9:299   10:299   11:299   12:299   13:299   14:290
    311   15:111   16:111   17:112
    312   15:121   16:121   17:290
    313   15:290   16:290   17:290
a   321    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    322    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    323    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    321    8:299    9:299   10:299   11:290   12:299   13:299   14:290
    322    8:299    9:299   10:299   11:290   12:299   13:299   14:290
    323    8:299    9:299   10:299   11:290   12:299   13:299   14:290
    321   15:290   16:290   17:112
    322   15:290   16:290   17:290
    323   15:290   16:290   17:290
a   331    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    332    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    333    1:299    2:299    3:299    4:299    5:299    6:299    7:299
    331    8:299    9:299   10:299   11:299   12:299   13:299   14:290
    332    8:299    9:299   10:299   11:299   12:299   13:299   14:290
    333    8:299    9:299   10:299   11:299   12:299   13:299   14:290
    331   15:290   16:290   17:112
    332   15:290   16:290   17:290
    333   15:290   16:290   17:290
```

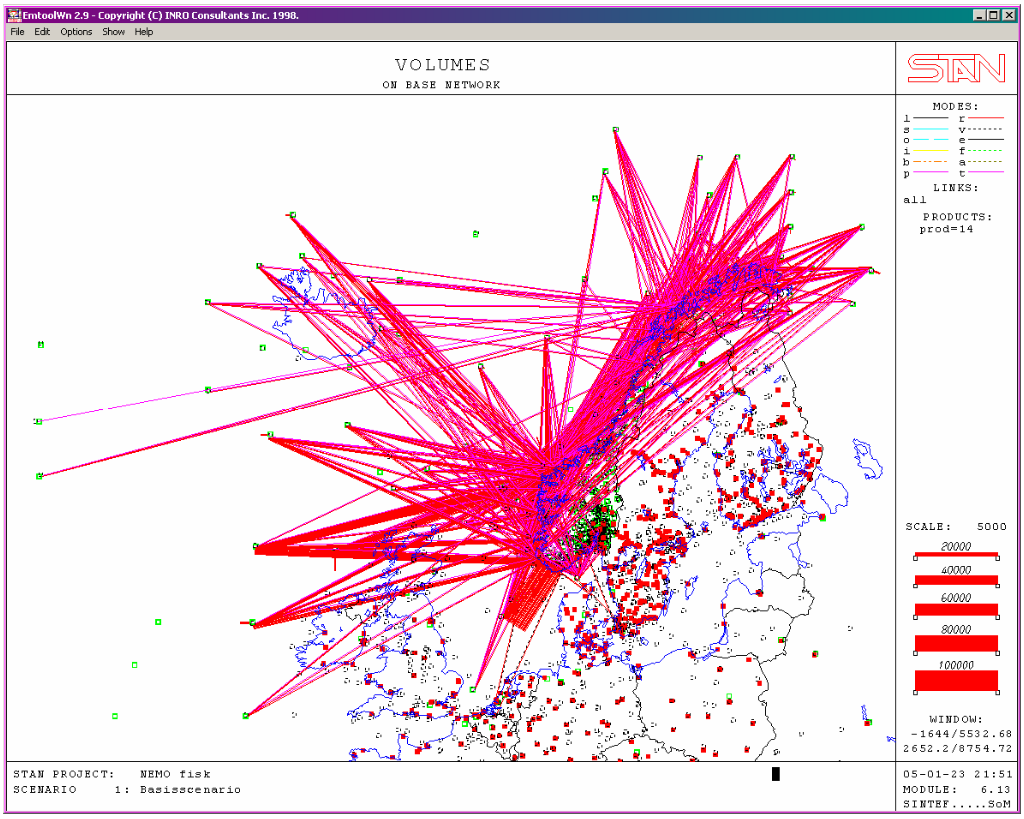
Functions for products 14 – 17 on the t mode

```
a fl111=phil * (uv1 * length + uv2 * length / (ul1 * ul2 * (18.2 / 18.5)
        ) * (1 + um1 / 1000)) * um3
a fl112=phil * (uv1 * length + uv2 * length / (ul1 * ul2 * (18.2 / 18.5)
        ) * (1 + um1 / 1000)) * um3 * 10.9
a fl121=up3 * length / (ul1 * ul2 * (18.2 / 18.5)) * (1 + um1 / 1000)
