Scientific Report for Appraisal Step

For deliverable D7.4

SSA 7.6 Søndeledfjorden, Norway

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WT 5.1 ESE COMPONENTS

5.1a Preparation of the ESE Models for Coupling to Simulation Model.

In this model the status of the local cod (*Gadus morhua*) population the study area is the indicator of the status of the ecosystem. The cod population in the model is affected by top predators (birds and seals), change in available habitat (2nd homes), fishing (eel-fishers, commercial fishers, recreational fishers and tourist fishers), aquaculture and stock enhancement. The effect from each of the above mentioned drivers can be regulated and the economical output is calculated.

The model can easily be adapted to other fjord systems. To change parameters, please see: "System Formulation; Part 2: Running the model".

5.1b Results of the ESE Interpretive Analyses

This model generates the local cod population in the study area over a 1-50 years period. The cod population are affected by annual recruitment at 0-group stage (September every year) and mortality rates between year-classes. The model can do between one and 100 simulations over the 1-50 years and the results from the different runs are saved in a MS Excel sheet. In the cases with more than one simulation, the excel sheet will calculate average numbers with confidence interval.

The environmental component model is a demographic model that projects the abundance of the coastal cod population in numbers by age (0 - 10 years age groups) forward in time. The body length of the individual cod in each year-class for each year in the 1-50 years run is drawn randomly from an observed normal distribution for each year-class, except for the 0-group where average length is used. The corresponding weights for each individual cod are calculated from the known length-weight relationship. The total weights of the population each year are calculated by summing the weight of all the cod. For more details on the environment component, please see MODEL SSA 7-6-desciption.v 1.21.pdf.

Several policy instruments influence the dynamics of the cod population: TAC (total allowable catch on each year-class per year), amount of bottom habitat occupied by marinas, and the number of predators (birds and mammals) which can be controlled by hunting. (The ecosystem model reflects the 2008 situation without any regulations). For more details on the social component, please see chapter 2 in MODEL SSA 7-6-desciption.v 1.21.pdf.

The main aim of economic component is to estimate (net) local economic benefits from tourism in the Søndeledfjord area. This is set equal to Risør municipality in our case. The economic benefits/costs related to tourism that we consider come from 1) expenditures from tourists visiting the area (except 2nd home building and maintenance), and multiplicator effects of those expenditures, 2) the building and maintenance of 2nd homes + multiplicator effects, 3) Changed value-added in the commercial fishery due to changes in the coastal cod stock, 4) Aquaculture production, including effect on wild cod stock (not ready yet), and 5) net local costs of coastal cod stock enhancement (not ready yet). For more details on the economic component, please see chapter 3 in MODEL SSA 7-6-desciption.v 1.21.pdf.

The model still has some bugs in the economical component, however, that will be fixed before the end of the year. The environmental component contain some limitation, as there is not included a carrying capacity of the cod stock.

5.1b.1 EnvirComp.

Coastal cod are distributed along the entire Norwegian coast. These coastal stocks are different from the open sea stocks in that they do not migrate over longer distance, but are rather stationary in the fjord systems or adjacent areas. In recent years it has been documented that each fjord system hold their unique cod stock that are genetically distinguished from stocks in nearby fjords and open sea stocks. The Søndeled fjord system is a typical threshold fjord along the southern coast of Norway, separated from the open Skagerrak by islands and sounds with sills of 30 meter or less. Inside of the sills are sheltered fjord basins with depths of up to more than 180 m. The local cod in Søndeledfjorden spawns in the inner (western) part of the area and recent studies shows that the pelagic cod eggs remain in the inner part of the fjord and are thereby protected from the coastal current outside the fjord.

There is a rising concern regarding the condition of the coastal cod stocks along the Norwegian coast, as the long term trend indicates a decreasing yield in the coastal cod fishery. The reasons for the observed reduction are most likely multiple; however, there is an increased concern that the fishing pressure in both the commercial and recreation fishery in general are too high. Although the recruitment in the Søndeledfjord was good in 2007, the recruitment to 0-group generally has followed the same trend as the Skagerrak coast. The abundance of adult cod the Risør area falls in the transitional zone between eastern Skagerrak where there has been a dramatic decrease in stock size, and the central areas where no such decrease has been observed.

The environment component is a demographic model that projects the abundance of the coastal cod (*Gadus morhua*) population in SSA 7.6 (Søndeledfjorden, Norway) in numbers by age (0 - 10 years age groups) forward in time.

- The abundance of the 0-group cod in the population is modeled as a function of the area of suitable habitats (eelgrass etc) for recruitment and the strength of the 1-group cod.
- The total population size and the strength of the different year-classes of cod is a function of natural predators (as birds and mammals) and fishing mortality (caused by tourists and commercial) and other human activities (Eco-tourists etc).
- The cod spawning stock (SS) consists of age-groups 4-10.
- The default fishable stock consists of age-groups 2-10, however, will vary between user groups.

Starting date

1 September is the starting date. This is the time of the year when 0-group cod have settled in the eelgrass areas and yearly beach seine surveys are conducted to estimate the year-class strength.

As the fish pass 1 January each year it will increase it age with one year. An example: 0-group cod will become 1-group cod from 1 January.

Starting population

The demographic model is initiated with a starting population of cod (numbers by age for the first year) provided in the table 1.1 (For explanation see Chapter 4.1). The first year of the simulation starts with a fixed numbers at age for year classes 1+. The number of 0-group, however, will be generated every year, including for the first year, as given in **chapter 1.4 "Annual recruitment"**. In addition the table 1.1 contains natural mortality (M) for each year-class, both as M-values (exponential) and expressed as percentage survival from one year-class to the next.

$S = N_t/N_0 = e^{-M}$, where S = survival, N_t =number at time t, N_0 = number at time zero (start), and M = natural mortality; ln S = -M.

The total biomass of cod (2-10 years old) is equal to 30.7 tons (density equal to 1.3 ton km^{-2} (see chapter 1.7)

Table 1.1. Starting population of coastal cod in Søndeledfjorden. Age = group or year-class, N = number of individual cod in each year-class, CCS_0 = Initial biomass, M = natural mortality (exponential value), S = percentage survival from one year-class to the next. Number of 0-group (see chapter 1.4) and mortality between 0-group and 1-group cod will be estimated in the model (see chapter 1.5.1).

Age	N	N km^{-2}	CCS_0 (tons)	CCS_0 (tons) km^{-2}	S (%)	Reference
0	156 513	6 645				Tab 6.3b
1	42 889	1 821	6,304	0,268	65	
2	26 014	1 105	12,019	0,510	85	
3	8 998	382	9,115	0,387	85	
4	2 819	120	3,890	0,165	85	
5	1 157	49	2,291	0,097	90	
6	535	23	1,753	0,074	90	
7	215	9	0,762	0,032	90	
8	98	4	0,464	0,020	90	
9	40	2	0,209	0,009	100	
10	27	1	0,157	0,007	0	
1-10	82 792	3 515	36,963	1,569		
2-10	39 903	1 694	30,659	1,302		Fishable stock
4-10	4 891	208	9,526	0,405		Spawning stock

Annual recruitment (0-group cod)

The annual recruitment (measured as a relative abundance index for 0-group cod in September every year) for each of the years 1919 to 2006 (historical data), is given Chapter 6.2 and Table 6.3a.

Annual recruitment (number of 0-group cod) in the model is randomly picked from a list of historical data (see Table 6.3a. The number of recruits (age 0; 0-group cod) for year t is selected as follows:

1. Select a random number (logr) from the log-normal distribution fitted for historical data
2. Back-transform the number logr to get a 0-group index: r= exp(logr +(σ^2)/2) where σ^2 is the variance of the mean of log-transformed recruitment indices
3. Total number 0-group cod = r * **15315**
4. If estimated number is less than **9317**, it is set to 9317 (equal to 10% percentile (see Table 6.3a)
5. If estimated number is higher than **412 572**, it is set to 412 572 (equal to 90% percentile (see Table 6.3a)

We assume that ln(x) is normally distributed, and fit the normal-distribution, N(mean(ln(x)), var(mean(lnx)) to the log-transformed recruitment indices. Ln(x) can have negative values. It is thus x (recruitment) that is assumed to be log-normally distributed, and x will not have negative values. X is obtained after back-transformation with the formula above. The below entry in Wikipedia is consistent with standard reference books such as Balakrishnan and Nevzorov, A primer on Statistical Distributions. Wiley. (http://en.wikipedia.org/wiki/Log-normal_distribution). The recruitment distributions for fish are generally skewed. The fact that the normal distribution is not rejected for the raw recruitment data in our case is likely due to low sample sizes.

