SALSEA-MERGE FP7-ENV-2007-1
Grant Agreement No 212529

Work Package 4

Deliverable - D 4.3

Final report on fish diet and stomach analyses

(Month 40)

D 4.3 - Final report on fish diet and stomach analyses

Introduction and material and methods

During the SALSEA-merge field campaigns in 2008 and 2009 a total of 1634 stomachs of salmon post-smolts, herring and mackerel were sampled on the dedicated SALSEA-merge cruises (http://www.nasco.int/sas/salseamerge_marine.htm) and analysed by the labs at the Institute of Marine research in Bergen, Norway, and Faroese Fisheries Laboratory, Faroes. Details of number of stomachs analysed per species and year are given in table 1 and 2. For comparison salmon stomachs from two contrasting years with known high growth, 2002 and 2003, were included in the analyses (Tables 1 and 2). Location of trawl stations for fish sampling are given in Figures 1-4. Further details of sampling at sea are given in the cruise reports (http://www.nasco.int/sas/salseamerge_marine.htm). Stomachs were frozen at sea and analysed for number and dry weight of food items in the lab. All stomachs sampled by Norwegian and Irish vessels were analysed in Norway. The Faroese stomachs were analysed in the Faroes. Unfortunately, in the stomachs analysed by the Faroes lab food items were counted but not weighed. Therefore, a ratio of weight to numbers were calculated based on the Norwegian and Irish stomachs and used to calculate dry weight of food items in the Faroese stomachs.

Table 1. Number of trawl stations with stomach samples per species and year.

SPECIES	2002	2003	2008	2009	Total
HERRING			20	30	50
MACKEREL			45	48	93
SALMON	28	35	67	71	201
Total	28	35	132	149	344

Table 2. Number of stomach samples per species and year.

SPECIES	2002	2003	2008	2009	Total
HERRING			95	109	204
MACKEREL			402	281	683
SALMON	355	314	351	396	1416
Total	355	314	848	786	2303