a fl290=0
a fl299=999999
```

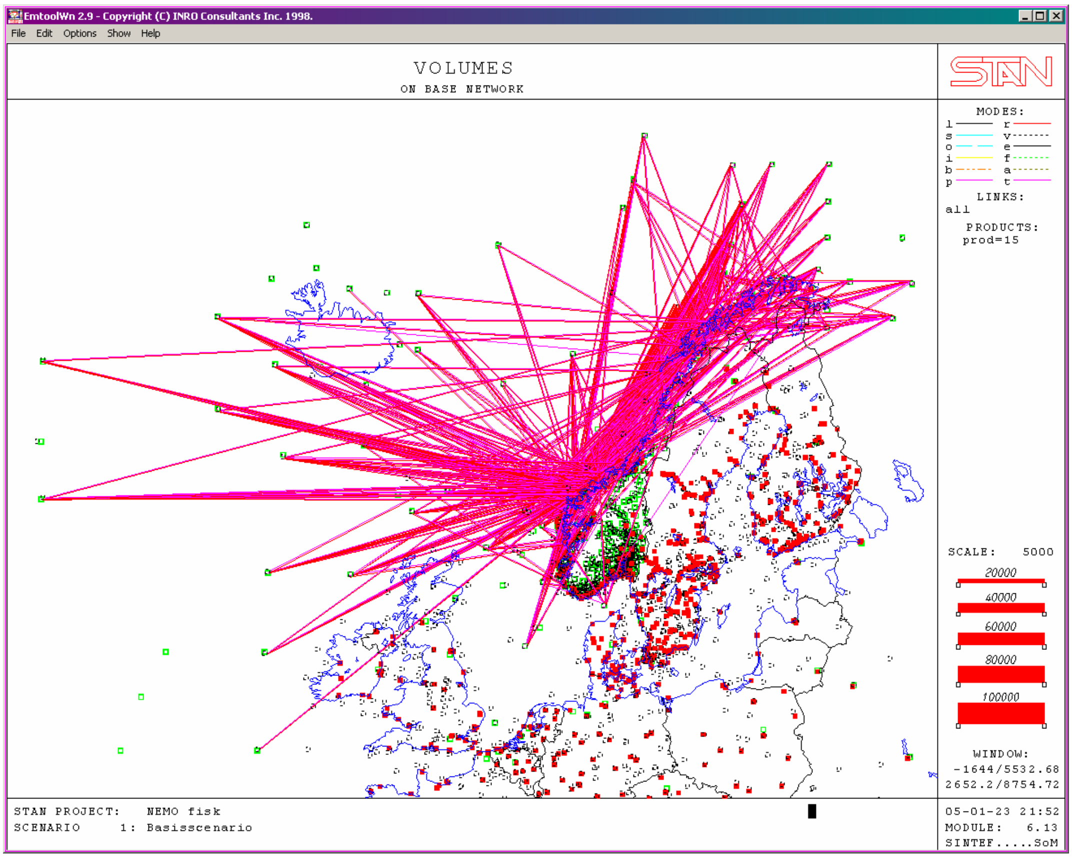
Appendix H: Assignment plots scenario 0



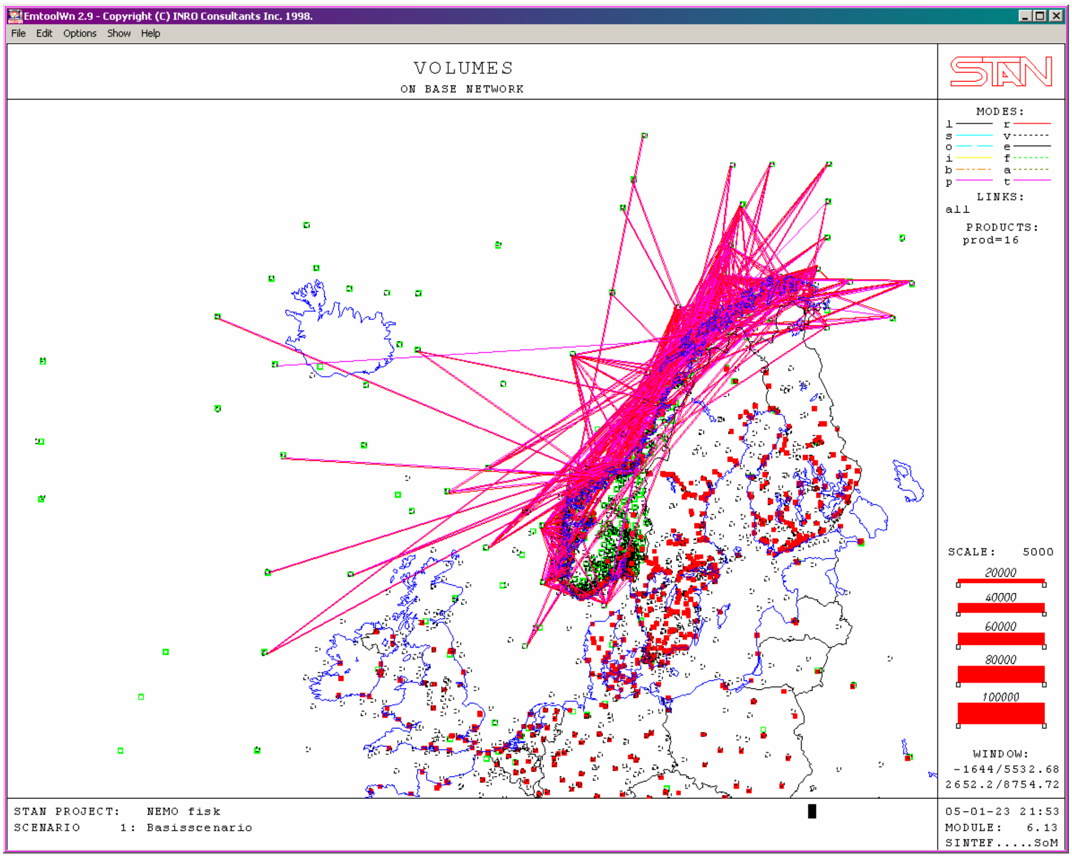
Fish, commodity group 14, 15 and 16, base network



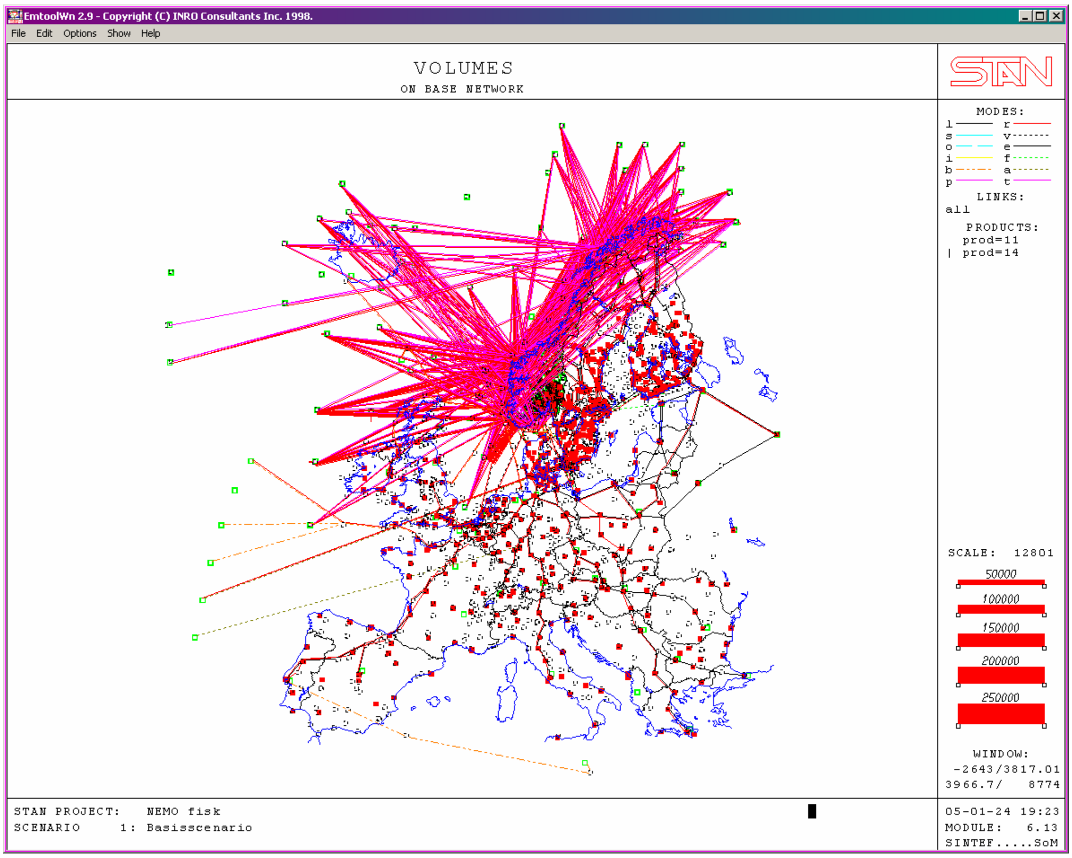
Fresh fish, commodity group 14, base network



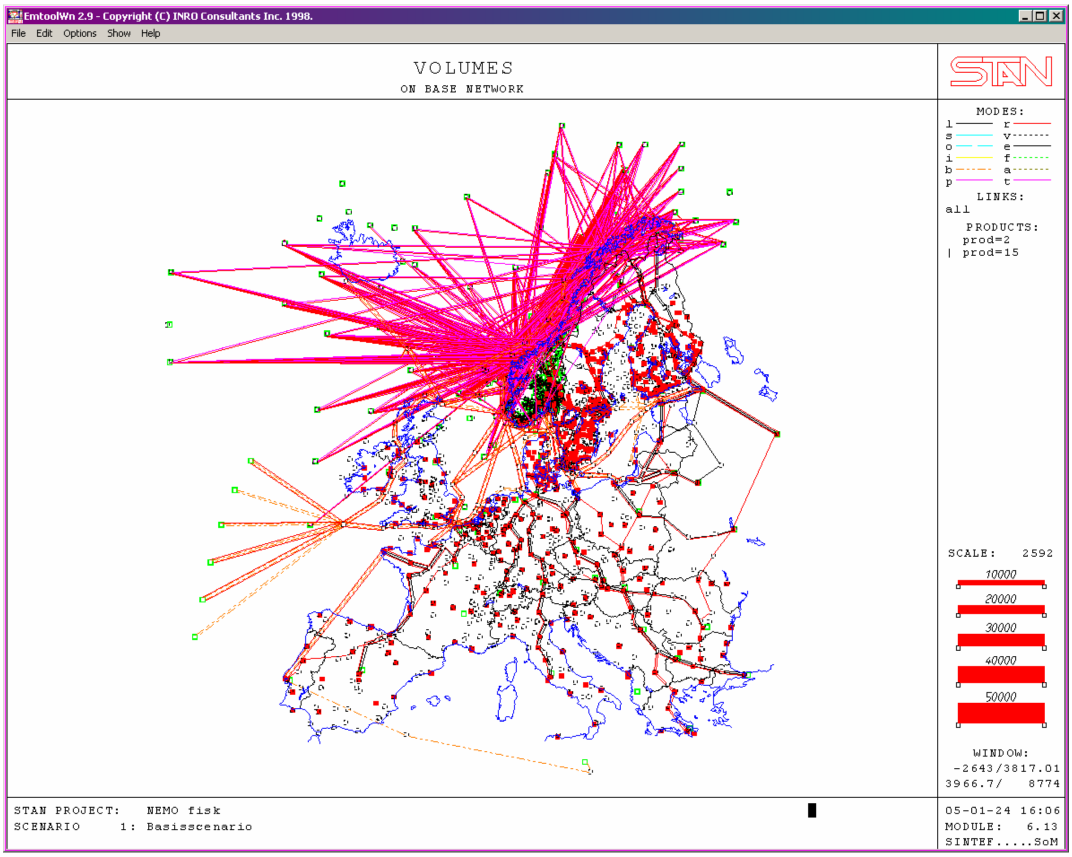
