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International Council for the  
Exploration of the Sea

C.M. 1984/8:25  
Fish Capture Committee  
Ref. Demersal and Pelagic Fish Cttees

NORFISK - an ecosystem simulation model for studies of the fish stocks off the coast of Norway.

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Abstract:

A biomass based ecosystem simulation model has been fitted to a restricted area of the Norwegian coastal waters. The model uses a holistic ecosystem approach and data on biomasses and their interaction with each other have been taken from the Møre region, western Norway. The main objective was to study interactions between cod, haddock saithe and herring and their prey in this area. Initial estimation of the biomasses was based partly on acoustic methods and partly on data from the literature. Sampling of stomach contents was conducted to provide data for food composition tables. The calculations in the model were based on biomasses only, but in the analysis each species was treated as eggs and larvae, juveniles and adults to give biomasses with relative homogeneous structure and behaviour. The problems of intergroup recruitment and migration have been discussed. The results indicate that using such a model as a tool to treat data can give a better understanding of the ecosystem.

## INTRODUCTION

### Scope of this report

This paper covers essential features of the NORFISK simulation, including a description of principle processes incorporated in the simulation, variable list and a discussion of the results of the first stabilization runs. A brief description of the species of main interest in the Møre region is given together with the description of the region itself.

### Objectives

This study was designed to fit a biomass based simulation model to a restricted area of the Norwegian coastal waters. The objectives were twofold:

- 1) To apply a holistic ecosystem approach (Laevastu and Larkins 1981) in an area where the required data fields were anticipated to be relatively complete for both the initial parameterisation and for the subsequent evaluation of the simulation, and:
- 2) To evaluate the inter- and intra-specific linkages in the fisheries ecosystem off the Norwegian coast and in the Barents sea.

A consequence of this study was to provide a vehicle for effective communication between the fishery scientists at the different institutions.

### Constraints

The simulation NORFISK is designed to simultaneously simulate the fish stocks in separate sections of the study area and to allow migration between the different sections. The sections taken together represent a closed ecosystem with the possible exception of apex predators (marine mammals and birds), and a limited number of highly migratory fish species. In the preliminary simulation described in this paper we were constrained to reduce the NORFISK simulation to one section of the study area only and thus had to allow for considerable migration of the dominant fish species into and out of this area. Thus the preliminary simulation described in this first report is no longer a closed system.

## DESCRIPTION OF SIMULATION

### The study area

The area for which the fisheries ecosystem is to be simulated lies off Møre on the west coast of Norway between 62° N and 64° N. The area corresponds approximately to Norwegian statistical area 07 (Fig 1). The major species using this area, their temporal presence and their mean biomasses as input to the simulation are given in Table 1.

Detailed information on the species / groups of species were obtained from relevant literature as well as from personal communication with scientists at the Institute of Marine Research, Bergen.

### Herring

The herring (*Clupea harengus* L.) at the northern Norwegian coast is divided into a northern and a southern component (Anon 1981a, 1982a). The northern stock has its nursery area from Helgeland and northwards and their spawning grounds from Møre to Lofoten. During the last several years the distribution of biomass on the spawning grounds and the migratory pattern of the components have shown considerable variations from year to year (I. Røttingen, Institute of Marine Research, Bergen, pers. comm.) In the model a mean of 60% of the northern herring component is assumed to be present in the area off Møre in February and March.

The southern herring has its nursery area from Møre to Helgeland and it spawns off Møre. Initially we allowed all the southern herring to be held within the area of simulation. The biomasses and age composition were obtained from ICES annual reports (ANON 1981a, 1982a).

### Cod

The cod (*Gadus morhua* L.) resources in the area are partly rather stationary coastal cod and partly north-east Arctic cod (Godø, 1983). The arctic cod spawn in the area from February to April. The mixed Arctic and coastal cod biomasses have been estimated by acoustic methods in recent years (Godø et al. 1982, 1983). The input mean biomasses of coastal and Arctic cod are based on these acoustic estimates and on preliminary mortality, catch and effort analysis. Age composition and yearclass strength were determined from published data (Godø 1981a, b, Godø et al 1982, 1983).

### Haddock

The haddock (*Melanogrammus aeglefinus* L.) biomass is assumed to stay within the modelled area all year round. Available data from unpublished tagging experiments show no indication of migration across the borders of the area. Mean input biomass is estimated using unpublished acoustic data; however these estimates are not very accurate and the haddock biomass will be adjusted in the model. Age composition was obtained from unpublished data on otolith readings.