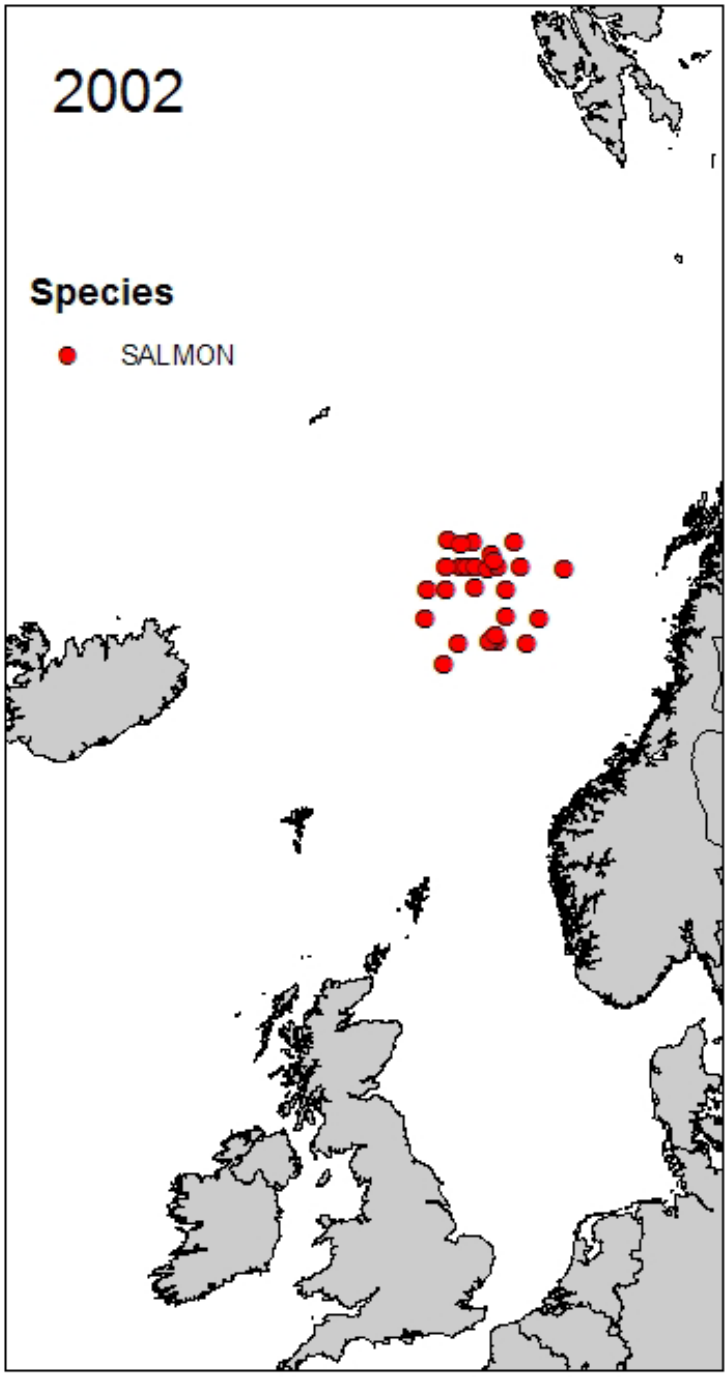

Figure 1. Location of trawl sampling stations in 2002.

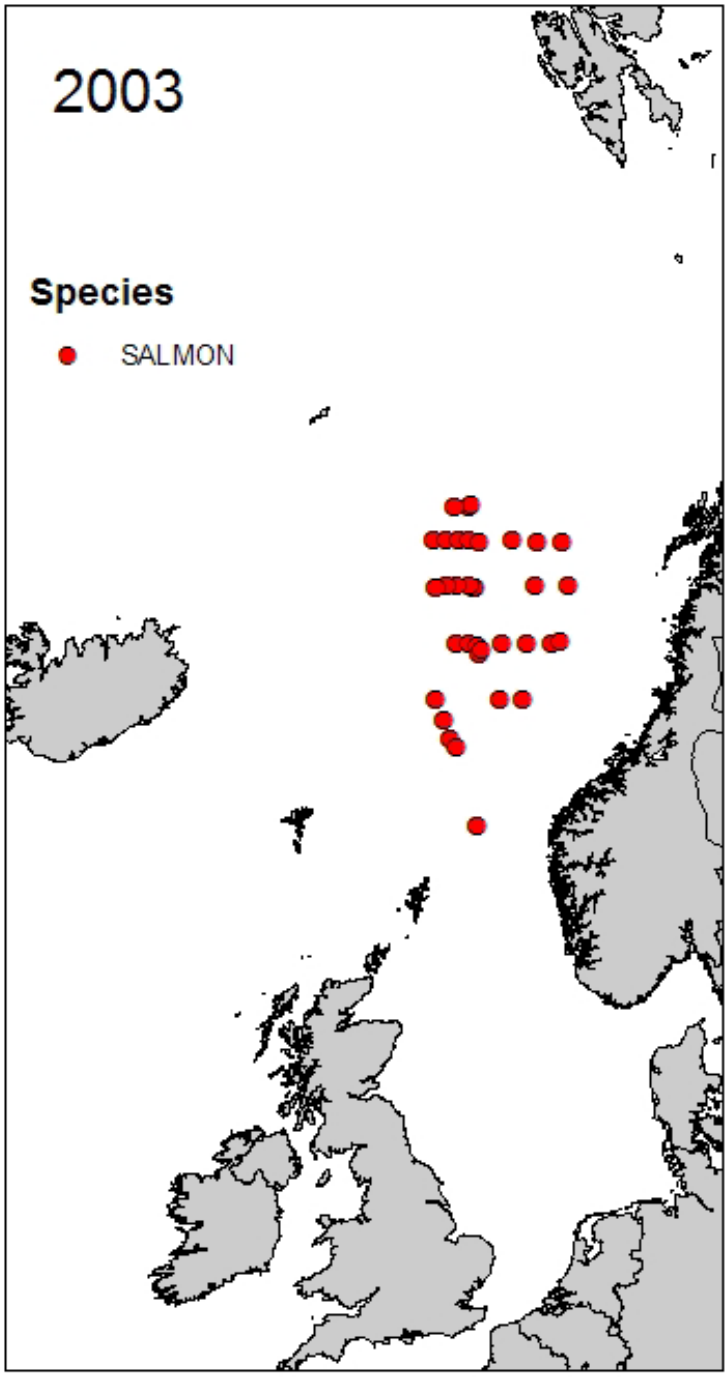

Figure 2. Location of trawl sampling stations in 2003.