Mortality

Annual natural mortality rate (M) and survival rate between year-classes is given in table 1.1. *The survival rates, except for the mortality between 0-group and 1-group cod (see chapter 1.5.1 below), are used in the ExtendSim model.*

The annual recruitment (number of 0-group cod) will also be modeled as a function of the area covered by eelgrass (area with eelgrass and of the size and numbers of marinas. The annual recruitment and mortality rates (or survival) between year-classes (age 0-10) will be affected by several possible interactions with human activities. Possible interactions are illustrated in the conceptual model given in Figure 1.1. All the interactions in the ExtendSim model (NC, SC and EC) are discussed in chapter 5.

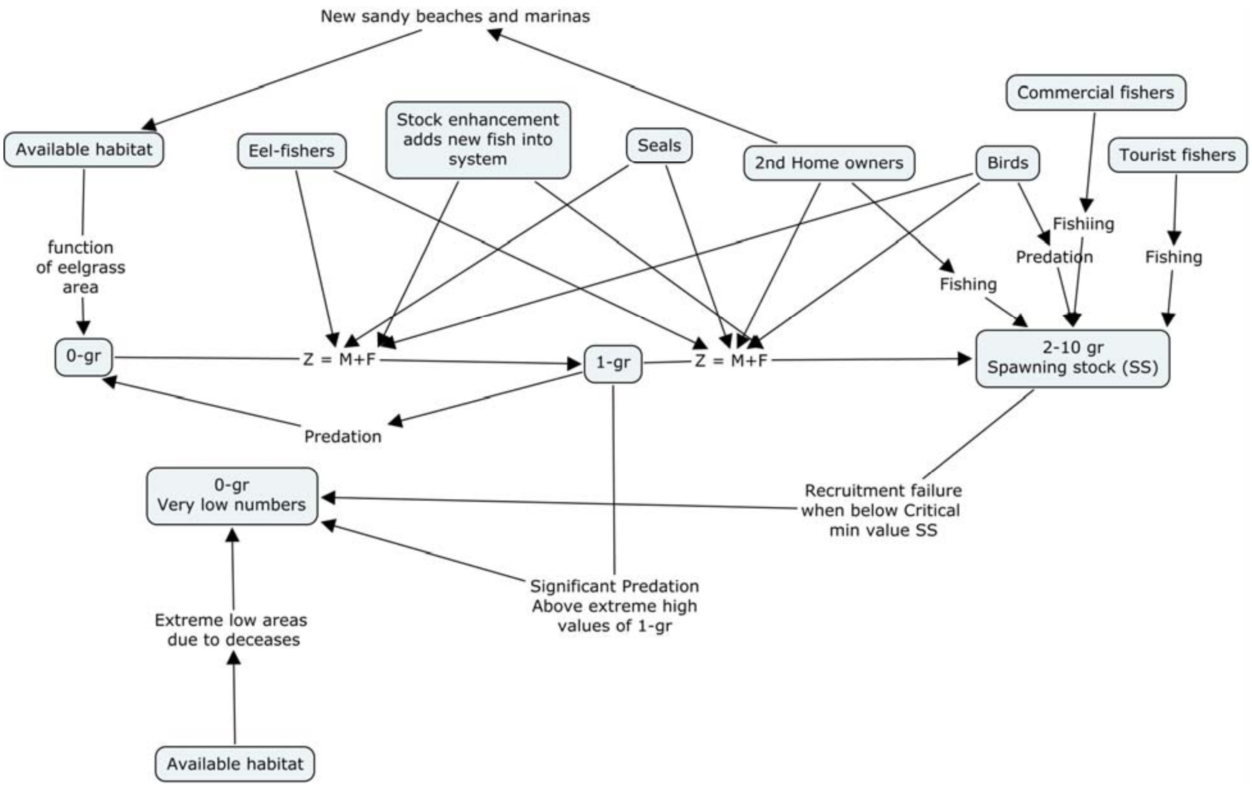


Figure 1.1. Conceptual model of the cod life history, with the main factors affecting mortality. Z = total mortality, M = natural mortality, F = fishing mortality.

Mortality rates between 0-group and 1 group cod

The mortality of 0-group fish is normally high (M = 3.8; see Julliard et al.; 2001), and cannibalism is a significant part of this mortality, and could explain up to 50% of the mortality in cases with high abundance with 1-group cod. In the model it is included a "basic mortality" of 1.9 and regulate the remaining 1.9 of the natural mortality according to number of 1-group, e.g. by making additional mortality a linear function of number of 1 group, so that it is zero at 1-gr =0, and 1.9 at average stock size. (Maybe the suitability of habitat should be taken into consideration so that the slope is steep when there are few hiding places and low when there are few).

Equa (1.1): $M = \exp*(p*(2{,}824+0{,}281*\mathrm{Log}(X_0)) + (1-p)*(2{,}496+0{,}381*\mathrm{Log}(X_1)))*H;$

Where: M = natural mortality in %; p = proportional natural mortality (value between 0 and 1); X_0 = number of 0-group cod; X_1 = number of 1-group cod; H = index for habitat

At present the index for habitat (H) should be set = 1. In the future a variable H might be included depending if the area or quality of the available habitat is increased or decreased.

Stock enhancement

Stock enhancement studies have taken place in the study area and the results indicate that release of 0- and 1 group cod can have a significant impact on the total cod population in the study area (Danielssen and Gjøsæter, 1994). A marine hatchery for juvenile cod and Atlantic halibut is located in study area. It has the capacity to produce both 0-group and 1-group cod. The production cost of cod is given in table 3.10. The release of 0-group cod will normally take place in September, and the release of 1-group cod will normally take place in March - April.

Fish consumption by harbour seals, Phoca vitulina*.*

Harbour seals consume from 3.4 (juvenile females) to 5.7 (adult females) kg fish per seal per day (Bjørge et al.2002). The composition of the diet is highly variable, and varies with the species available. The proportion of cod has been observed to vary between 2 and 35 %. Most of the fish taken is less than 30 cm long. (Olsen og Bjørge 1995; Berg *et al*. 2002). Assuming a food consumption of 4 kg pr day, a proportion of cod in the diet of 10%, and a average size of the cod eaten of 20 cm (100 g), one seal will eat 4 cod a day. Number of cod eaten per year is given in Table 1.2.

Table 1.2. Number of harbour seal and cormorant in the starting population and the estimated number of cod (by age group) predated by each harbour seal and cormorant per year.

		age group cod	age group cod	age group cod
	Starting number	0	1	2
Harbour seal	6	730	730	0

Cormorants	50	108,5	292	73

It is assumed that the predation on cod depends on the density of cod at any time. It is further assumed that the published predation rates reflect a average cod population with the following densities of 0 and 1 group cod:
Density of 0-group cod = 6722 km^{-2} (see table 1.1 and 6.3a)
Density of 1-group cod = 1821 km^{-2} (see table 1.1)

For harbor seal the following relationships between cod densities and predation from each harbor seals are used:
Equa (1.5): Y = 0,109 * X; where Y = number of 0-group cod eaten and X = Density 0-gr (number km^{-2}).
Equa (1.6): Y = 0,401 * X; where Y = number of 1-group cod eaten and X = Density 1-gr (number km^{-2}).

Fish consumption by cormorants, Phalacroax carbo sinensis*.*

Barrett *et al*. (1990) found that cormorants eat 660 g fish a day and that most of this was small cod and sandeels. Measuring of otoliths showed that most of the cod consumed measured from 60 – 340 mm, and belonged to the 0- I- and II-group. Off the Koster islands Härkönen (1988) found that cod constituted 24 % the stomach contents (in weight), while Skarprud (2003) found that cod constituted ca. 20 % of the food in the Øra area in Østfold. Assuming a food consumption of 660g pr day, a proportion of cod in the diet of 20%, and a average size of the cod eaten of 20 cm (100 g), one cormorant will eat 1.3 cod a day. Number of cod eaten per year is given in Table 1.2.

It is assumed that the predation on cod depends on the density of cod at any time. It is further assumed that the published predation rates reflect an average cod population with the following densities of 0, 1, and 2 group cod:
Density of 0-group cod = 6722 km^{-2} (see table 1.1 and 6.3a)
Density of 1-group cod = 1821 km^{-2} (see table 1.1)
Density of 2-group cod = 1105 km^{-2} (see table 1.1)

For cormorants, the following relationships between cod densities and predation from each cormorant are used:
Equa (1.7): Y = 0,016 * X; where Y = number of 0-group cod eaten and X = Density 0-gr (number km^{-2}).
Equa (1.8): Y = 0,16 * X; where Y = number of 1-group cod eaten and X = Density 1-gr (number km^{-2})
Equa (1.9): Y = 0,066 * X; where Y = number of 2-group cod eaten and X = Density 2-gr (number km^{-2}).