### Saithe

The saithe (*Pollachius virens* L.) in Norwegian waters consist of a northern and a southern stock. The northern part has its nursery and feeding area from Helgeland and northwards. It has spawning grounds off Møre, Helgeland and Lofoten. The southern stock has nursery and feeding grounds from Møre and southwards along the coast. It spawns in the North Sea. This description is a simplification of the situation described by Jakobsen (1978, 1981a, b). A part of the northern spawning stock (aprox. 60%) appears in the Møre area in February and March and spawns there (T. Jakobsen, Institute of Marine Research, Bergen, pers. com.). Most of the spawning products from this area drift northwards, but some remain. Thus approx. 29% of the juvenile part of the northern stock stay at Møre until maturation (T. Jakobsen, pers. com.). They spawn for the first time at an age of

5 or 6 years. The youngest stages stay close to the shore, but they go out into open sea before they are 4 years old. We have allowed about half of the spawning products to stay in the Møre area to produce the above mentioned juvenile fish biomass and no migration in or out of the area before maturation. Biomass estimates and age compositions are obtained from ICES annual reports (ANON 1981b, 1982b).

#### Other demersal fishes

This group consists of Norway Pout (*Boreogadus esmarkii* Nilss.), Blue Whiting (*Micromesistius poutassou* Risso.), Whiting (*Merlangius merlangus* L.), Tusk (*Brosme brosme* L.), White Ling (*Molva molva* L.), Blue Ling (*Molva dipterygia* Penn.), Redfishes (*Sebastes* sp.) and other less important bottom fishes. The biomass has been estimated using acoustic methods; however, the estimate is not as accurate as for Cod, Haddock and Saithe and could be adjusted in the runs.

#### Pelagic fishes

This group is divided into two, Forage fishes consisting of Sandeel (*Ammodytes* sp.) and *Argentinus* sp. and Other pelagics consisting of Lantern fishes, Sprat (*Sprattus sprattus* L.), Mackerel (*Scomber scombrus* L.) and other highly migratory species. No accurate estimate was available for these groups and the proposed biomasses are meant to be adjusted during the runs in order to get a good fit with the input food composition tables.

#### Zooplankton and Benthos

The biomasses of these groups are given at levels high enough to ensure that they are not limiting factors in the initial runs. These biomasses could also be adjusted later on.

#### Seals and Whales

These groups are important predators on all levels. Their numbers are given by Bjørge, Institute of Marine Research, Bergen (pers. comm.) together with their daily mean consumption.

#### Squids

This group is present for a limited period of the year and a suggestion for their biomass is given by Wiborg, Institute of Marine research, Bergen (Pers. com.)

The study area described above is one of several areas to be included in the model. Together they will comprise a closed ecosystem. However, as mentioned previously, we were restricted to the Møre area in this first simulation. Therefore no other areas are described.

### THE SIMULATON

The general model structure is based on SKEBUB, a skeletal bulk biomass simulation model developed at the NWAFC (Laevastu and Bax, unpublished manuscript; Bax 1983a). SKEBUB is a simplification of the extensive biomass-based simulation by Laevastu and Larkins (1981) without spatial resolution. It was designed to use, as much as possible, the available data keeping unknown parameters and constants to a minimum. This simulation model contains an equilibration routine

which forces the simulation towards an equilibrium position, where the annual growth of each biomass equals its annual mortalities. Equilibrium is reached by adjusting the input species biomass and repeating the simulation, although at least one species or species grouping must be self-regulating. A requirement for the application of the equilibration routine is that the system under study is at a steady state (which for the purposes of this simulation means that all species or species groupings show annual percent changes of less than a designated value, usually 5%); however, the procedure is valuable in examining the implications of the input data and the formulation of the model -- unrealistic data values or unrealistic hypothesized interactions are readily identified. A sensitivity analysis of the simulation under equilibrium conditions can then detail the sensitivity, or unstable, species and interactions within the system (eg. Bax 1983b).

NORFISK is an extension of the SKEBUB simulation, providing spatial resolution and age structure for the fish stocks of major commercial and/or biological importance. Species included in the NORFISK simulation can be simulated in two distinct manners. In the first (for the "variable" species) the biomass can increase or decrease depending on the events occurring in the relevant time step. These events are detailed in Fig. 2 and will be described in more detail below. In the second the monthly biomasses are fixed, often as an annual mean with a prescribed annual fluctuation. While these "fixed" species do exert a predation pressure and are preyed upon by the other species their biomasses do not change. This second manner of simulation is limited to those species or species groups for which either insufficient data are available to enable their more complete simulation (eg. other demersal fish), or for those species groupings whose more complete simulation would greatly increase the complexity of the simulation (eg. plankton). The species of principal biological or commercial importance are simulated as variable species.