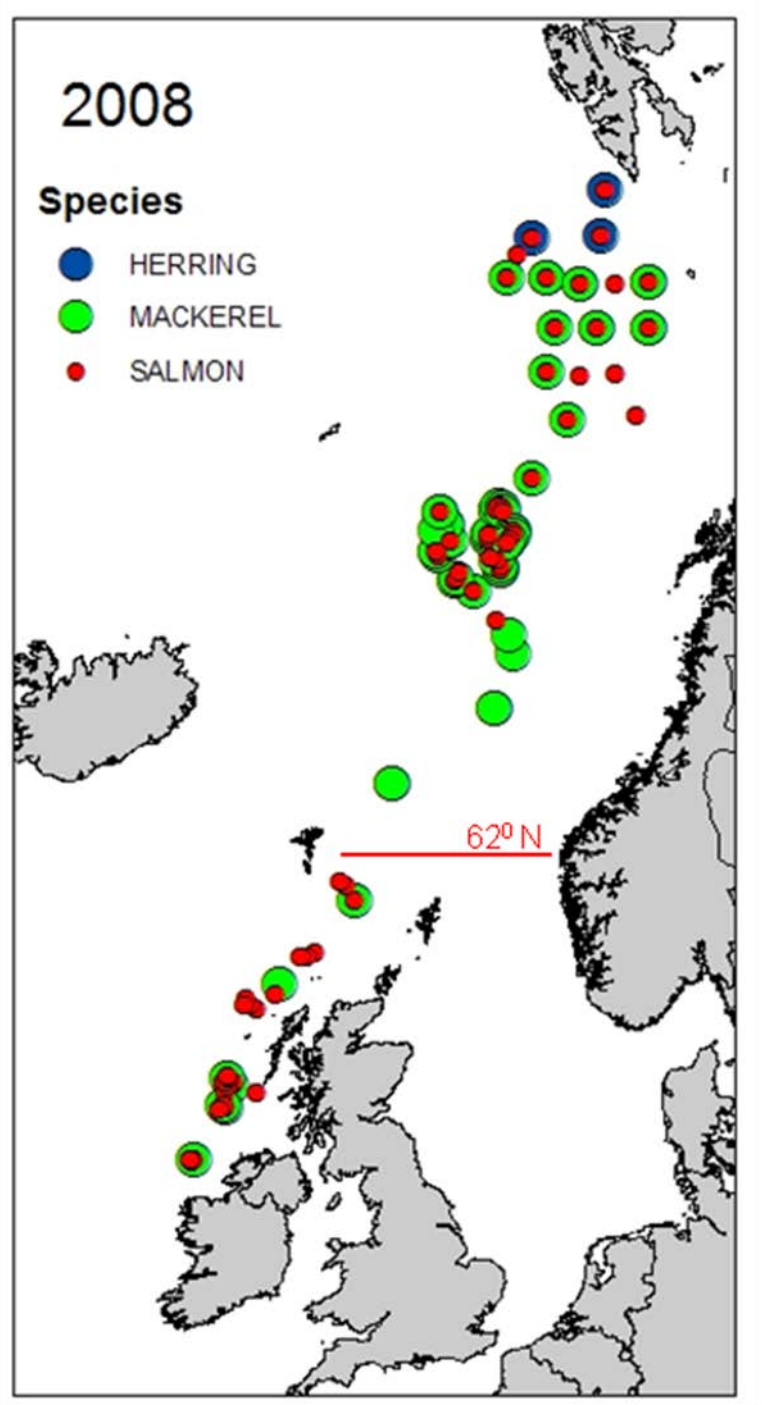

Figure 3. Location of trawl sampling stations in 2008.

