METHODS AND RESULTS IN THE JOINT PINRO-IMR STOMACH SAMPLING PROGRAM

by

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ABSTRACT

In 1984 IMR started a stomach sampling program on cod (Gadus morhua) in the Barents Sea. The aim of the program was to provide the multi-species model with quantitative data on the cod's food selection. Later other species have been included in the investigations. In 1987 PINRO joined the program, and the two countries have almost identical methods for sampling at sea, laboratory analyses and computer registration of the data. Stomach data are exchanged annually on data medium and the two countries have built up identical stomach content data bases.
The data base now contains information from more than 56000 individually analysed fish. 40000 of these are cod, and the majority (34000) are sampled from 1984 to 1990. A number of works are based on the stomach data base; describing the diet of several species and the cod stock's food consumption, comparing individual growth and food consumption in the cod stock and calculating mortality on several preys induced by cod.

INTRODUCTION.

In the beginning of the 1980's the work on a multispecies model for the Barents Sea was initiated at IMR. Cod (Gadus morhua) and capelin (Mallotus villosus) were the starting point for the building of the model (Mehl et al. 1985), and an essential requirement for the model were quantitative data on the cod stock's food selection. A stomach sampling program on cod started winter 1984, and a stomach content data base has been built up. Later, data on other species than cod have been included in the base.

International cooperation on the developement of multispecies models are necessary (Mehl and Tjelmeland 1990). The fish stocks are managed by international agreements, and the resources needed for developing multispecies models exceeds what can be expected to be spent by one country. Especially, the data requirements are high. The stomach data must be extensive both in time and space, and the predators' main area of distribution should be covered several times of the year. To meet this requirement, an exchange program between IMR and PINRO on stomach content data was initiated in 1987. This paper describes the methods used in the joint stomach sampling program, as well as the present status of the joint stomach content data base. The result of some work based on the stomach data base are also refered.

METHODS

The methods used for sampling, stomach analysis, data recording and computer input are mainly the same as for the ICES "Stomach sampling project 1981" in the North Sea (Anon. 1974, 1980, 1981; Westgård 1982; Mehl 1986a; Christiansen 1987a; Tretyak et al. 1990). Samples have been collected onboard Norwegian and Russian research vessels during routine surveys in the Barents Sea and the Svalbard area (Fig. 1). The gears used are both pelagic and bottom trawl, but the bulk of the samples are taken by the latter. The reasons for this are several: cod is difficult to catch by pelagic trawl, there is not enough time available for pelagic trawling during a bottom trawl survey, the Russian vessels can only have one type of trawl ready for trawling at a time.

In the North Sea project a minimum of ten stomachs per statistical rectangle per quarter should be collected for each given predator length group. The sampling intensity in the Barents Sea has been adjusted to the two countries' survey programs in the area. On Norwegian surveys, the aim has been to collect up to ten stomachs of cod for each 10-cm length group on stations with other biological sampling (otoliths etc.). The trawl stations are randomly spread within each stratum of the investigated area, and the sampling continues over 24 hours per day. A portion of samples collected by PINRO for 1986 and 1988-1990 has been obtained in special cruises for observations over daily dynamics of fish feeding. In these cases the samples have been taken in the same area in definite intervals of time during a day or more (Tarverdieva and Yaragina 1989; Dolgov 1989; Dolgov and Yaragina 1990).

Fish which show evidence of regurgitation, are if possible replaced with non-regurgitating feeding fish. Onboard Norwegian vessels, each stomach is frozen separately as soon as possible after sampling. Data on the length, weight, sex, maturity stage and the number caught per trawl haul of each individual predator are recorded together with the station data. Age data are included later after the otoliths are read and age determined. Onboard Russian vessels, the stomachs are preserved individually in 4 % formalin. In addition to the above mentioned data, the weight of the predator's liver is normally recorded.

In the laboratory the frozen stomachs are open as soon as practically possible. Fish prey and shrimps are identified to species level when possible, other prey is identified to species level when practical. Each recognizable prey species, genus, family or higher order are split into size-classes and damp dried on bibulos paper. Numbers and total wet weight, measured to the nearest milligram, are recorded for each size-class and prey category separately.