#### SPECIFIC FORMULATIONS

These descriptions are organized to correspond to the sequence outlined in Fig. 2. The cycle of events in Fig. 2 is simulated for each 2-week period; at the end of 26 cycles (1 year) the equilibration routine is implemented and the simulation resumed for a further 26 cycles.

#### BIOMASS at time t

In the first cycle of the simulation the biomasses of the different species or agegroups are the input values. In subsequent cycles they are the biomasses remaining at the end of the previous 2-week cycle. At the end of 26 cycles the simulation again returns to the input biomasses, but this time adjusted by the equilibration procedure so that biomasses where growth exceeded mortalities are reduced below their previous input value and vice versa. These equilibration changes are additive over successive years a long simulations. The fixed species or species groups have prescribed biomasses and do not change annually.

### Recruitment

Recruitment in NORFISK is simulated in two ways, age recruitment and migration recruitment. The biomasses of each species were divided into 3 groups; the mature component, the juvenile component and the stages from eggs to juveniles (lasting for about 3 months). In the model each group act as if they were species with their own parameter values. Only the recruitment mechanism link them together into a single species. The mechanisms in use to performe this recruitment were simple numerical transfere from one group to the next. This transfere was spread over a sufficiently long time periode to prevent large perturbations of the system.

Spawning recruitment is effected by the removal of a predetermined percentage ( currently 10%) of the mature biomass and the addition of half this biomass to the egg and larval biomass. The other half is spawning products that are lost into the sea, mainly male spawning products.

The percentage of recruitment from juvenile to adult is calculated from the age distribution and the amount of each age group that is assumed to be mature. Some effort has been put into allowing the percentage recruitment to change with the growth or decline of the biomass but this work is not included in this report. Thus manual adjustments of the recruitment percentage have been done during the procedure of stabilization in order to compensate for growth or decline in the biomasses.

In the complete NORFISK simulation migration into and out of areas is controlled by either redistribution of the entire specie biomass according to an input matrix of percentage presence of the species in each area time-step, or by redistribution of biomass between adjacent areas according to an input matrix of migration vectors between the areas for each biomass and time-step. In the abbreviated NORFISK, which simulates one are only, migration between areas was not possible. Instead migration into an area is represented as a fixed addition of biomass. When this migration supplements an existing biomass its proportionate contribution is recorded and this same proportion removed at the time for emigration. In instances where spawning results partly from an immigrant biomass the above proportion is removed from the resulting egg and larval biomass at the time for its emigration. In instances where the entire adult biomass migrates from the area but juveniles are always present (eg. Saithe) the proportion of eggs and larvae remanining in the area is set equal to the proportion of the total juvenile stock in the area.

### Estimate of potential growth

Mean growth coefficients are input to the simulation for the variable species, and can be varied by a harmonic or temperature dependent function to simulate seasonal variability in growth. The biweekly growth coefficient is derived fom the observed increase in individual weights over a one year period:

$$G = [\ln W_{t+1} - \ln W_t] / 26$$

When more than one year class is contained within an age group the growth coefficient becomes the mean of the individual year class growth coefficients weighted by their estimated biomasses. This procedure may underestimate population growth when there is a higher mortality of faster growing fish ("Rosa Lee's phenomenon", eg. Ricker 1975). This can be corrected during stabilization runs. When studies of recruitment variability are undertaken this method will be revised to simulate changing age structure within age groups.

The input growth coefficient is the mean value for individual growth and is adjusted at each time step to reflect food availability. In this estimate of potential growth this input value is adjusted by the fraction of the biomass of required food that the species group obtained in the previous time step (ie. for this estimate of potential growth it is assumed that the same proportion of required food will be obtained in the time step as was obtained in the last). The effect of a food ration different from that required is assumed to be linear following Jones and Hislop (1978):

$$GSA(N) = GS(N) - [SC(M,N)*0.01*GS(N)]$$

where all variables are as defined in Appendix 1. This estimate of potential growth is now used to estimate the food requirements of each biomass.

It should be mentioned that eggs and larvae are assumed to neither grow or feed during the time step they were spawned and that one following.

#### Food required for potential growth and maintenance

The food requirement consist of food requirement for growth and a food requirement for maintenance. The food requirement for growth is computed from the estimated potential growth in biomass, uncorrected for fishing mortality, natural mortalities or consumption:

$$GRO = BB(M,N,K)*(EXP(GSA(N))-1)$$

The food requirement for unit growth in biomass for daily maintenance are input variables and thus the total food requirement is calculated from:

$$FOOD(M,N,K) = (BB(M,N,K)*FRM(N)*14) + (GRO*FRG)$$

In the simulation of fixed biomass species growth is not explicitly calculated and thus GRO equals zero. For these species groups FRM(N) is input as the combined daily requirement for growth and maintenance. However, plankton and benthos do not explicitly feed in this simulation.