Frozen fish, commodity group 15, base network



Other fish, commodity group 16, base network

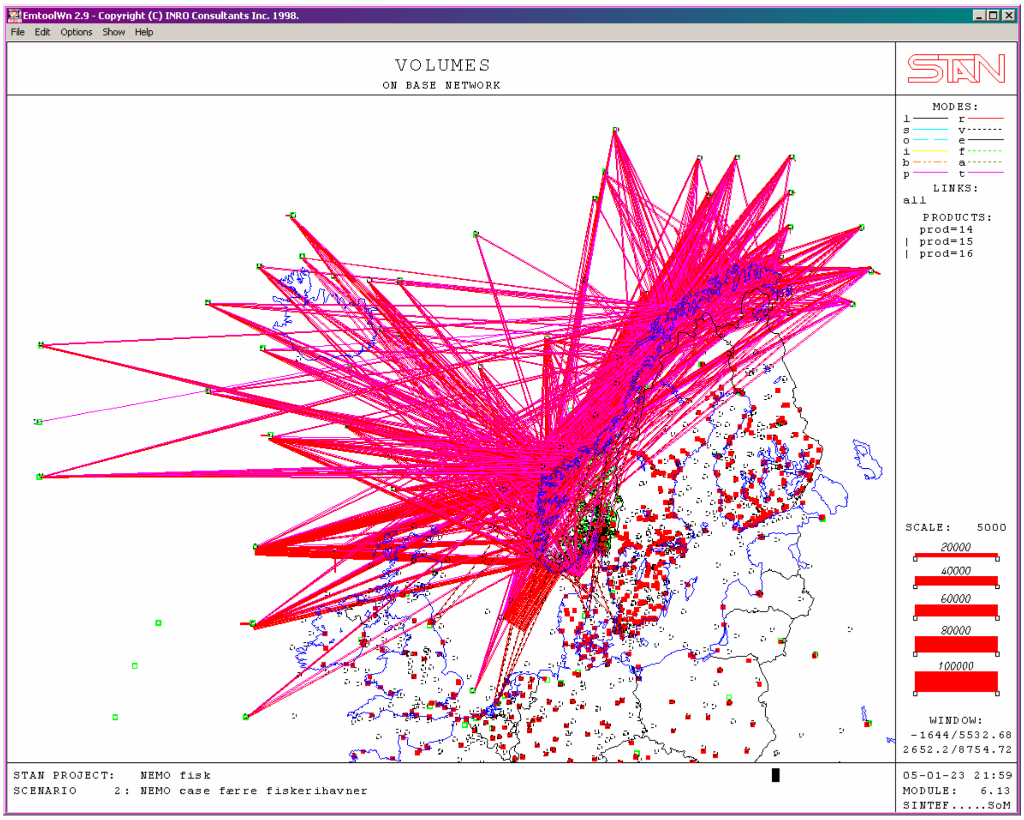


Fresh fish, commodity group 11 (NEMO) and 14 (fishery model), base network

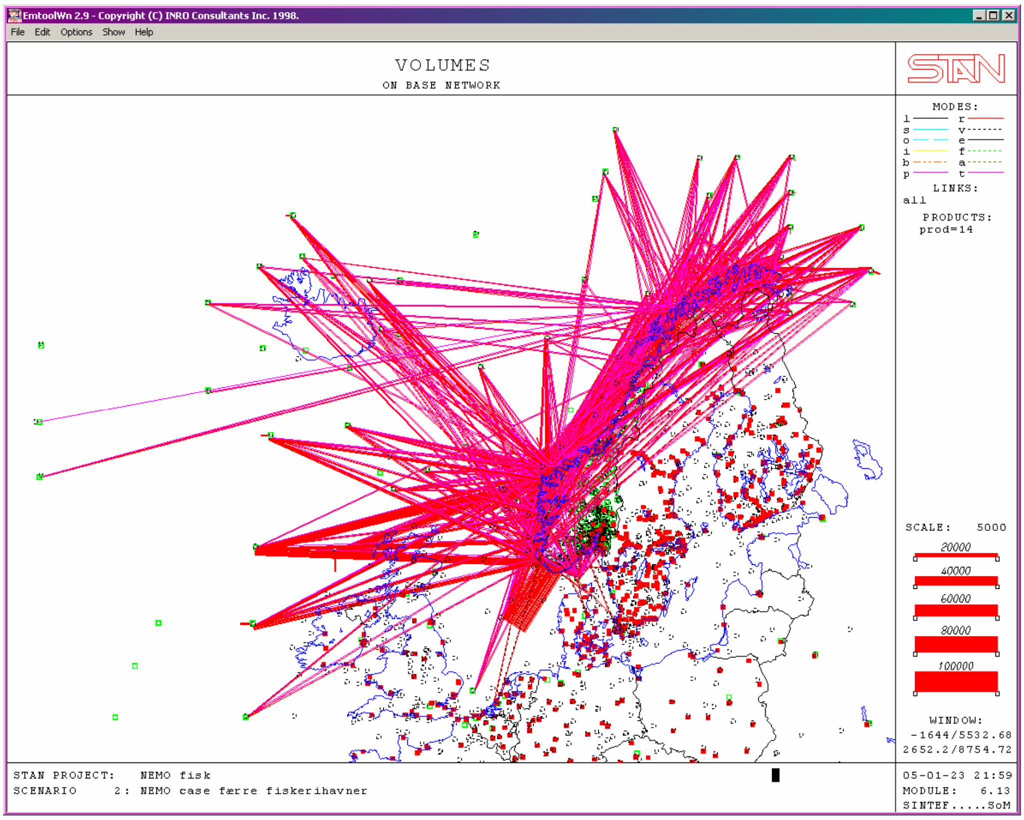


Frozen fish, commodity group 2 (NEMO) and 15 (fishery model), base network

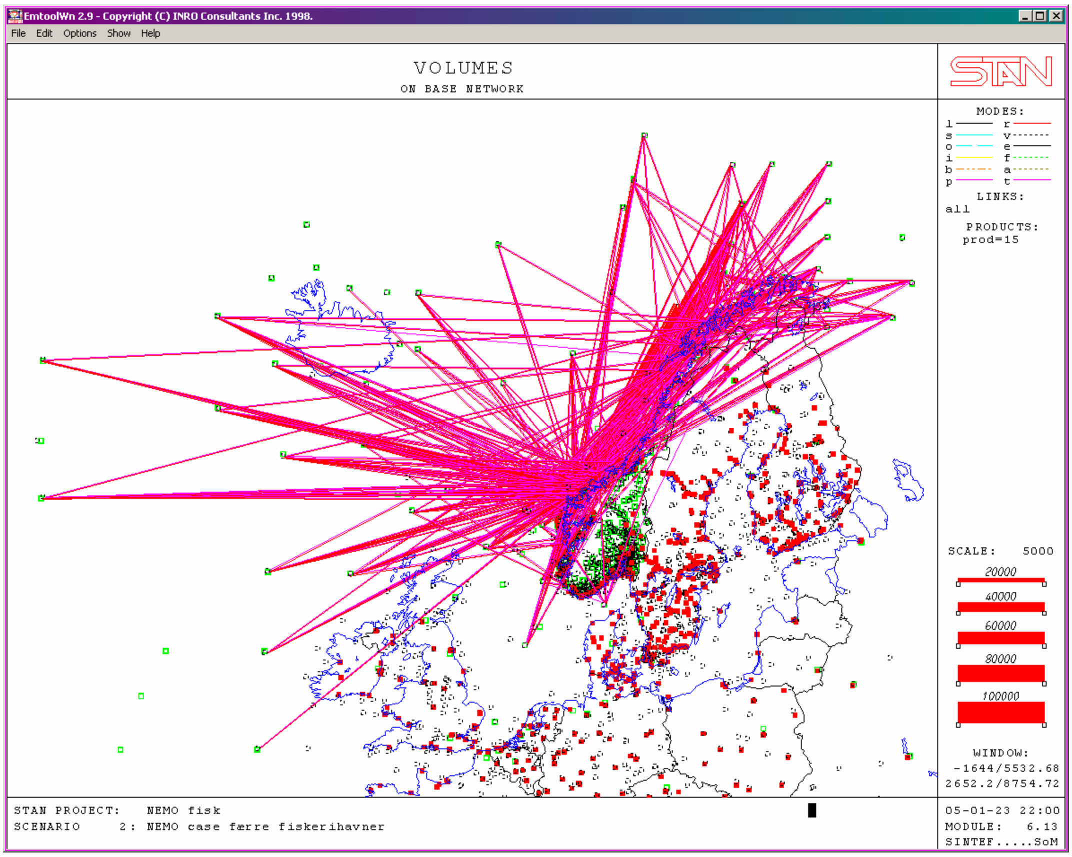
Appendix I: Assignment plots scenario 1