Human harvest of cod

It is not easy to obtain precise and accurate figures for the annual yield from the commercial cod fishery in the study area because not all of the catches are sold at the local buyer. To get an idea of the annual catches of cod in the study area, an interview was made with the leader of the local buyer, Mr. Yngvar Aanonsen at Risør Fiskemottak (http://www.fiskemottaket.no/). His background is as a commercial fisher in the area and he had the following description of the cod fishery and an estimate of annual catches. Normally the commercial fishery take place with nets and the best fishery was during spring with annual catches between 3-4 ton for each boat. In addition, herring fishers normally catch high number of cod in their fishery. His overall estimate was that the annual yield commercial fishery varies between 12 to 15 ton. This corresponds to catches between 0.5 – 0.6 ton km^{-2}. These numbers a very similar to estimated yield in the North Sea cod fishery.

In addition he informed about a very active recreational and tourist fishery in the area, and expected a reasonable high yield of cod in this fishery as well.

Recreational and commercial fishers, and tourists in the different tourists groups harvest cod. It is assumed that the amount harvested depends on the fishing effort by the different groups, but also the size of the cod stock. The bigger the cod stock is, the more catch can be expected for a given amount of fishing effort. In other words, the catch per unit effort (CPUE) depends on the stock size. In addition the fishing effort or effectiveness depends on regulations. See section 2.2.2.2 (Fishing regulations for cod/MPA-cod) on limitations of fishing period and use of gears. The formulas below must be adjusted in accordance with descriptions in 2.2.2.2.

Schaefer (1957) established a simple harvest function for fisheries that have been much used in bioeconomics (Eide et al 2003) when biomass models of the stock are used:

Equa (1.10): $h = q\, E^{\alpha}\, X^{\beta}$; E = fishing effort, X = stock biomass, h = harvest, q = catchability coefficient.

It gives a relationship between fishing effort E, stock biomass X and the harvest h. The coefficient q is referred to as the catchability coefficient, and is a constant specific for fish species/stock and fishing gear, as is the coefficients α and β. In the simplest form of the Schaefer harvest function α and β are 1, and then there is a purely linear relationship between harvest and fishing effort, and harvest and stock biomass.

Based on the Schaefer harvest function we model fish mortality from fishing pressure both from the different groups of tourists and commercial fishers. We will calculate harvest in biomass, and then relate it to number of individuals harvested in each year-class. This will be based on the age structure of the cod stock, included the fractions of the biomass in each year-class, which we have data on from the ecological model component.

Cod mortality due to tourists

Fishing effort by tourists is measured as fishing days per year, based on number of tourist days per year for each tourist category. For each tourist category, the number of fishing days for a given number of tourist days will be different. Further, they will have different catchability coefficients, and their catch will be made up of different year-classes of cod, as they have different fishing gear and fishing locations. For example, the fishing by 2nd home owners is different from the one performed by fishing tourists. The category 2nd home owners have a very different demographic composition than fishing tourists, and include both adults and children. Children may fish very near shore, with tackle that mainly gives fish of the youngest year-classes. Fishing tourists typically have coarser tackle and fish at larger depths, on older year-classes.

Cod mortality due to commercial fishers

In interviews with local fishermen/fish buyers it is estimated that a normal annual cod harvest from the Søndeledfjord system by commercial fishers is 10-15 tonnes (see box above). It is estimated in the ecological component of the model that a "normal" standing biomass for the cod stock is approximately 30 tonnes (year-classes 2-10). We will assume that commercial fishermen catch 1/3 of the standing biomass annually. This will naturally vary with economic factors like prices on cod, prices on other fish species, fuel prices, and more. However, as a first approximation, we will assume that commercial fishermen catch 1/3 of the standing biomass annually, even when the standing biomass changes. To prepare for possible later refinements to the model, allowing for profit maximising behaviour by commercial fishermen, we will use a similar Schaefer harvest function as for the tourists. We assume that the three registered vessels in Risør together fish 50 days in the Søndeledfjord system, and then get a catch of 10 tonnes given a 30 tonnes standing biomass. The corresponding catchability coefficient, and other data, is given in the table 1.3 below.

For example:
The harvest by camping tourists should be calculated in the following way:

Equa (1.11): Harvest as biomass = Tourist days by camping tourists * Catch per unit effort indicator per cod stock unit * Cod stock biomass

With tourist days= 35 000 and Cod stock biomass = 30 tonnes, Harvest as biomass = 35 000 * 0,0000002 * 30 = 0,21 tonnes.

As camping tourists target year-classes 1-10, the relative distribution of biomass among these year-classes is calculated, and 0,21 tonnes is distributed accordingly among the year-classes. Depending on the average weight of a fish in each year class, a specific number of fishes are removed from each year-class.

Table1.3. Effort indicator and relation to annual catch for different categories of tourists, and for commercial fishermen.

Category	EI - Effort Indicator	FE - Fishing effort as proportion of EI	Fishing effort unit	q - Catchability coefficient	Catch per unit effort indicator, per cod stock unit (= FE * q)	Year-classes harvested on	Example EI value	"Normal" cod stock biomass (tonnes)	Example harvest tonnes biomass
								30	
Hotel tourists	Tourist days	0	days	x	x	x	32 000		0,00
Camping tourists*	Tourist days	2 %	days	1,00E-05	0,0000002	1-10	35 000		0,21
2nd home owners	Tourist days	3 %	days	1,33E-05	0,0000004	0-10	115 000		1,38
2nd home renters*	Tourist days	3 %	days	1,33E-05	0,0000004	0-10	100 000		1,20
Fishing tourists**	Tourist days	75 %	days	1,67E-05	0,0000125	2-10	4 000		1,50
Recreational fishers ****	Active days	100 %	days	1,67E-05	0,0000167	2-10	4 000		2,00
Commercial fishers***	vessel days at sea	100 %	vessel days	0,006666667	0,006666667	2-10	50		10,00
							Sum harvest tonnes		**16,29**

* Not counting Fishing tourists, even though they may be staying at this type of accomodation

** Each boat with fishing tourist catches 1,5 kg cod per day, and have ca 3 tourists per boat on average (Volstad 2009, prelim results survey)

*** Commercial fishermen catch about 10 tonnes cod per year in the Søndeledfjord system. We assume with 50 vessel days.

**** Active fishing days = «total number of inhabitants in Risør municipality» * «average number of fishing days in Søndeledfjord by each inhabitant»

Total number of inhabitants in Risør municipality = 6938

Average number of fishing days in Søndeledfjord by each inhabitant = 0,1

Cod mortality due to eel fishers

The eel fishing take place mainly during the summer months and the estimated numbers of cod in the different year-classes caught are given in Table 1.4. In the Risør area there is one very active and 2 – 3 periodically active eel fishermen harvesting eel. One fisherman has about 100 ell pots in this area. (Unpublished information).

Nedreaas et al. (2008) collected some information about by-catches in the eel fishery. In the Risør area they found that number of cod pr pot varied from 0.7 to 1.6 with an average of 1.1 cod pr haul (Lekve *et al*. 2006). These values are slightly higher than in Østfold, but lower than in western Norway.

The length distribution of the cod caught in experimental fishing with eel pots in Risør varied from 5 - 50 cm (Fig 1.2)