#### Food available

The food available to an individual biomass is a function of the absolute availability of potential prey items, the mean food composition for the predator and the food requirements of other predators. The mean percentage prey composition for each predator (CF(KK,N,I)) is estimated from empirical data for each quarter of the year. This input percentage prey composition is adjusted to reflect prey availability producing the final percentage prey composition for

each predator (FCN(N,I)). The adjustment is performed simultaneously for each predator group according to the following formula:

$$FCN(N,I) = CF(KK,N,I)*(1+A*EXP(-B))/(1+A*EXP(-B*FCOC))$$

which is the logistic curve modified to pass through (1,1), where A and B are constants and FCOC is the ratio of available to required biomass from the prey species. This final prey composition is multiplied by the food requirement of the predator to find the food required from each prey group by each predator group (note that a biomass is usually both predator and prey). The total biomass required as food from each prey biomass is compared to that available and if insufficient biomass is available the predators feeding on it will experience starvation.

The percentage of each prey biomass designated as available for these calculations cannot be estimated with any precision from empirical data. It is, however, a parameter to which a simulation can be very sensitive (Bax 1983b). In the NORFISK simulation the availability of a biomass is assumed proportional to the growth rate of that biomass. There are not empirical data to support this assumption, although the point is made that growth rates and also predation rates often decrease with increasing size. This assumption does reduce the number of parameters to be estimated (the same proportionality is used for all species) and thus negates a potential source of subjective bias.

#### Actual growth

Actual growth is computed in the same manner as potential growth except that the value for the proportion of required food obtained is derived from the calculations in the current time step rather than from those of the previous time step.

#### Losses from biomass

The losses from the biomass are either input constant values (apex predation), input constant rates (fishing mortality, disease and senescent mortality), or values determined within the time step (predation by other fish). Apex predation and fishing mortality are derived from the literature and unpublished data reports. Disease and senescent mortality are assumed to be small and relatively insignificant. This source of mortality has been used to represent plankton or benthos predation on eggs and larvae. Predation by other fish is computed in the feeding routines.

#### Biomass at time t+1

The biomasses at time t are updated at the end of each 2-week time step to produce the biomass at time t+1 according to:

$$BB(M,M,K)*EXP(GSA(N,K)-GMS(N)-C-F(KK,N))$$

where  $C = -\text{ALOG}(BB(M,M,K) - CC(M,N) - SS(N,K)) / BB(M,N,K)$



## CONCLUSIONS FROM INITIAL STABILIZATION RUNS

Both the migration of the mature biomasses and the recruitment from juvenile to adult occurred over one two week period in the first runs. This led to severe perturbations of the system due to the different growth coefficients in the various groups. This made the system very unstable.

The age group recruitment routines have the advantage of being numerical very simple. The recruitment was therefore recalculated to last over several time intervals. It was calculated to give the same biomass recruiting in each time interval.

A constraint on the simulation was its restriction to the Møre area. This required having large fixed biomasses of migratory species entering and leaving the simulation area without being able to simulate their stock dynamics. The local cod stock was initially about one order of magnitude less than the migratory part. In the first runs it seemed as though this local stock had to have high growth. However the recruitment to the adult stock took place after the migratory part of the stock had left the area. We changed the juvenile to adult recruitment to occur simultaneously with the immigration of the spawners and allowed a larger part of the stock to leave together with the adults, keeping a minor part of adult cod in the area during the winter. We made similar changes for the saithe.

All these changes led to a stable system with the exception of the southern herring. We had to let approx. 10% of the adult part to emigrate each year due to very good growth. Trials of reducing the biomass dramatically only led to higher growth and an increase in biomass also led to overproduction. The haddock biomass seemed to have a little too high growth, but it was only about 2% a year. All the other species biomasses showed less growth per year. The actual biomasses are given in Table 1.

An additional problem that had to be solved was the problem of regulating the growth of the larvae. The food of the various groups in the model was determined by the amount of the species found in the stomachs. However, larvae are difficult to detect and the predation of larvae had to be given by intuition. In order to achieve sufficiently large predation an unrealistically high proportion of the food composition had to be larvae in order to have the various fishes switch to larval food. And having enabled the predation of larvae it often happened that they were completely eaten. In order to allow some of the larvae to survive, a lower limit of percentage presence in the diet was defined and no more larvae were eaten when this limit was reached.