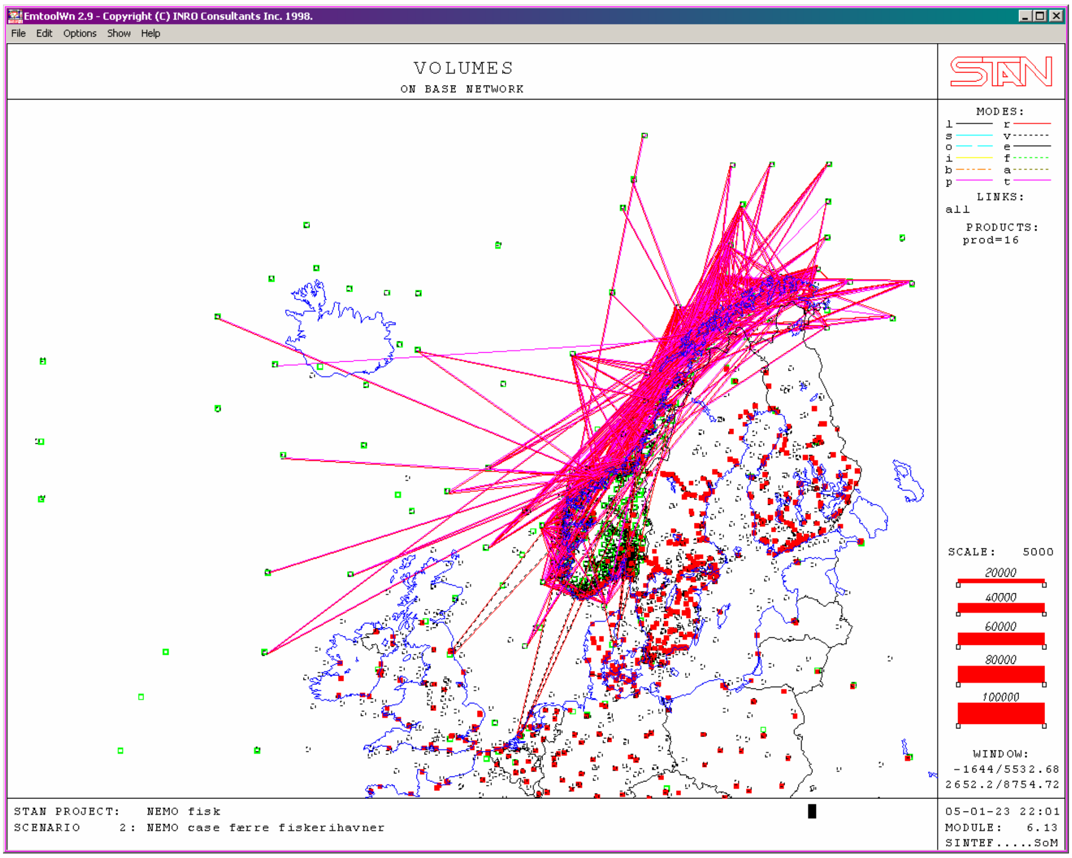
Fish, commodity group 14, 15 and 16, reduced numbers of fishery harbours



Fresh fish, commodity group 14, reduced numbers of fishery harbours



Frozen fish, commodity group 15, reduced numbers of fishery harbours



Other fish, commodity group 16, reduced numbers of fishery harbours

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