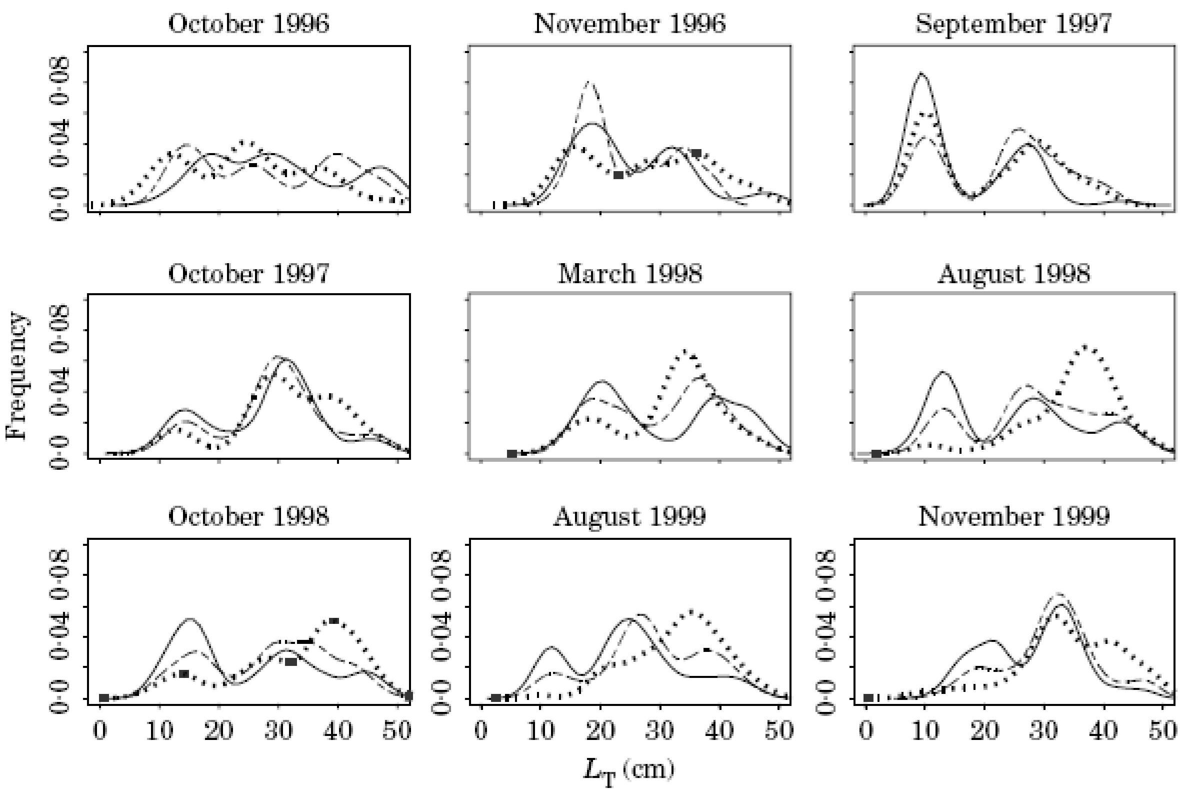
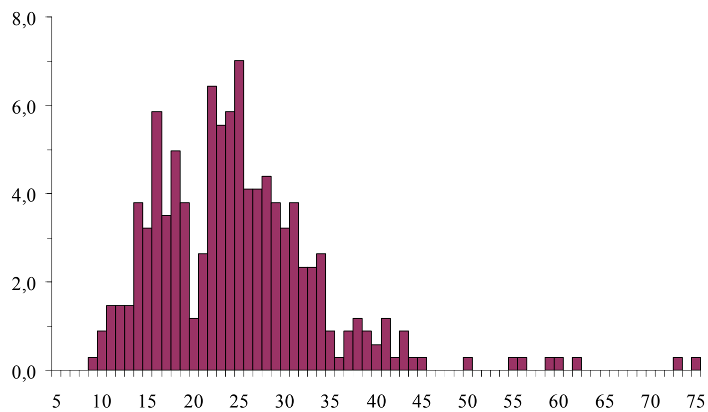


Figure 1.2. The smoothed distributions of cod total length frequencies for the three areas [the Skerries (–), the outer fjord (- -) and the the inner fjord (. . .)]. The graphs are produced by a Gaussian kernel in S-plus (Venables and Ripley, 1997). The number of cod caught in 1996 was very low (Table I), and was interpreted with care. (from Lekve et al. 2004)

Size distribution of cod caught in eel pots in the Bjørnefjord, western Norway (Agnalt et al. 2007) show a similar pattern (Fig. 1.3)



Figur 1.3. Length distribution of cod caught in eel pots in Bjørnefjorden (Hordaland) 1995–2006 (from Agnalt *et al.* 2007).

Table 1.4. Estimated annual reduction in number of cod in the different age-groups caught by eel fishers.

Age-group	Eel-fishers (per year)	Equation number	Y = number of 0-group cod caught and X = Density x-gr (number km^{-2}).
0	2500	1.13	Y = 0,372 * X
1	1000	1.14	Y = 0,549 * X
2	700	1.15	Y = 0,633 * X

Cod mortality due to recreational fishers

The local inhabitants of Risør municipality also fish in the Søndeledfjord system. Cod mortality is modeled similarly as for the other groups, with a Schaefer harvest function.

Growth

Growth from one year to the next for each cohort of age 1+ will be modeled by selecting the lengths of all individuals in a year class randomly from expected length distributions as given in Table 1.5 below. The mean length and standard deviation for each age group are estimated from data for the cod population in Søndeledfjorden. This simple approach ensures that the projected population in numbers by age will have an expected length distribution in each age group that is consistent with empirical data, and is an alternative to the selection of von Bertalanffy growth curves for each cohort.

Change in size (length, weight) from one year to the next for each individual fish in a cohort is calculated from a table of mean size (μ) and the associated standard deviation (σ) by age group as calculated from empirical data. The length of each individual fish in an age group, $x(i)$, is randomly selected from a normal distribution, $N(\mu, \sigma)$. The weight of each fish is then determined by a length-weight equation (see equation (1.2)).

Table 1.5. Average length (cm) of cod in each age group (year-class) with Standard deviation (SD) (Age 3-10 comes from Gjøsæter and Danielssen (In prep)) and average wet weight (g) with standard deviation (Age 3-10 is calculated using equation 1.2). N = number of observations.

Age	Average length (cm)	SD	Average weight (g)	SD	N	Reference
0	9,63	2,10			➢ 1000	Own data
1	23,8	3,0	147	73	991	Own data
2	35,9	3,3	462	150	70	Kristoffersen et al (In prep)
3	47,0	7,0	1013	NA	302	
4	52,2	7,4	1380	NA	112	
5	59,0	9,7	1980	NA	34	
6	70,0	10,2	3276	NA	27	
7	71,9	12,6	3545	NA	13	
8	79,3	10,6	4732	NA	6	
9	82	10	5222	NA	60	
10	85	10	5806	NA	60	

Calculation of individual cod weight

The weight (kg) of each individual in an age-group estimated from the length-weight equation (1.2) given below. Total biomass by age group is obtained by summing the individual weight (after back-transformation from log 10-scale; equation (1.3) over all individuals.
Equa (1.2): lg W = 2.946892916 lg L - 1.921950107; where lg = log 10, w = weight (kg) of cod, L = length (cm) of cod
Equa (1.3): $W = 10^{(\lg W)}$, where lgW is from Equa 1.2

Calculation of total cod biomass

Total biomass by age group is obtained by summing the individual weight calculated in equation (1.3) over all individuals.
Equa (1.4): Total weight by age group (kg) = sum of all individual weights (W) in the age group

Spawning stock (SS) of cod

The spawning stock (SS) of the coastal cod in SSA 7.6 (Søndeledfjorden) consists of age-groups 4-10. If the spawning stock comes below 50 cod (age-group 4-10), it is below a minimum critical value and will result in a recruitment failure and the number of 0-group cod will be equal to zero.

The starting population of cod (age 1-10) is given in Table 1.1 The spawning stock (age-group 4-10) consist of 4.891 individuals representing a total biomass of 9.5 ton. The density of the spawning stock is calculated to 0.405 ton km^{-2} (total area = 23.52 km^2).

Cod stock indicator

To assess the "health" of the cod stock a simple indicator is needed. One option is to use exploitation rate or similar indicators (e.g. Pitcher and Hart, 1982) but we have decided to use a more easily measurable indicator i.e. the number of recruits age 1 (N_1) as proportion of the adult stock size ($N_{(2-10)}$).

Equa (1.12): $E = N_1 / N_{(2-10)}$; N_1 = Density 1-group cod, $N_{(2-10)}$ = Density (2-10 group cod)

Habitats for 0-group cod

Suitable habitats for 0-group cod are above a depth of 25 meters and consist of eel-grass, macroalge, muddy areas. In the period 1933-1937 the eel-grass suffered high mortality due to diseases and resulted in very low biomass in the area and thereby a significant reduction in suitable habitats for the 0-group cod. In these years the recruitment of 0-group cod was at a very low level. It is assumed that all area above 25 m depth is productive areas for 0-group cod (see table 1.6 and chapter 6.3.1).

Table 1.6. Calculated productive volume (from tab. 6.6) and calculated area (for depth less then 25m; from tab. 6.4a) in the Søndeledfjord system.

Basins	Calculated Volume (m^3)	Calculated Area (m^2)
Nordfjorden	798.693.797	6.263.157
Sørfjorden	130.896.705	4.457.576
Total Søndeledfjorden	929.590.502	10.720.733

1

Habitats for 1-10 group cod

Suitable habitats for 1-group and older cod are the total area and volume with suitable 0_2 content in the water column (See table 1.7 and 6.6). In the present model, it is assumed that volume available for cod is constant. A separate Maritime spatial planning (MSP) are given in chapter 6.4.

Table 1.7. Calculated productive volume (from tab. 6.6) and calculated area (from tab. 6.4b) in the Søndeledfjord system.