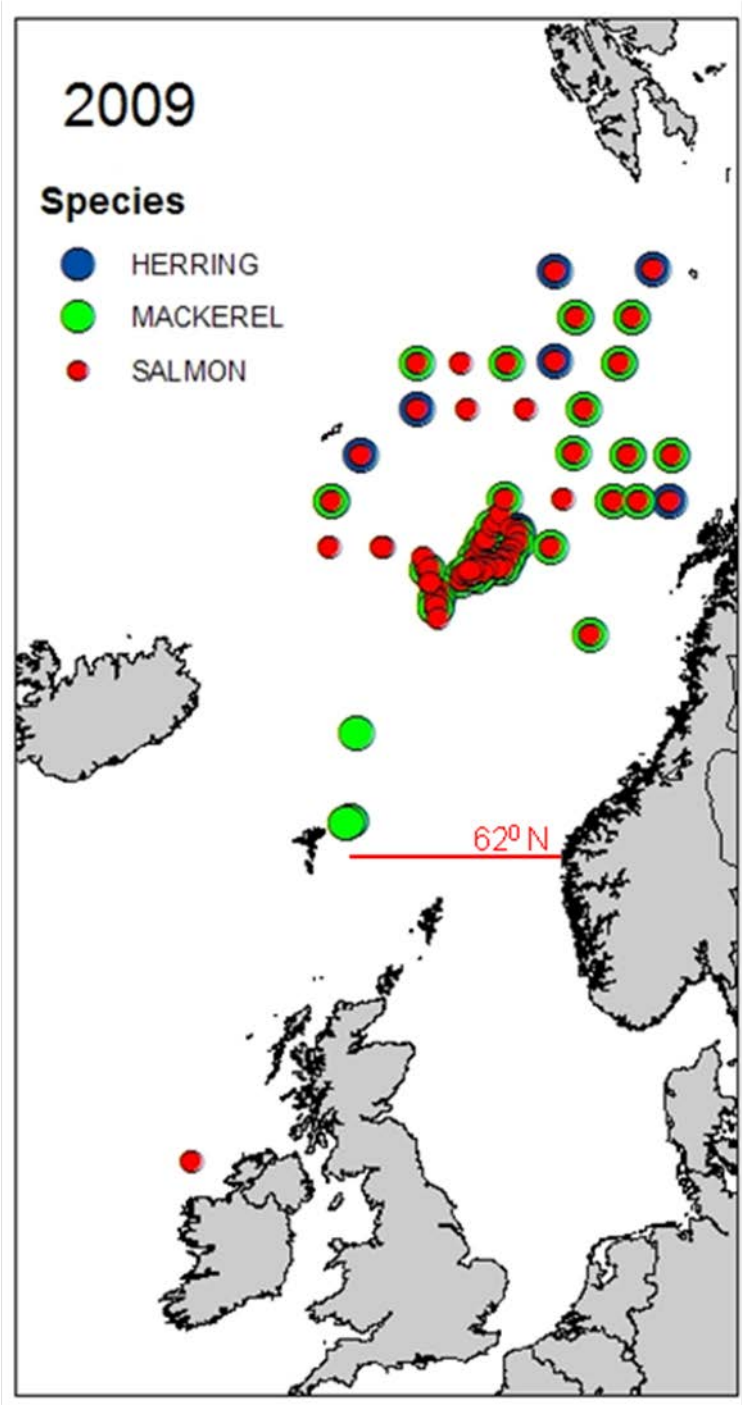

Figure 4. Location of trawl sampling stations in 2009.

The taxonomic composition of the diet of the three fish species was analysed based on the measure, **Percentage by mass**, $M\% = 100M_{ij}M_j^{-1}$, where M_{ij} is the mass of item i eaten by fish j, and M_j is the total mass of items eatenby fish j.

Feeding activity was analysed using **Forage ratio**, $FR = 100M_{Stotal}\ (M_F - M_{Stotal})^{-1}$, where M_{Stotal} is stomach content dry weight and M_F is body dry weight of the fish.

Before analyses the fish were grouped into regions north and south of 62°N, because the post-smolt sampled in the southern region west of Ireland and Scotland were sampled in May as opposed to July-August further north, and therefore were both younger and smaller.

Results

The diet of the fish was initially analysed by a few major taxonomic groups (Fig. 5). Even at this coarse scale we see differences among the three species. Salmon mainly feed on crustaceans and fishes, both groups comprising about 50% of the food. Herring feeds almost exclusively on crustaceans while mackerel in addition feeds on cephalopods and 3-4 other groups.