Our clear impression was that although the system was stabilized the food composition tables that were input did not coincide with those generated by the system in the stable situation. Furthermore, very few adjustments were made to the fixed biomasses surely leading to wrong estimates of both the food composition tables and the variable biomasses at the stable point.

It is encouraging that even at this crude level of refinement of the NORFISK simulation a stable situation was reached and that this situation indicated where to seek further refinement in the architecture of the model and which data need to be investigated

further. This suggests that this type of simulation exercise could be useful in the initial stages of project design to identify the more important data and processes.

All the objectives of this study have not been achieved at the time of writing. It does appear that the holistic ecosystem simulations can, with limited modifications, be applied to Norwegian waters. Further development would include the extension of the simulation to the other areas of the Norwegian waters to get a closed system. Also separate investigations should try to solve the problems of dynamic recruitment and migration.

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Table 1 NORFISK stock composition

STOCK	AGE CLASSES INCLUDED	TEMPORAL PRESENCE AT MØRE	RECRUITING PERIODE	RECRU. IN % OF BIOMASS	INPUT MEAN BIOMASS (1000 kg)	SIMULATION TYPE	BIOMASS AT END OF STABILISATION	COMMENTS
Southern Herring	eggs+larvae juveniles (1-3.5)	Mar-Jun	May-Jun	100	calculated	variable		
	adults (3.5 +)	Jan-Dec	Jun	28	122 000	--"---	101 000	
		Jan-Dec	Mar	10	160 000	--"---	158 000	+ 10% out of the area
Northern Herring	eggs+larvae juveniles (1 - 3.5)	Mar-July	May-July	100	calculated	variable		migrate out of the area
	adults (3.5 +)	Not pres.	Jun					
		March	March	10	67 500	fixed		
Coastal Cod	eggs+larvae juveniles (1 - 3)	Mar-Aug	June-July	100	calculated	variable		
	adults (4+)	Jan-Dec	Feb-April	36	4 000	--"---	6 250	
		Jan-Dec	April	10	500	fixed		Increased by recruitment before spawning
Northern Cod	eggs+larvae juveniles (1 - 5)	Mar-July	June-July (1)	100	calculated	variable		Northern cod calculated together with coastal cod
	adults (6+)	not pres.	1)					
		Feb-April	April	10	48 000	fixed		
Haddock	eggs+larvae juveniles (1 - 2)	Mar-Aug	June-Aug	100	calculated	variable		
	adults (2 +)	Jan-Dec	Feb-April	52	4 500	--"---	4 130	
		Jan-Dec	April	10	11 500	--"---	10 500	
Saithe	eggs+larvae juveniles (1 - 4)	Mar-July	May-July	100	calculated	variable		
	adults	Jan-Dec	Jan-Mar	19	110 000	--"---	114 000	
		Jan-Mar	Mar	10	51 800	fixed		

STOCK	AGE CLASSES INCLUDED	TEMPORAL PRESENCE AT MØRE	RECRUITING PERIODE	RECRU. IN % OF BIOMASS	INPUT MEAN BIOMASS (1000 kg)	SIMULATION TYPE	BIOMASS AT END OF STABILISATION	COMMENTS
Forage Fish	all	Jan-Dec			50 000	fixed 2)		
Other Pelagic	all	Jan-Dec			25 000	fixed 2)		
Other demersal	all	Jan-Dec			100 000	fixed		Acoustic estimates (Godø & Sunnanå, unpubl.)
Squids	all	Aug-Dec			25 000	fixed		Wiborg, IMR (Pers comm.)
Benthos	all	Jan-Dec			500 000	fixed 2)		
Zoo-plancton	all	Jan-Dec			300 000	fixed 2)		
Seals	all	Jan-Dec			3 025 individ.	fixed		Mean consumption 4.5 kg/individ/day
Whales	all	Oct-Mar			1 000 individ.	fixed		Mean consumption 106 kg/individ/day

- 1) The northern cod has no juvenile stage at Møre and the eggs and larvae leaving the area when recruiting to juveniles are removed as the portion belonging to the northern stock.
- 2) Input biomasses were not available for these stocks. The figures are "guestimates" that can be adjustet to produce acceptable diets to predators.