Since the Norwegian and Russian methods for sampling at sea and laboratory analysis were almost similar, it was decided to use the Norwegian data form (with some minor changes) for data recording. This was agreed upon during a meeting between Norwegian and Russian scientists in Murmansk 15 - 26 April 1987. An example of the dataform and coding instructions is given in Christiansen (1987a). 10-digit NODC species codes (Anon. 1984) are used for coding the predator and prey species. Mehl (1985) lists the species and codes that are most frequently used in the stomach program. Norway and Russian have slightly different codes for maturity stage, degree of stomach filling and degree of digestion (Table 1). In addition, the two countries have opposite codes for sex (1=male and 2=female in Russian, in Norway the other way around). During the meeting it was decided to leave it this way in the data base and to convert the scales to match each other in the computer programs retrieving data from the data base.

Attempts were made to install the IMR stomach program system on PINRO computers, but this failed. Back in Bergen, the Fortran programs on the IMR Norsk Data computer were converted to MS-DOS (Alvheim 1987) and installed on a personal computer which later was lent to PINRO. During a meeting between Norwegian and Russian scientists in Bergen 7 - 18 December 1987 the stomach program system was demonstrated for the Russian scientists and they got some experience using the system. It was decided that the first exchange of stomach data on data medium (diskettes) should take place in Murmansk at the annual spring meeting in 1988.

Since 1988 stomach data have been exchanged annually, and both countries have built up identical data bases. The structure of the data base is described in Westgård (1982), Mehl (1986a), Alvheim (1987) and Christiansen (1989). Several computer programs have been developed for extracting information from the data base (Westgård 1982; Mehl 1986a, Alvheim 1987, Christiansen 1987b, 1989). The most commonly used program aggregates information over areas and time periods and produces a summary table for the specified predators diet after criteria given interactively on the screen (Christiansen 1989). The user has to specify time period, geographical area, predator species, predator size group or age group, prey size or not, taxonomic level on output and which stomachs to be included (all or only those with content). Other criteria have default values that can be changed: weight unit on output, time of the day to be included, depth interval, gear, weighting factor in aggregation procedure, nation and which predator age to be used (punched or calculated from an age/length key). The result file first gives information on the number of stations in the given area and time period with the specified predator, total number of stomachs, percentage empty, average filling degree, mean index of stomach fullness, relative index of fatness (if liver-weight data) and average predator weight. The following diet list gives information about each prey category (mean values): weight per predator and weight percentage, number per predator and number percentage, weight of an individual prey item, frequency of occurence, index of relative importance and the average weight percentage per stomach.

THE STOMACH DATA BASE.

Table 2 lists the present number of stomachs included in the data base by species and year. All together data from 56737 fish are now in the base. Cod contribute with more than 70 % of the stomachs (40512) and haddock (Melanogrammus aeglefinus) with almost 20 %. A smaller number of stomachs from capelin, herring (Clupea harengus), redfish (Sebastes spp.), blue whiting (Micromesistius potassou), polar cod (Boreogadus saida) and plaice (Pleuronectes platessa) are also included in the data base.

The cod stomachs are sampled from 1950 to 1990, but the bulk of them are from 1984 and onwards. Table 3 presents the number of cod sampled from 1984 to 1990 by year and quarter. The first and third quarter of the year are best covered with samples. All of the stomachs collected in 1990 are not yet analysed and included in the data base.

Fig. 1A-D show the geographical distribution of trawl stations with sampling of cod stomachs by quarter for the period 1984-1990. In the first quarter of the year the main area of distribution is well covered north to the ice edge, and almost 500 stations have been taken in the period. The second quarter is least sampled, and most of the 150 stations are taken during the Norwegian shrimp survey in the central Barents Sea. The sampling in the third quarter cover most of the Northeast Arctic cod stock's area of distribution at that time of the year. More than 400 stations have been sampled, many of them during the Russian-Norwegian multispecies survey. The last quarter of the year has the best coverage in the south-eastern part of the Barents Sea, where the major part of about 200 stations have been taken.