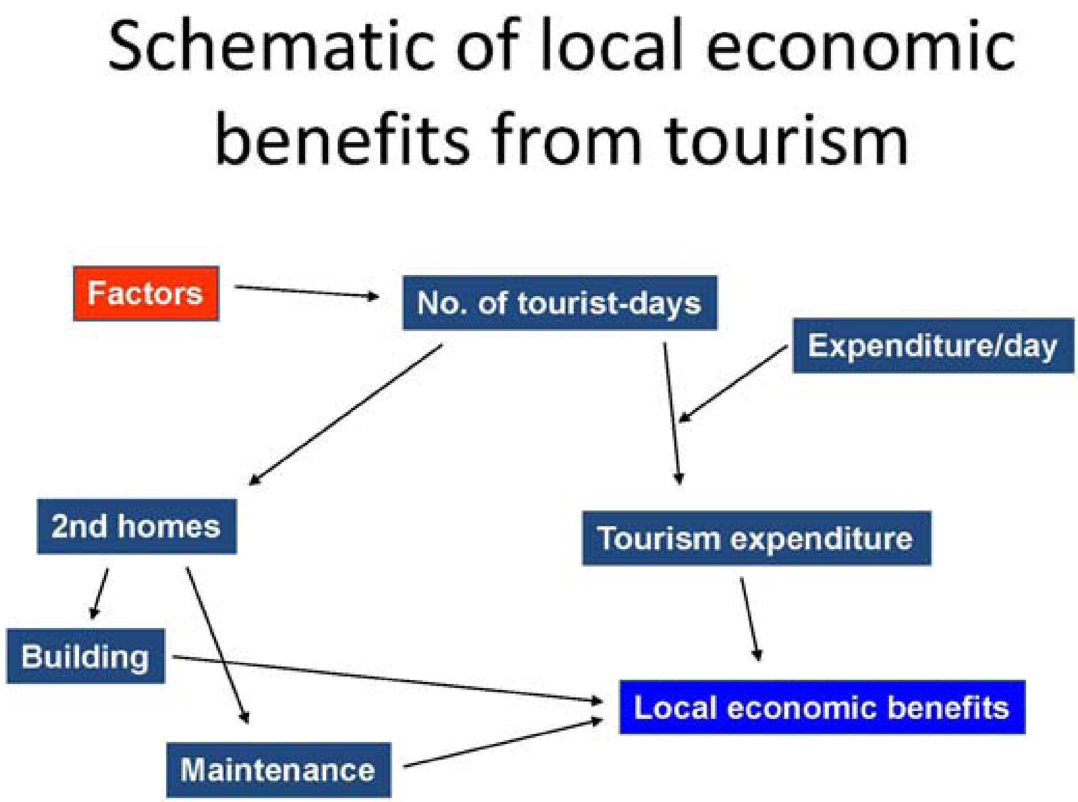
Basins	Calculated Volume (m^3)	Calculated Area (m^2)
Nordfjorden	798.693.797	15.732.236
Sørfjorden	130.896.705	7.819.964
Total Søndeledfjorden	929.590.502	23.552.200

5.1b.2 EconComp.

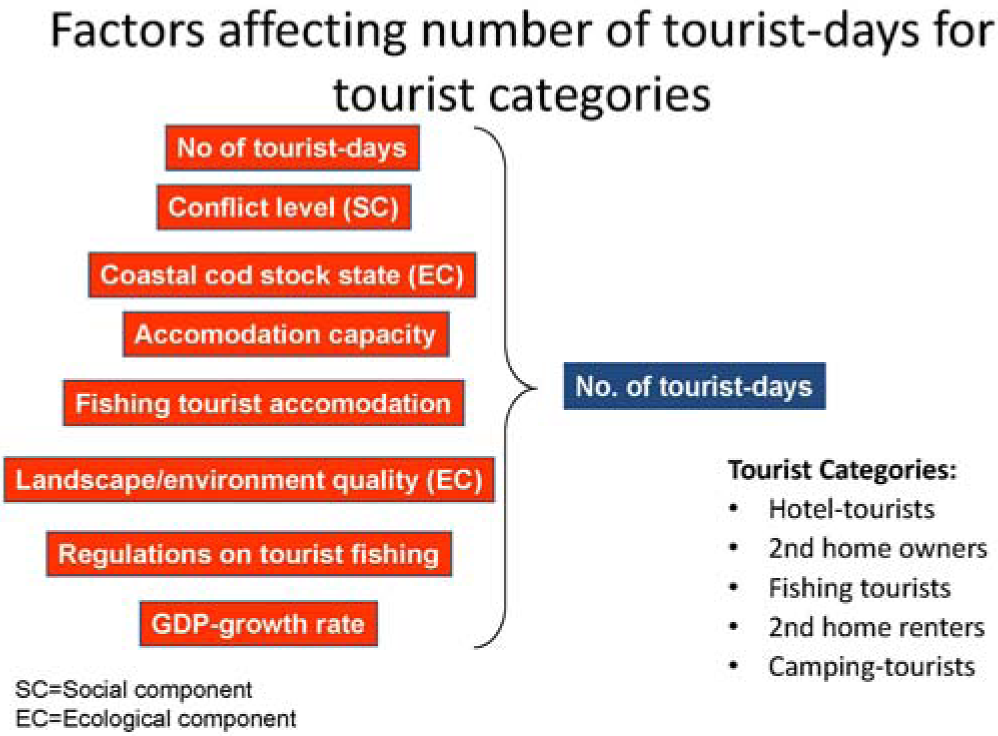
The main scope of the economic component is to estimate (net) local economic benefits from tourism in the Søndeledfjord area. This area is set equal to Risør municipality in our case.

The economic benefits/costs related to tourism that we consider come from
1) expenditures from tourists visiting the area (except 2nd home building and maintenance), and multiplier effects of those expenditures,
2) the building and maintenance of 2nd homes + multiplier effects,
3) Changed value-added in the commercial fishery due to changes in the coastal cod stock,
4) Aquaculture production, including effect on wild cod stock (not included yet), and
5) net local costs of coastal cod stock enhancement (not included yet)**.**

We have divided tourists into 5 categories: Hotel-tourists, camping-tourists, 2nd home owners, 2nd home renters, and fishing tourist. The model is basically built up according to the figure below. A number of factors are assumed to affect the number of tourist-days for each category of tourists. The factors are included in figure on the next page. Each tourist, in each category, has an average expenditure per day. This sums up to a total tourism expenditure, and via a multiplier effect it gives local economic benefits. In addition to this, for 2nd home owners, the building and maintenance of 2nd homes is a significant element for tourist expenditure, that also, via a multiplier effect, adds to local economic benefits.



The diagram below show which factors that influence number of tourist-days for the different categories of tourists. It is indicated which of these factors that come from the social or environmental component of the model, wholly or in part. In addition to this, some of the policy options, that are defined as belonging to the social component of the model, influence the number of tourist days. These are the Fishing tourist accommodation (see section 4.4 and 3.1.2 in the system formulation report), the fishing regulations (see section 4.3 in the SF report), the regulation of construction of sandy beaches and marinas (section 4.2 in the SF report), and the regulation of the maximum number of 2nd homes (section 4.1 in SF report).



Given tourist numbers for hotels and camping/cabin-rental, which we have official statistics on, the base values of relevant variables have been set accordingly. To get meaningful variables for our policy issue, and that also make the links between the economic, ecological and social components sensible, some variables have had to be constructed (conflict indicator and landscape quality index). Parameters for these are highly uncertain, but qualitative effects of the changes will (very likely) be of the correct sign. For the effect of the cod-stock status on tourist-day numbers we have chosen our "best guess" on data on catch rates for fishing tourists and 2nd-home owners in Norway. For some of the other variables, we only have data from other/larger regions (these include daily expenditures by tourist category, use of 2nd homes per year, investment and maintenance costs for 2nd homes). Based on these we have chosen what we consider a "best guess" on values / influence on tourist-day numbers or expenditures. For the effect of GDP on tourist-days we have made a simple statistical analysis of annual GDP growth rates for both the OECD (as these make up the major tourist-groups to Norway), and Norway itself (most tourists to Risør are Norwegian), against growth rates in tourist numbers to Norway for the period 1990-2007. From this we selected Norwegian GDP growth rates as the most relevant variable (explaining about 35% of the variation in tourist numbers' growth rate).

Although surveys to estimate importance of fish abundance on tourists numbers would have been useful for our model's calibration, the available resources in the project prohibits this.

There is also a limited commercial fishery in the area. To estimate the changed economic benefits related to the commercial fishery due to tourism-related activities (via habitat-effects on recruitment, or increased mortality form tourism fishing), we use the market price method for changed harvests in the commercial fishery. The change in the harvest in the commercial fishery is calculated in a very simplistic manner. It is simply assumed that deviations from the size of the cod stock compared to what is taken as the base value for the cod stock, proportionally translates into changed catches in the commercial fishery. Given an assumed fixed price per kg of cod, this gives a changed income for fishermen. With a multiplier effect for this, it translates into changed local economic benefits. The shortcomings of this method are discussed in the System formulation report, section 3.3.1.

The model is still being refined, based on experiences from experimenting with it, and availability of new data. However, running simple scenarios indicates that it is behaving as expected. As we have mentioned elsewhere, the numbers are not to be taken too concretely, for instance for local economic benefits given a specific scenario. However, we hope that we get order of magnitude effects correct, and the qualitative effects correct. Running the model with different scenarios will then give us a good indication of the trade-offs and compromises that practical policymaking will involve.