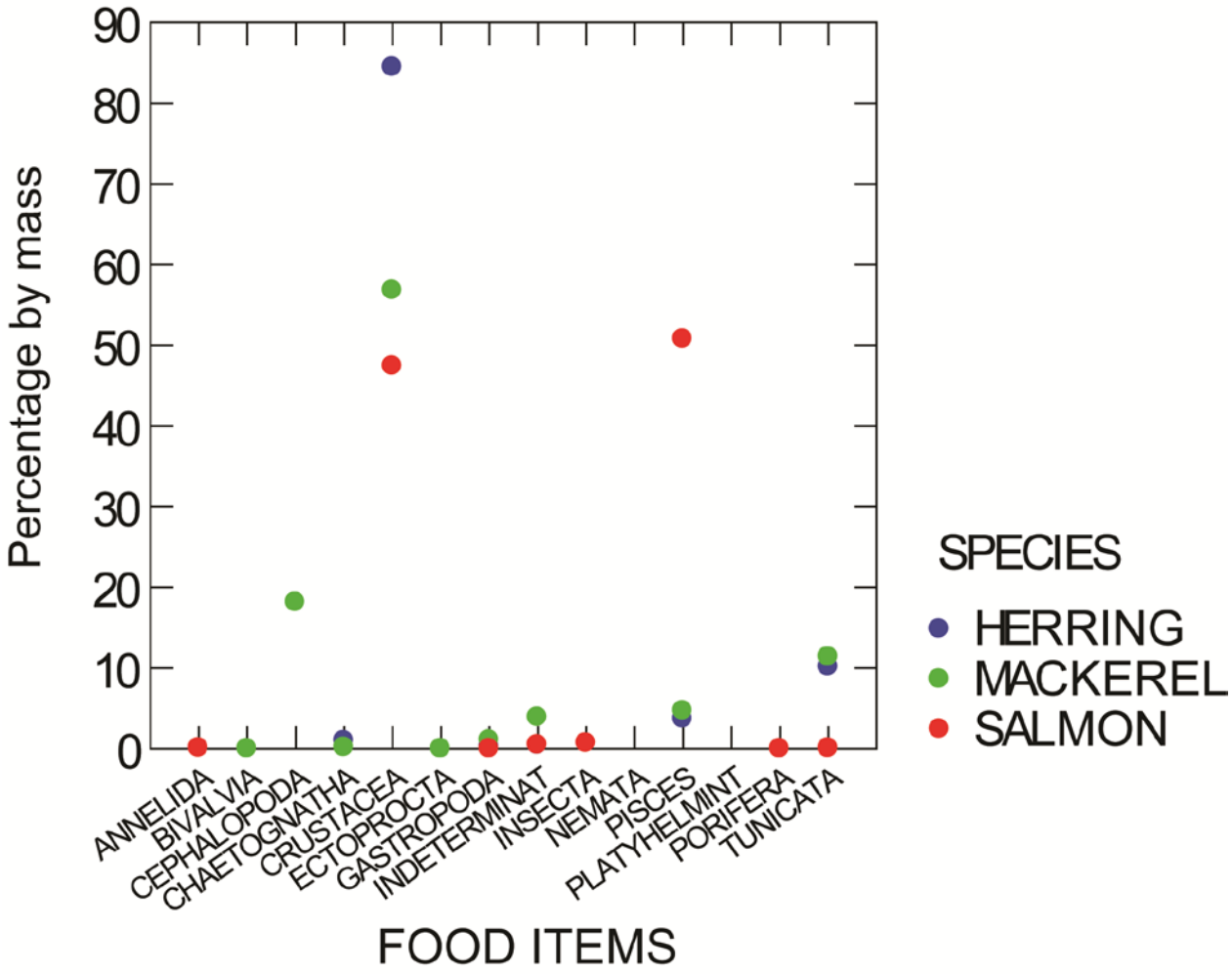

Figure 5. Diet of salmon, herring and mackerel by major taxonomic groups. Stomachs from all years and regions.

When the diets of the three species are broken down into lower taxonomic entities we see that there are clear differences in food preferences (Fig. 6). The main food item for herring and mackerel is *Calanus finmarchicus*. Amphipods and euphausiids are also important to both species while mackerels have a broader diet also eating a lot of gastropods, ascidians and some fish. The post-smolt are specialized on amphipod and fish, and their tendency of a very near surface feeding mode are demonstrated by the feeding on *Anomalocera pattersoni* (a blue surface dwelling copepod) and various insects.