Table 4 presents the number of cod stomachs sampled by predator size group and year for the period 1984-1990. The size groups between 30 and 70 cm are best represented, but also the groups 20-29 cm and 70-79 cm are reasonably well covered. Few fish below 10 cm and over 80 cm are sampled. Although the sampling strategy has been to collect the same number of stomachs from the different size groups, strong year classes are better represented than weaker ones. In the table we can follow the 1983 year class from it enters size group 10-19 cm in 1984 and goes across the table to size groups 60-69 and 70-79 cm in 1989-90.

RESULTS.

This paper does not intend to present any new results by its own, but the result of some of the work based on the stomach data base is summarized in the following.

The cod's diet and consumption

The prey spectrum of cod is broad, and there are size related, spatial, seasonal and year-to-year variations in the diet (Mehl 1986b; Orlova et al. 1988, 1989, 1990a). The general trend is that crustaceans, mainly copepods, krill (Euphausiacea) and amphipods (Hyperiidae), are the dominant food of smaller cod and fish are the major prey of cod larger than 25-30 cm. Capelin is the main fish prey, and is most important for medium-sized cod. Crustaceans such as deep sea shrimp (Pandalus borealis), amphipods and krill also are important for medium-sized cod. The largest cod prey more upon larger fish such as haddock, redfish (Sebastes spp.), blue whiting, flatfish (Pleuronectidae) and cod (cannibalism).

The diets of cod and haddock have been compared (Burgos and Mehl 1987), but the diet overlap was low except in spring and fall when smaller sizegroups of both species prey on krill. Observations on 2- day stations indicated the indices of food similarity for cod and haddock to vary during the day and the highest indices resulted from an occurrence of euphausids in feeding spectra of these fishes (Dolgov and Yaragina 1990).

The Northeast Arctic cod stock's total consumption has been estimated by combining stomach content data for each agegroup with data on gastric evacuation and the number of cod in each agegroup (Mehl 1989; Bogstad and Mehl 1991). Capelin has made up the largest part of the total consumption, and the increasing cod stock in 1984-86 probably contributed to the quick depletion of the capelin stock. The consumption of capelin was lowest in 1987 and started to increase from 1988. Shrimp, redfish and amphipods have also contributed much to the cod stock's consumption. Herring, haddock and young cod have made up a minor part of the diet measured in biomass consumed, but measured in numbers consumed, the predation pressure must have been considerable on several year classes of these prey species during the mid 1980s. The cod stock has probably consumed a higher number of itself than what is recruited to the fishable part of the stock (3+) in an average year (Korzhev and Tretyak 1989; Mehl 1989; Skagen et al. 1990).

The consumption estimates are strongly dependent on the gastric evacuation model used in the calculation and may vary by a factor of 2.0 depending on the chosen model (Bogstad and Mehl 1990). This is too much when the consumption of some important prey species are of the same order of magnitude as the catch. The estimates are also dependent on the quality of the stomach content data and how representative the data are for the different components of the cod stock. The stomach content may vary for fish feeding pelagic and near the bottom (Ajiad 1990). The survey design will affect the precision of estimates of average stomach contents (Bogstad et al. 1991). Theoretical calculations made by Tretyak et al. (1990) showed that 50 stomachs from each 10-cm size group are necessary for obtaining statistically reliable data, characterizing feeding of cod in any month. The total yearly number of samples with allowance for 7 areas of the Barents Sea then increases to 20.000, which hardly can be achieved.

There seems to be a food availability dependent growth in cod (Ajiad et al. 1989). The cod partly compensated the loss of capelin by preying more intensively on other food items. But change of qualitative food composition was followed by variations in seasonal growth of cod (Yaragina 1989; Orlova et al. 1990b). Scarce quantities of capelin, apparently influence upon the maturation of cod due to efficiency of feeding and variation in growth rate of cod (Orlova et al. 1990b). Total annual consumption and individual growth was dramatically reduced, and average fish weight decreased by about 50 % in most age groups from 1985 to 1988 (Mehl and Sunnanå 1990). Because the quotas are in tonnes, more fish than expected were caught. This together with the increased cannibalism caused management problems (Mehl 1991).