An example:
Comparing the output from two different scenarios, where one has increased the available accommodation specifically targeted on tourist fishers (again, see 4.4 in SF report), and their average rating, from 40 beds with 3 stars to 200 beds with 5 stars, and also has stricter regulation on the construction of sandy beaches and marinas, leads to the following effects:

- The annual number tourist-days from tourist fishers increases substantially, the number of tourist-days from 2nd home owners goes down, but overall there is an increase in tourist day numbers.
- The economic benefits increase.
- The cod stock goes down
- The conflict level goes up

This demonstrates the workings of the model, and the relevance of the outputs from it in relation to the chosen policy issue.

The results of the valuations made in the context of the larger economical CZ system.

The first point is discussed above.

For the second point; it would be sensible to include the extentions that are already mentioned in the system formulation report, regarding more advanced modeling of the effects on/from the commercial fishery, the possibility of stoch enhancement, and also including possible aquaculture-fisheries interactions. While these may only have limited value in the Søndeledfjord case, it would certainly be extentions that give the model a great potential for use elsewhere in Norway, and probably also in other geographic locations.

5.1b.3 SocioComp.

Normally the fishery along the Norwegian coast is difficult to regulate as this fishery is regulated as an open "free for all" in accordance with the "The Free Access Right" (Allemannsretten). However, some restrictions apply: There is no charge for fishing in the sea, and Norwegian citizens can engage in sports fishing with handheld line, fishing rod and one motorized trolling-line, fishing nets with collected length of no more than 210 meters, lines with no more than 300 hooks, and up to 20 traps, fish pots or lobster pots. These types of equipment can be used together in the outlined quantities. However, the limitation applies to the vessel and not per person. A recreational fisher can sell up to 2000 kg cod pr. year (Directorate of Fisheries 2008).

Fishing pressure – user groups

There is a long history of fisheries on cod in the fjord; however, the local cod stock has declined over the past 10 years. The local cod stock in the fjord can be divided in two components, a slow growing and smaller cod in the inner part and a faster growing and bigger cod in the outer part, both belonging to the same stock and use the same spawning area. The fishery pressure are different on these two components, where owners of second-homes normally will fish more on the cod in the inner part, while tourist fishers will fish mainly on the cod in the outer part. Over the past 10 years the numbers of tourist fishers has more than doubled (Sørlandets Feriesenter; pers comm), and are visiting the area outside the summer months, while the second-home owners are normally using the area during the summer months. At present there are **1523** second homes in the area, and there are plans to expand this within the next five years to approximately 1900, an increase of approximately 27%. A significant proportion of existing and planned second homes are for rent-out. The construction activities in the coastal zone may cause habitat destruction (e.g. *Zostra marina*), by dredging, dumping, fillings and artificial beaches, reduced value of fishing and trawling grounds because of cables, pipelines and marine installations. Some mussel plants are located in the fjord-system and these may hinder sailing and leisure fishing and enhance local biodiversity and production.

The present impact in Søndeledfjorden is the decline in coastal cod abundance. An obvious management challenge is to ensure an increase in local economic benefits from tourism, while minimizing negative impacts on local coastal cod stock, and conflicts with local users of the fjord system.

Table 2.1. Overview of starting numbers of different user groups

User group	Starting number	Comments
second homes	1523	May 2009
Eel fishers	3	May 2009
Commercial fishers	3	May 2009

Residents, Tourists and Second homes

The Skagerak coast is very popular for summer holidays and the population along the coast increases at least two or three fold during the summer months. Both visitors and the owners of the great number of second homes want access to the sea, moorings, buoys, floating piers, marinas, and other boat related facilities. In many cases these are established in productive areas, like mud- and eel-grass habitat, important habitats for juvenile cod. Besides boating, the tourists want sandy beaches along the coast for playing, sunbathing, swimming etc.. To increasing numbers of such artificial beaches contributes to the deterioration of other important habitats for living marine resources. However, tourists and second home owners bring money and revenue to the coastal municipalities, and accounts for an increasing part of the regional and local economy. While entrepreneurs have plans for many more second homes, the municipality administration hopes for larger economic benefits from tourism without large negative ecological effects or conflicts with local residents/industry. How can increased revenue and benefits to the region take place while actually reducing the negative impacts? An increase in the number of tourist can in itself obviously not be the answer. Tourism brings income to the Risør/Søndeledfjord area in several ways. Sales of goods and services to 2nd home residents or the “occasional” tourist are probably the most important part, whereas construction of second homes, or other types of accommodation are somewhat less important. However, it seems to be the case that those making most money from this so far have been from other areas/regions. The municipality mayor has put forward the ambition of increasing the numbers of high-paying tourist with well-developed ecological awareness to the Risør area. Selling services of high quality related to this seems to be a natural part of such a scheme. The municipalities also have tax revenues from second homes.

For the residents in the Risør area Søndeledfjorden represent an important source for recreation, and in addition regularly provide many household with fresh fish. Also for visitors, either on an occasional visit or seasonally returning as owner of a second home, fishing is often an important leisure and recreational activity. The number of visitors is then likely to affect the fishing pressure in the fjord. The main conflicts between local residents and tourist are related to the seasonal over-crowding of most part of the coast and the coastal towns. The locals claim that “the tourists have invaded us”. There are also conflicts between boaters and second home owners/local residents over the access to coastal areas. The local authorities want to further increase the numbers of visitors to the area, but by extending the summer season in both ends. In Risør there are entrepreneurs planning to develop scarce industrial areas to second homes. However, the Risør municipality is, through the Planning and Building Act in charge of the physical planning in the area, and has well-developed tool for dealing with area- and space-related conflicts. The Act provides the municipality with tools for physical planning in both the terrestrial and marine parts of the territory. Included in the act is also a general (national) prohibition of building within the 100 meter zone from the watermark, but the municipality may exempt from this.

The Søndeledfjorden has a few blue mussel rigs located north and west of Barmen, the island in the centre of the fjord system (see fig. 6.1 and 6.3). These are not too welcomed by the second-home owners due to limiting the boat traffic and they perceive these installations are deteriorating the esthetical qualities of the area. On the other hand these installations could increase the food production for fish, and they provide habitats where fish can feed and hide.

Living resources, tourist fishers and second home owners

Norwegian coastal waters contain plentiful and valuable resources that contribute to the well being and economy of the people living along the coast. Fishing for household consumption has always been a legal right for Norwegian citizens and this fishery is considered rather stable. Hallenstvedt and Wulff (2004) estimated that the total Norwegian non-commercial catch in 2003 was approximately 10,000 tons (round weight) in each of the regions in Eastern Norway, Western Norway and mid-Norway (Møre and Romsdal, South Trøndelag, North Trøndelag); and 18,000 tons in Northern Norway (Nordland, Troms, Finnmark); altogether 48,000 tons. During the 1990's tourist fishing became an important part of the Norwegian tourist market (license for sport fishing in Norwegian coastal waters is not required). It has been estimated that the economic value generated by a fish caught by a tourist is ten times higher than when caught by a commercial fisher (CGE&Y 2003). Motivated by this observation, the Ministry of Fisheries and Coastal Affairs has suggested recently that it may be advantageous to assign part of the Norwegian commercial quota to tourist fishing companies. At present there are no precise statistics on how many tourists fish along the coast or how much and which species they catch. The most recent report (2003) on tourist fishing in Norway is by the consultant company Cap Gemini Ernst & Young (CGE&Y). CGE&Y estimated that the tourists catch about 6,000-9,000 tons (round fish) each year. In comparison, Hallenstvedt and Wulff (2001) estimated the total catch by tourists at between 12,000 and 15,000 tons per year. According to CGE&Y about 17% of the tourist catches are caught in southern Norway. CGE&Y concludes that these estimates are very uncertain, and there is a strong need for more comprehensive research to achieve better catch estimates and information on species and size composition. According to St.meld. no. 19 (March 2005), the Norwegian government ("Stortinget") desires to make tourist fishing a significant component of the tourist industry in Norway. To achieve this goal, the Government will ensure that tourists can fish along the Norwegian coast and regulate the fishery so that it is sustainable. In addition, recently several new laws and regulations have been introduced to ensure the sustainable utilization of coastal resources and to prevent unnecessary conflicts among stakeholders. Reliable regional knowledge about species composition, size and seasonal variation is crucial to manage the resources in a sustainable way, to obtain a sound balance between resources and harvest, and to formulate laws and regulations that fit the actual conditions along the coast.

User groups and impact

Commercial cod fishing

Commercial cod fisheries are here defined as fishing carried out as an occupation on a commercial basis. Net-fishing is very efficient but also quite selective. Minimum mesh size in

Norway is 35 cm, which generally means that 2 year old cod and larger are caught. Some fishers also do line-fishing, but that is quite rare, and does not account for much of the volume landed.