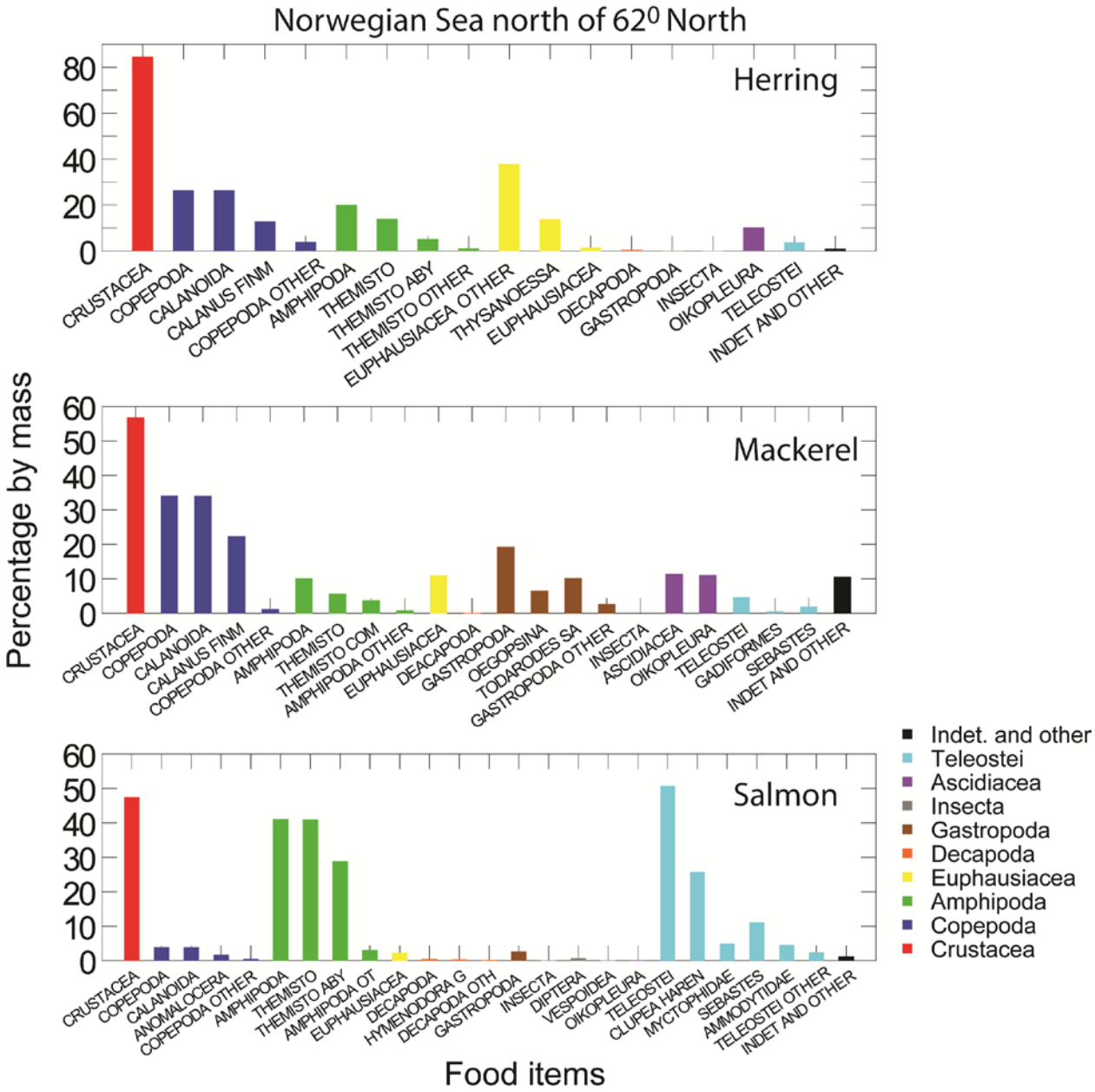

Figure 6. Detailed diet of salmon, herring and mackerel north of 62°N. All years.

When the diet of post-smolts are compared between years we see that although the main food items always are fish or amphipods, the relative importance of the two are differing and also the species of prey fishes are variable (Fig. 7). During 2002 and 2008 the post-smolt are mainly feeding on one species of fish and one or two species of Themisto. In 2002 herring larvae and the Atlantic amphipod, *Themisto abyssorum*, are the main food items, while in 2008 Sebastes larvae and the Arctic amphipod, *T. libellula*, dominate. In 2003 *Themisto abyssorum* is the dominant food item. In 2009, when large preys like fish and amphipods are not as dominant, the post-smolt seem to eat more small preys like copepods. This may be a less energetically efficient way of feeding.