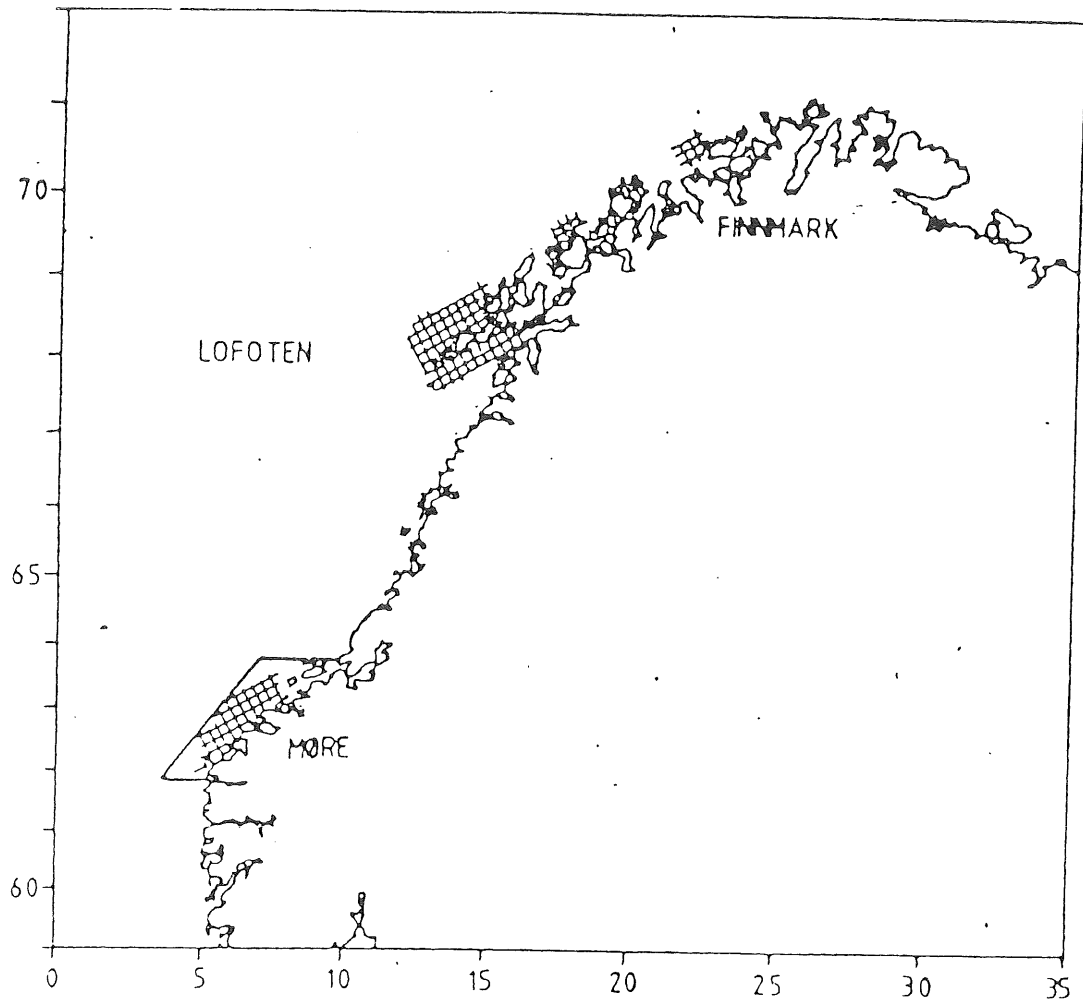


Fig. 1. The Norwegian coast. Study area at Møre is framed. Hatched areas are important spawning areas for cod.