The diet of other fish species

The diet of a few other species has also been described based on data from the stomach data base. Haddock is a less ichthiophagous predator than cod and prefer more benthic preys including echinoderms, gastropods, bivalves and polychaetes (Burgos and Mehl 1987). The diet of polar cod, an opportunistic feeder, consist primarily of amphipods (Parathemisto spp.), copepods (Calanus spp.) and krill, the composition varying from region to region (Ajiad and Gjøsæter 1990).

Stomach data in multispecies models

The main purpose for the stomach sampling program has been to provide the multispecies model for the Barents Sea with data on the cod's food selection. The data are used in connection with the parameter estimation of the predation equations in the model. The model has been used to calculate the mortality on mature capelin induced by cod (Tjelmeland 1987; Bogstad and Tjelmeland 1990, 1992). The obtained mortalities range from about 0.5 to 2.0, and vary from year to year depending on changes in the cod stock and in the environment.

The stomach data have also been used in a spreadsheet system to do a transparent multispecies analysis of the Barents Sea and Norwegian coast (Bax et al. 1990). Output from the spreadsheet showed discrepancies between the biomasses estimated from surveys and commercial fishery statistics on the one hand, and losses in biomass estimated via food habits and catch data, on the other.

Stomach data on cod have been essential when VPAs modified for cannibalism are made (Skagen et al. 1990; Korzhev and Tretyak 1989). These works show that cannibalism has been considerable during the second half of the 1980s, and such informations must be taken into account when prognosis are made.

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Table 1 Russian and Norwegian codes for maturity stage, degree of stomach filling and degree of digestion

Maturity stage		Stomach filling		Digestion	
IMR	PINRO	IMR	PINRO	IMR	PINRO
0	I,II	1	0	1	1
1	III,IV	2	1	2,3	2
2,3	IV-V	3	2	4,5	3
4	V	4	3		
5	VI	5	4		
6	VI-II	6	5		
7	-				

Table 2 Number of stomachs included in the PINRO-IMR stomach data base at 26 April 1991 by species and year.

Year	Cod	Haddock	Capelin	Herring	Redfish	Blue W.	Pol. Cod	Plaic.
1950	141							
1951	25							
1952	616							
1954	134							
1955	188							
1956	1005				74			
1957	522							
1958	453							
1959	1028							
1960	186							
1973	174							
1975	199							
1980	608	241	125					
1981	408							
1982	833		225					
1983			441					
1984	3731	593	636	998				
1985	4153	1240	98	430		21		
1986	6044	1039	365	77		103	208	
1987	5945	1006	50			228	488	
1988	5419	2296			110		752	15
1989	6406	2224	728				625	32
1990	2264	757						
SUM	40512	9396	2668	1505	184	352	2073	47

Table 3 Number of cod stomachs sampled in the period 1984–1990 by quarter and year.

YEAR	QUARTER				
	1	2	3	4	SUM
1984	1087	346	1009	1289	3731
1985	1882	512	1271	488	4153
1986	1969	471	2952	652	6044
1987	1654	921	2045	1325	5945
1988	2513	252	1226	1428	5419
1989	2800	846	2497	263	6406
1990	1163	682	419		2264
SUM	13068	4030	11419	5445	33962

Table 4 Number of cod stomachs sampled in 1984–1990 by predator sizegroup and year.

	Predator sizegroup										
Year	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+	Total
1984	13	500	610	640	747	508	372	245	67	29	3731
1985	30	330	804	664	831	762	433	175	87	37	4153
1986	40	419	618	1111	1211	1344	1041	201	37	22	6044
1987	4	205	637	1004	1590	1164	910	350	59	22	5945
1988	3	44	358	979	1734	1644	558	204	54	23	5419
1989	12	141	287	724	1368	1842	1484	423	94	31	6406
1990	1	191	187	264	258	398	506	342	81	36	2264
Total	103	1830	3501	5204	7739	7662	5304	1940	479	200	33962