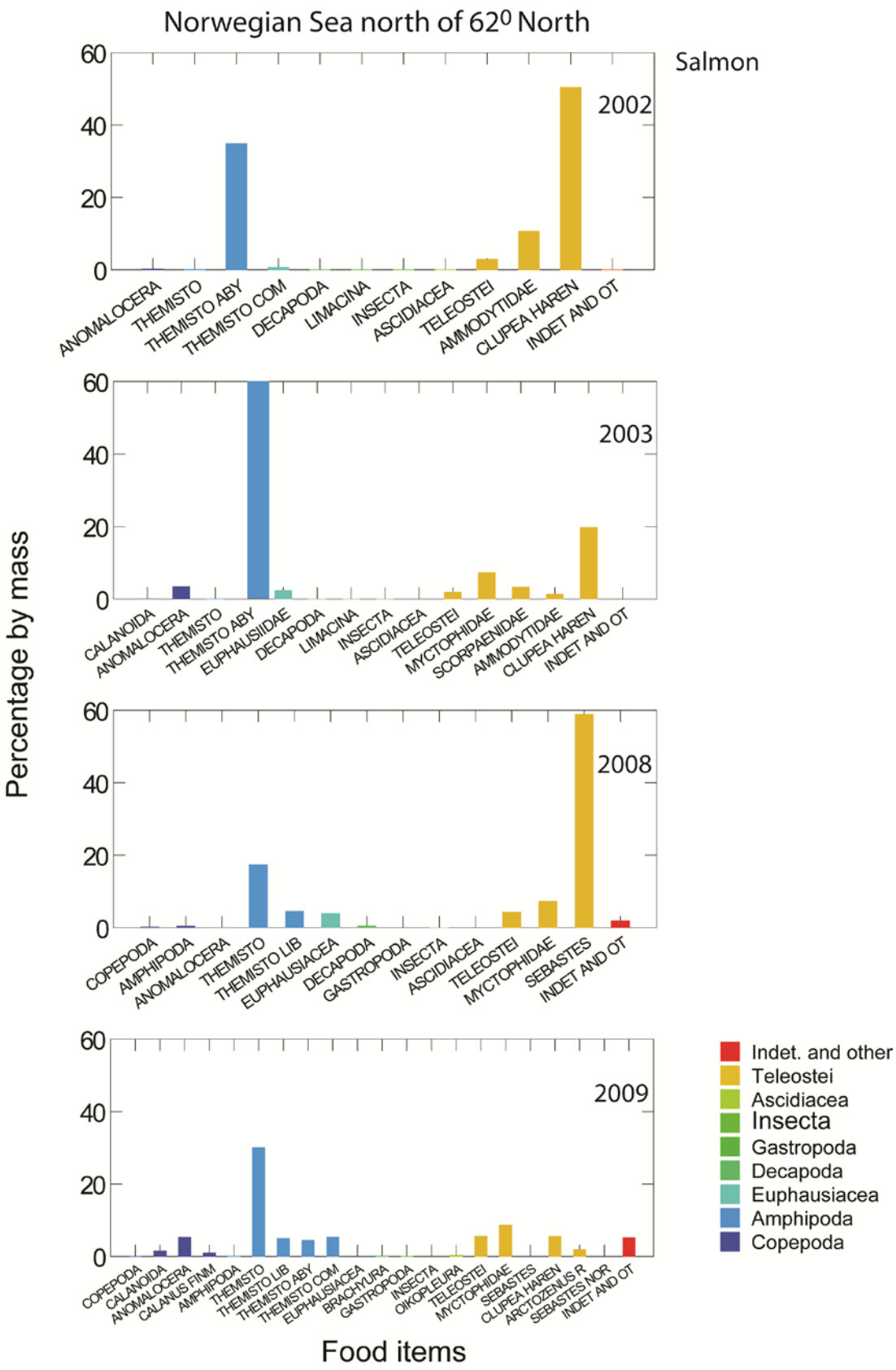

Figure 7. The diet of post-smolt salmon north of 62°N, during 2002, 2003, 2008 and 2009.