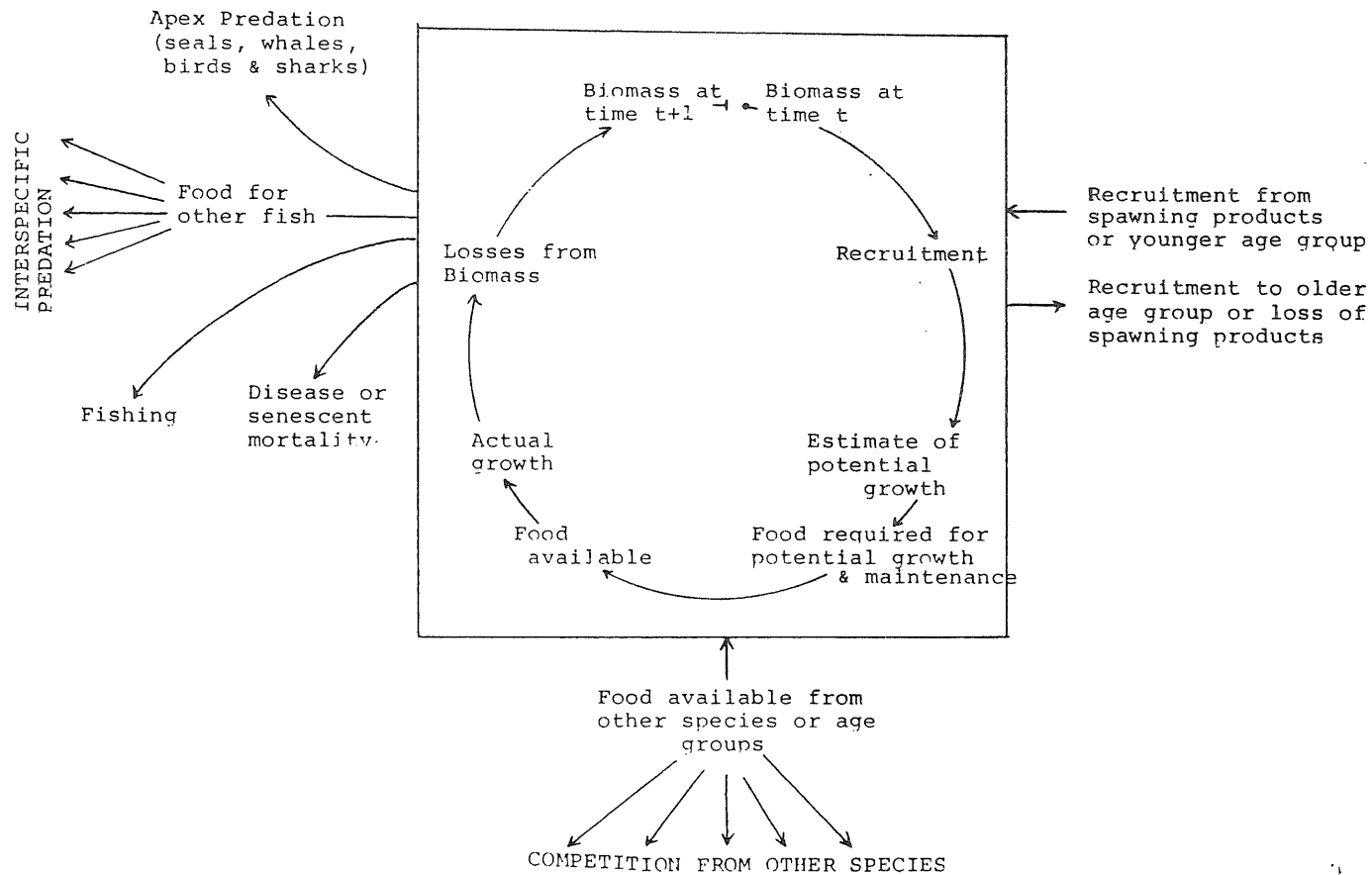


Fig. 2 Schematic of processes occurring in one time-step (2 weeks) of the simulation model NORFISK.



APPENDIX I -LIST OF VARIABLES IN NORFISK  
(asterisks denote input variables)

A	Constant used in prey switching calculations derived from DMAX and B
AC(I)	The amount of biomass of species I available for consumption -- derived from AP(I) and BB(M,N,K)
AGA	Constant used in equilibration procedure to regulate changes in input biomassess. derived from AGAIN and L
AGAIN*	Initial value for AGA
ALP	Intermediate in cosine function simulating seasonal fluctuations in biomass (fixed species) or growth (variable species)
AP(I)*	Percentage of species I available to predators. -function of growth or input variable
APADJ*	Global constant used to adjust overall availability to predation
B*	Constant in prey switching calculations. -- determines rate of prey switching with changes on availability
BB(M,N,K)	Biomass of species N, in area M, and month K
BBFDEV(M,N)*	Maximum variation in the biomass of fixed species N, in area M, expressed as the proportion of it's mean annual biomass
BBFMAX(M,N)*	Month of maximum biomass of fixed species in N in area M
BBSUM	Working variable -- total biomass of a species in all areas
C	Working variable used to transform absolute amount of consumption on a species to a rate
CC(M,N)	Consumption of species N, in area M
CF(KK,N,I)*	Percentage of diet of species N, that is from species I, in quarter KK
CHBIOM	Constant controlling when annual changes in biomassess are output -- see INT
D2	Intermediate variable in equilibration procedure -- summed change in biomass of species N and NM
DIF(N)	Annual change in biomass of species N
DIV	Constant used to reduce biomass of spawning products