Eel fishing

Eel fishing are an important user group because as cod are caught in high numbers as by-catch. Eel (*Anguilla anguilla*) is fished mainly in the fjord system, and the surveys and general knowledge about the system indicates that by-catch of cod is substantial in this fishery. Given the recruitment problems and the limited cod resources in the inner fjord, reduction of eel fishing may contribute to the overall improvement of the general abundance of cod. Reducing or stopping the eel fishery can primarily be done through regulations in accordance to the Salt Water Fishing Act by the national and/or regional fisheries authorities. However, the municipality may, at least theoretically; also buy out the few local fishers involved in this fishing, but the municipality has no legal power to stop anyone to (re)enter the fishery. There are only a handful of fishers within the case area involved in eel fisheries, and these are generally retired people getting some income while carrying out their hobby. The eel fishers are generally not selling their cod by-catch, as they often do with the eel. The cod is mainly used for household consumption and often given to neigbours, friends etc.

Recreational fishing

Recreational fishing is fishing carried out by local residents or people occasionally passing by the coastal areas by boat or car, thus cabin-owners with cabins along the case area are not included in this group. The importance of this fishery is difficult to assess, but the volume is generally believed to be high. Some of the local residents are in possession of nets and thus represent a potential high fishing pressure. However, these fishers generally fish only for their own household consumption, and it is unlikely that this potential fishing pressure is heavily utilized.

Tourist fishing

Tourist fishing is fishing where anglers are coming to designated cabin/hotel facilities to stay while fishing, and where boats and other type of infrastructure are provided by the tourist fishing company. These fishers varies from team-building groups that happened to chose fishing as their arena, to dedicated trophy anglers chasing only the big ones, and to those quantity seekers who fish to fill their freezers with cod fillets. This type of fisheries is carried out through the tourist enterprise, and they facilitate and administer the activities with their own guides and boats etc. Foreigners may engage in sports fishing with hand held tackle, but not with fixed equipment like pots, lines and nets. Further, they cannot sell their catch. Also an export quota applies, and it is currently not allowed to bring more than 15 kg of fish, plus one trophy fish, out of the country. Freshwater species are not subject to this regulation.

With support from cost-benefit analyses and so on, the authorities can, again theoretically speaking, channel the cod to the user group that provides the largest economic and social benefit for the municipality or the region or country as a whole. However, this assumes that a certain amount of fish can easily be allocated to the targeted user-groups, and that each of them has the capacity to actually land the allocated amount of cod. This is most likely not the case. The model will distribute the costs and benefits between the user groups and may thus also be an indicator of resource conflicts. If the commercial fishers get more on the expense of tourist fishers, it is likely that the tourist fishing operators and anglers interest groups will mobilize and start media campaigns etc. to change the decision in their favour.

Second Home owners

The 2nd Home owners can be considered as a subgroup of the Recreational fishing group discussed above. However, we see the fishing pressure presented by the 2nd Home-owners as a rather fixed share of the numbers of cabins along the coast. Thus, the fishing pressure from this group may to some extent depend on the numbers of cabins in the coastal areas. And the number of 2nd Homes is largely under the control of the municipality through spatial planning in accordance with the Planning and Building Act. This means that the municipality to some extent indirectly may influence the increase in fishing pressure in the case area. We suggest three alternatives:

- Alt 1: No further increase in second home developments in Risør municipality
- Alt 2: Some local restrictions in second home developments, indicated by increasing numbers (but a lower increase than Alt 3)
- Alt 3: No local restrictions in second home developments, indicated by increasing numbers

Eco-tourism

There are many definitions on ecotourism. Some put emphasis on that development and management of tourism takes place in such a way that the environment is preserved, and that the income from tourism adds to the investment into landscape conservation (Colvin, J. 1994). Some definitions also state that ecotourism should appeal to the ecologically and socially conscious, and also contribute to such consciousness. Often are local culture, local heritage and local nature in the centre of attention. This form of tourism put emphasis on leaving as little “footprints” and other negative impacts as possible.

To some extent the local authorities can facilitate or allow eco-tourism development at the dispense of non-eco tourism/ordinary tourist fishing developments. It is, however, doubtful whether rather small increases in the abundance of cod in the local waters of Risør will significantly improve the chances for further eco-tourism development.

Regulations

Minimum cod size

To reduce the fishing pressure a minimum size of 35 cm (13.78 inches = 2 year) on fished cod already applies for the commercial fisheries. This measure could also be expanded to and introduced in the tourist and sport fisheries, as it is quite likely that many of these fishers often land fish under this minimum size. The minimum size can also be changed in the model and will affect both commercial and sport/tourist fisheries. The option in the model is to change the minimum year-class (age-group) the different users can fish on.

MPA (Marine protected areas)

The definition of a marine protected area (MPA) adopted by IUCN and other international and national bodies is:
"Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment". (Kelleher and Kenchington, 1992).

A protected area is: **"A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values". IUCN 2008**

IUCN 2008 differs between:

1) a) Strict nature reserve, and b) Wilderness area,
2) National park,
3) Natural monument or feature,
4) Habitat/species management area,
5) Protected landscape/seascape,
6) Protected area with sustainable use of natural resources.

In our case only 4, 5 or 6 may apply.

There is, theoretically, possible to close the study area for all kind of fishing by introducing a MPA. There is already a lobster reserve established along the Risør town waterfront. However, to establish a MPA covering large part or all of the study area is highly unlikely, both in terms of practicality and political support and legitimacy. There would also be difficult to justify such strong measures vis-à-vis the national fisheries authorities, and it will most likely also require changes in the fisheries legislation.

MPA-habitat

In the present version of the model the estimated effect of each new 2nd home is that each will contribute to reduce available habitat for 0-group cod with 50 m^2. However, three levels of regulations are included, which will affect the available habitat for 0-group cod.

Table 2.2. Regulations that affect establishing new sandy beaches and marinas.

Option	Regulation	The estimated effect of each

		new 2^{nd} home is that each will contribute to reduce available habitat for 0-group cod with:
1 (Default)	Non	50 m^2
2	No new sandy beaches	25 m^2
3	No new sandy beaches and marinas over depths less than 25 m	0 m^2

Calculation of available habitat for 0-group cod as a function of existing 2^{nd} homes and new 2^{nd} homes:

Equa (2.1): New available habitat = available habitat – (2^{nd} homes)*50 – (Delta)*(option; 1=50; 2=25; 3=0);

MPA-cod / Fishing regulations

In the present version of the model the spawning stock of the local cod can be protected by closing the spawning season for fishing and a third option which stop all fishing of cod in the study area.

Table 2.3. Regulations to protect cod and affect tourist and commercial fishers.

Option	Regulation	Effect on Tourist fisher	Effect on commercial cod fishery	Comments
1 (Default)	Non	Non	Non	
2	No fishing during spawning period (3 months) with nets	Non	50 % reduction in fished cod = 5 ton $year^{-1}$	Will affect the ecosystem (table 1.1 with annual survival rate) and economical model
3	No fishing during spawning period (3 months) with nets and hooks	Reduce their available annual fishing period with 30%	50 % reduction in fished cod = 5 ton $year^{-}$	Will affect the ecosystem (table 1.1 with annual survival rate) and economical model (see chapter 3.1.2)
4	No fishing of cod through the whole year with nets and trawl	Non	100 % reduction in fished cod = 10 ton $year^{-1}$	Will affect the ecosystem (table 1.1 with annual survival rate) and economical

				model
5	No fishing of cod through the whole year with nets, trawl and hooks	No touristfishing – 100% reduction	100 % reduction in fished cod = 10 ton year^{-1}	Will affect the ecosystem (table 1.1 with annual survival rate) and economical model (see chapter 3.1.2)

The effect on Tourist Fishers (Option 3 and 5) is through Equa (3.4):

Equa (3.4): $$T_i = \left[T_{i0} + \sum_j b_{ij}(A_j - A_{j_0}) \right] \left[\left(100 + \left(b_k \ln(A_k) - 1{,}3 \right) \right) / 100 \right]$$

The MPA-cod will affect equation (3.4) in the following way:

If MPA-cod = 3; the first part of the equation ($\left[T_{i0} + \sum_j b_{ij}(A_j - A_{j0}) \right]$) should be multiplied with 0.7

If MPA-cod = 5; the first part of the equation ($\left[T_{i0} + \sum_j b_{ij}(A_j - A_{j0}) \right]$) should be multiplied with 0

The effect on the Commercial cod fishery (Option 2, 3, 4 and 5) is through reducing “Days at sea” with 50% (option 2 and 3) or 100% (option 4 and 5)

Process (in-put) legitimacy and content (out-put) legitimacy (result)

Legitimacy can in this context consist of either process (in-put) legitimacy (the degree of support and content with the decision-making process) or content (out-put) legitimacy (the degree of support and content with material content of the decision). The important point is that sometimes too little of one can be compensated by more of the other. Also, that more legitimacy is generally better than less legitimacy.