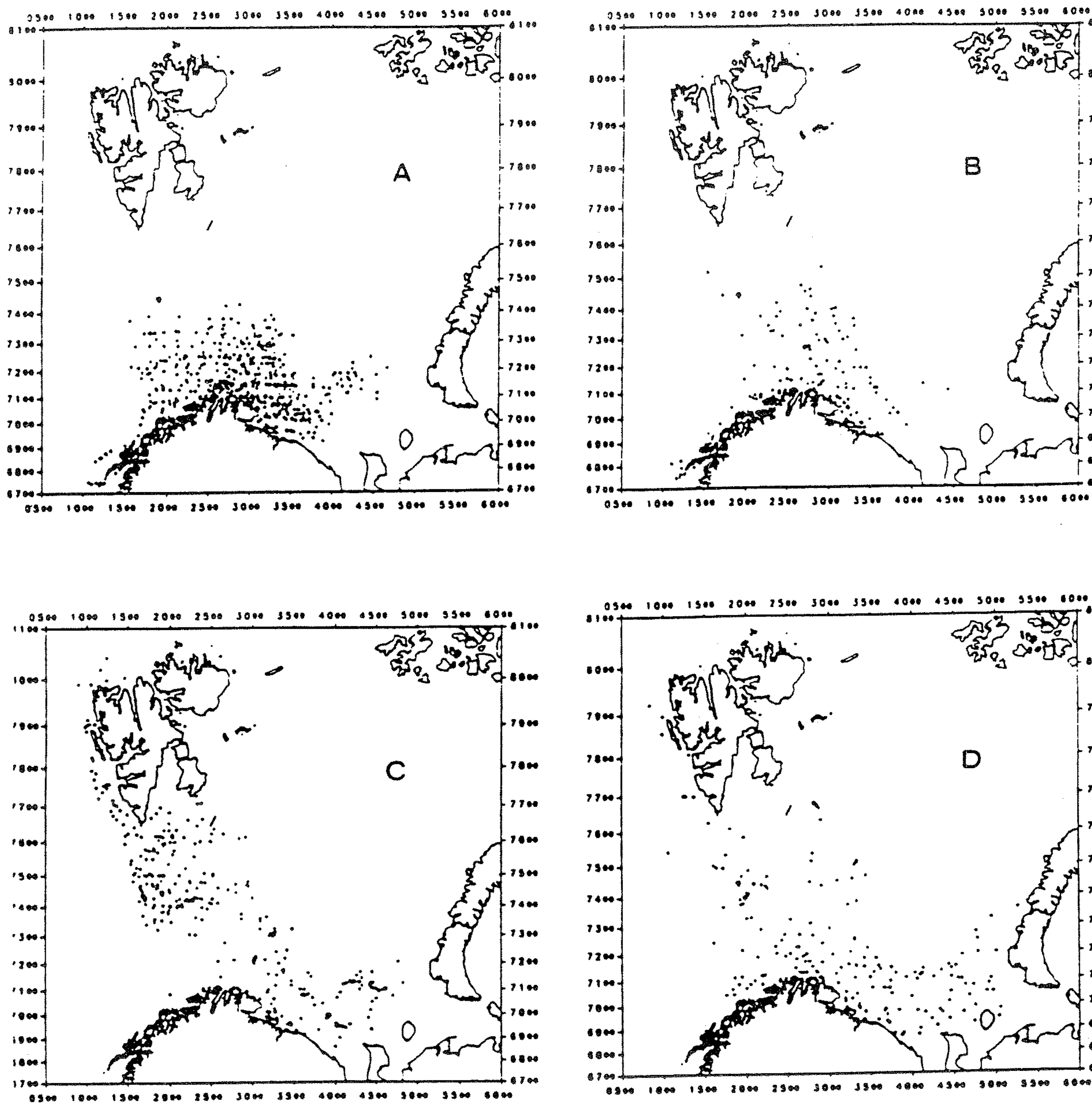

Figure 1: Geographical distribution of trawl stations with sampling of cod stomachs by quarter in 1984–1990. Q1 (A) = 497 stations, Q2 (B) = 149 stations, Q3 = 435 stations, Q4 = 221 stations.