	to biomass of fertilized eggs
DMAX*	Maximum allowed upward in percent-food composition
F(KK,N)*	Fishing mortality for species N in quarter KK
FCN(N,I)	Intermediate food composition table used in calculating fortnightly predation and consumption -- derived from CF(KK,N,I) or adjusted CF(KK,N.I)
FCOC	Ratio of available food to required food -- used in prey switching calculations
FISHRY*	Constant used to control output of data on the fisheries -- see INT
FOOD(M,N,K)	Food required by species N, in area M, and month K for maintenance and maximum growth -- function of FRG(N), FRM(N), BB(M,N,K) and GSA(N)
FRG(N)*	Food requirement for unit growth of species N
FRGN	Intermediate in calculation of required food
FRM(N)*	Food required for daily maintenance of species N, expressed as percent of biomass. (For the fixed biomass species this represents total daily food requirements in percent of biomass daily)
G(N)*	Maximum rate of growth of species N in a 2 week period
GADJ*	Global growth adjustment -- usually set at 1.0
GDEV	Maximum seasonal variation in the base value for the growth coefficient
GMS(N)	Natural mortality, excluding predation, but including starvation effects for species N.
GRO	Intermediate in calculation of food required
GRODIE*	Constant used to determine outputs of growth coefficients, and daily food requirements -- see INT
GS(N)	Expected growth of species N, derived from G(N) and accounting for seasonal variation
GSA(N)	Expected growth of species N, derived from GS(N) and adjusted for starvation
I	Group identifier of species or age group (prey)
INOUT*	Constant to used determine outputs of variables input to the simulation -- see INT
INT*	Value assigned to printing constants

0 -- no output; 1 -- output in years 3,15,LAL;  
2 -- output in all years

IV\* Value of N in BB(M,N,K) that contains first species in simulation

K Fortnight values of 1 to 26

KIK\* Maximum number of years in simulation

KL k-1;if k=1 then KL=26

KK Index representing periods of the year longer than one fortnight (K). Currently representing quarters starting in February

L Year -- in the equilibration mode L, represents the number of individual yearly simulations

LAL\* Number of individual yearly simulations to be run in equilibration mode

M Area in simulation -- simulation is currently dimensioned for up to 4 years

MA\* Number of areas in simulation

N Group identifier of species or age group. (predators)

NADULT (NN)\* Odd values in this array (1,3,5...) are the group identifier (1 to 25) of the oldest age group for each species to be included in equilibration. For the even values (2,4...) the following applies  
0 -- only the oldest age group is included in equilibration  
1 -- both adults and juveniles included in equilibration  
99 -- oldest age group is returned to its input value

NF\* Number of fixed biomass species in model

NFEED Index counting number of times that the input food composition is adjusted by prey availability in each month

NFROM(N)\* Group identifier (N) recipient of recruitment minus group identifier (N) of donor of recruits

NFV\* Total Number of species and age groups in simulation (NF+NV)

NL Group identifier of recruits -- calculated from N and NFROM(N)

NM Group identifier of age group to be included with older age group in equilibration -- calculated from N and NADULT(NN)

NUM\* Identifying number for simulation  
 NV\* Number of variable species + age groups in model  
 -- includes non-assigned categories  
 PC(N) Percent of biomass N that was consumed in current time  
 step -- calculated from CC(M,N) and BB(M,N,K)  
 PCNTBB(M,N,K)\* Migration matrix  
 MA=1: positive values indicate absolute biomass of  
 migration of species N into area in time period K  
 negative values - emigration from area  
 if PCNTBB(M,N,K)=-1. The same proportion of the  
 biomass emigrates from the area as immigrated in  
 previous immigration. For eggs and larvae the  
 proportion of the biomass that emigrates equals the  
 proportion of adults emigrating,  
 if PCNTBB(M,N,K) is less than 1 the value is the  
 percent of the biomass that will emigrate at time K  
 PROP(N) Proportion of biomass immigrating or emigrating from  
 area -- calculated from PCNTBB(M,N,K) and BB(M,N,K)  
 RECRMT(N,K)\* Proportion of the biomass of an age group recruiting  
to another age group at time K. For adults this  
 represents the proportion of the biomass forming  
 spawning products -- although only 50% of these enter  
 the egg and larval biomass  
 RL Real value of an integer variable  
 SC(M,N) Starvation, or proportion of food required by N not  
 obtained -- calculated from FOOD(N) and SUF(N)  
 SS(I,K)\* Apex predation (1000kg units) by whales, seals, birds  
 and sharks of species I, in time period K  
 SUF(N) Total percent or total amount of food obtained by  
 species N -- calculated in feeding routine  
 T Real value of K calculated to the nearest month  
 V(N)\* Input biomasses of variable species  
 VF(N)\* Input biomasses of fixed species (mean values) - note  
 VF(N) =BB(M,NV+N,K)  
 WKBIOM\* Constant determining output of fortnightly and mean  
 annual biomasses  
 ADDITIONAL VARIABLES  
 FCNMIN\* Minimum allowed percent composition in a predators  
 diet