Stakeholder participation in the policy process is thus believed to lead to better and more well-informed decisions, which again will lead to increased support of and compliance to, the regulations agreed upon. Participation ought to be seen as a way to address and reduce the potential for user-conflicts. In addition, participation also has intrinsic values, and is a goal in its own right. Participation is expected to increase the conflicts in the first stages of the decision making processes, but reduce them at the final decision-making stages.

Theoretically, more participation the better. However, participation also has costs, and at some point the benefits will be outweigh by the cost. Thus, to strike the right balance is essential.

However, even if the in-put/process legitimacy cannot be directly manipulated, it can be seen as a function of the amount of user-group/stakeholder participation. More participation leads to improved legitimacy. This does not necessarily hold true for all cases, but can be a good enough estimate for use in the model. With a slider this can be illustrated with a slider going from extensive participation to no participation.

User conflicts/Output-legitimacy

This is a result of the participation and the decision-making and can as such not be treated as a variable that can be directly manipulated. Legitimacy is also a highly complex variable that is very difficult to operationalize. However, it can be measured through indicators such as 1) letters of complaints received by the municipality administration, 2) fisheries and coastal zone related conflicts displayed in the local media, or 3) numbers of cod/coastal zone related conflicts. We doubt these variables easily lend themselves for modelling.

Conflict-potential indicator

As avoiding/limiting the level of conflict between locals and tourists is a definitive objective in the policy issue, it would be useful to have this indicator as an output of the model. In addition, it is an input to the function determining the attractiveness of the area for tourists. To set up such an indicator two questions must be answered:

1. What variables are reasonable to include in an indicator of the conflict-potential?
2. How should the variables influence the indicator (functional relationship)?

- The number of tourists in the different categories
    - A higher number of tourists make conflicts over scarce resources more likely, and thus increases the general conflict potential level
    - However, there could be different effects from the different categories of tourists, as they to different degrees contribute to conflicts over resources, external effects, etc.
    - It is thus possible to include the number of tourists in each category, but give them different weight
    - However, we will here just use total number of tourists for simplicity. Last years numbers.
- The economic benefits the tourists give the region
    - If tourists give economic benefits of real significance to the people in the area it reduces the propensity of conflicts for otherwise constant number of tourist days.
    - Will use last year's values here too

Conflict indicator:

Equa (2.2): $$A3 = \beta_3 \frac{A_1}{\sum_{1}^{5} L_{i_{t-1}}}$$ Let $\beta 3=1000$; L_i refer to the total sum in Equa (3.6).

WT 5.2 SYSTEM SIMULATIONS

5. 2a The Simulation Model Construction

5.2a.1 Model Setup

Please see the document: MODEL SSA 7-6-desciption.v 1.21.

5.2a.2 Link ESE Components

Please see the document: MODEL SSA 7-6-desciption.v 1.21.

5.2a.3 Run & Test Simulation Model

Please see below

5.2a.4 Hindcast with Policy Issue

This model generates the local cod population in the study area over a 1-50 years period. The cod population are affected by annual recruitment at 0-group stage (September every year) and mortality rates between year-classes. The model can do between one and 100 simulations over the 1-50 years. The importance of running up to 100 simulations for each scenario is to reduce the effect of annual recruitment on the total cod population.

As the model is predicting the future and not looking back in time (there is no data available to do hindcasting), the focus has been on testing if the model reflects the present cod stock with the present stakeholders involved. To do this the model has been runned and the results from the model have been compared with a capture-recapture study in the study site. The results from these two approached match pretty good and indicate that the model are able to reflect the status of the cod stock. There is, however, some bugs in the model regarding the economic component. This will be fixed before the end of the year.

Cod population size in Sørfjorden

Estimated from capture-recapture data

A capture-recapture study on coastal cod was conducted in the Søndeled fjord, Risør, southeast Norway in 2005. During four sampling occasions (20 May, 25 May, 6 June and 10 June) we captured a total of 303 cod of 25 – 80 cm body length (Espeland *et al*. 2008). Unless tagged on a previous occasion, all cod were individually tagged with an external T-bar anchor tag (Hallprint, Australia) paralell to the anterior dorsal fin. All cod were captured in traps in shallow water in collaboration with a local fisher. All fish were released alive at the point of capture immediately after being tagged and measured for length. Usually, each trap would hold 1 – 3 cod. Therefore, our approach ensured that a small number of tagged cod were released throughout the study area. This should improve mixing of tagged and untagged fish and allow us to draw inference on the total population in the area.

Assuming a closed population througout the study period (20 May – 10 June 2005), we estimated population size (N_C) as outlined by McCallum (2000), adjusting for small sample size:

$$N_C = ((n_1 + 1) \cdot (n_2 + 1) / (r + 1)) - 1,$$

where n_1 is the number of cod captured and tagged on the first occasion (20 May), n_2 is the number of cod captured and examined for marks during occasion 2 – 4 (25 May, 6 June and 10 June), and r is the number of cod tagged on the first occasion and then recaptured during occasion 2 – 4. Following McCallum (2000), an approximate standard deviation of the population size (N_C) was estimated as the square root of the variance (var):

$$\text{var}(N_C) = (n_1 + 1) \cdot (n_2 + 1) \cdot (n_1 - r) \cdot (n_2 - r) / (r + 1)^2 \cdot (r + 2)$$

On the first occasion we captured and tagged a total of 102 cod. During occasion 2 – 4 we captured a total of 201 cod, of which two individuals were recaptures from the first tagging occasion. From this, we estimate the total popuation size of cod in Sørfjorden to 6934 individuals (SD = 3391). This does not include fish smaller than 25 cm, since these were not tagged in the first place. We note that our result should be interpreted with care due to the very small number of recaptures.

R script

```
#ESTIMATE POPULATION SIZE OF COD IN SØRFJORDEN RISØR BASED ON
CAPTURE-#RECAPTURE DATA 2005
#Total of four capture occasions: 20 May, 26 May, 6 June and 10 June
n1 <- 102
n2 <- 201
r <- 2
#n1 is the number of cod captured and tagged on occasion 1
#n2 sums up all captures during occasion 2-4
#r sums up all recaptures during occasion 2-4 (fish tagged on occasion 1)

#Population estimate
N <- ((n1+1)*(n2+1)/(r+1))-1

#SD of population estimate
var <- ((n1+1)*(n2+1)*(n1-r)*(n2-r))/(((r+1)^2)*(r+2))
SD <- sqrt(var)
```

Estimated total number in both Sørfjorden and Nordfjorden

The total number of cod (age 2-10 years) in both basins in the study area has been estimated in the following way:

Estimated number in Nordfjorden:
Based on area: ((6934/7819964)*15732236) = 13.950
Based on volume: ((6934/130590502)*798693797) = 42.409

Estimated total number of cod (2-10 years) in Sørfjorden and Nordfjorden combined:
Based on area: 6934 + 13.950 = 20.884
Based on volume: 6934 + 42.409 = 49.343

The model produces under the present condition the following number of cod:

1-10yrs	72361
2-10yrs	28639

Table 6.4b. Calculated Total productive volume and area for **1-10 group cod** in the Søndeledfjord system (Nordfjorden and Sørfjorden; From Tables 6.6 and 6.7).

Area	Area	Volume (m^3)	Area (m^2)
Nordfjorden	I	798.693.797	15.732.236
Sørfjorden	II	130.896.705	7.819.964
Total		929.590.502	23.552.200

5.2b Results of the Simulation Model Runs

5.2b.1 Edit final Scenarios

Please see the documents:
MODEL SSA 7-6-desciption.v 1.21.pdf
MODEL SSA 7-6-Running-Model.v 1.20.pdf

5.2b.2 Input data for Scenarios

The documents:
MODEL SSA 7-6-desciption.v 1.21.pdf
MODEL SSA 7-6-Running-Model.v 1.20.pdf

Contain an overview of all input data, and also instruction how to set new scenarous.

5.2b.3 Conduct and evaluate Scenario Runs

N/A

WT 5.3 OUTPUT PREPARATIONS

5.3a Complete Interpretive Analyses

5.3a.1 Describe and Interpret Scenario Results

N/A.

5.3a.2 Complete Collateral Analyses

N/A

5.3a.3 Draft Conclusions of Simulation Analysis

N/A

5.3b Generate Scientific Products

N/A

5.3b.1 Interactive versions of Simulation Model - N/A

5.3b.2 DST requirements and other visualizations – N/A

5.3b.3 Discussion with Output Step regarding SSA needs –N/A

5.3b.3 Maintain Contact with Participant Group –

The contact with the participation group continues. In addition a local high school is now included, as the students will make interviews with stakeholders and count seals and birds that predate on cod. Results from this cooperation will be included to improve input values in the model.