Figure 8 shows that the diet of herring and mackerel vary between years, as well. Both species seem to have a broader diet in 2009 compared to 2008.

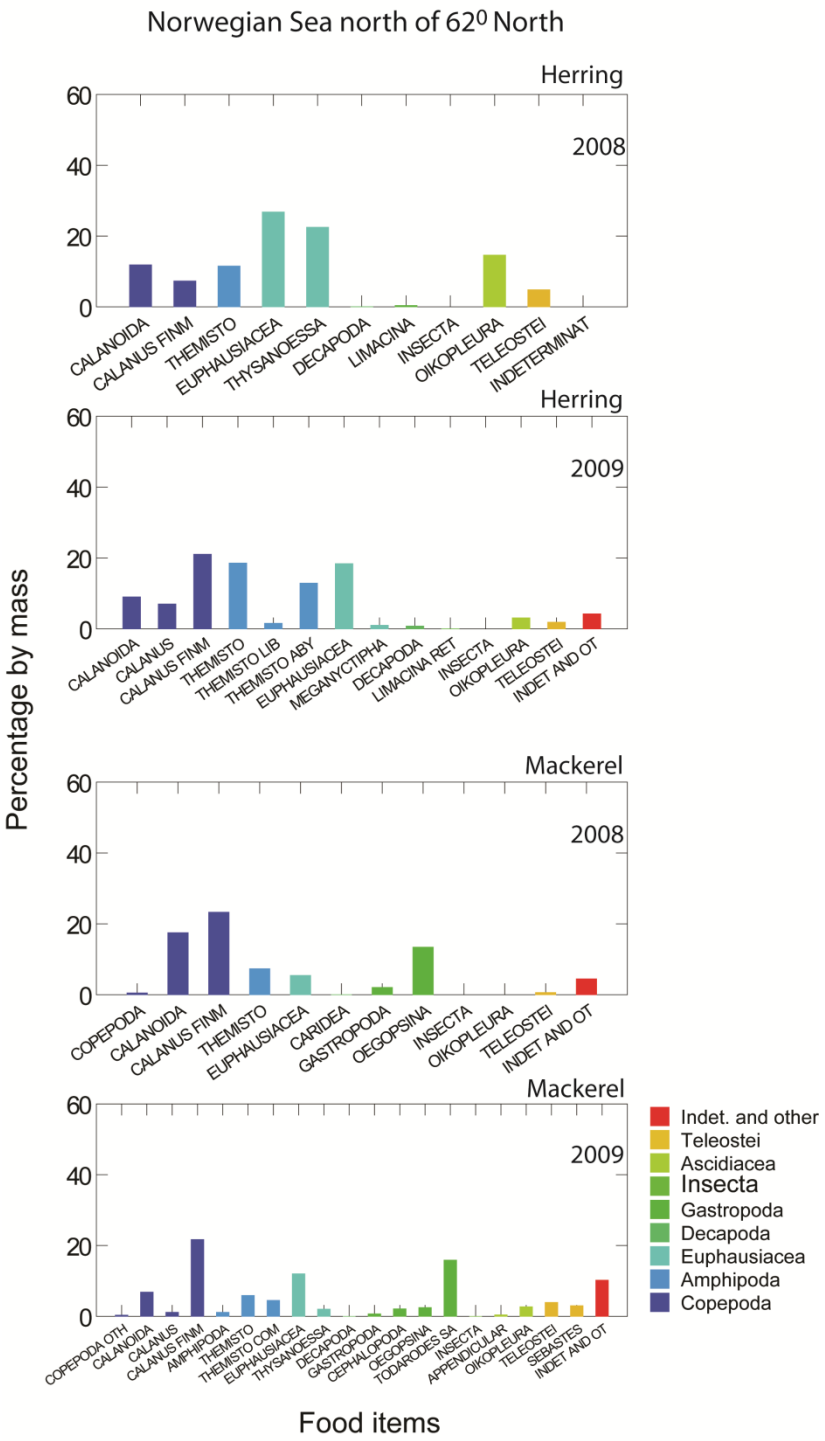

Figure 8. The diet of herring and mackerel north of 62°N in 2008 and 2009.

Diets of salmon and mackerel south of 62°N are shown in Figure 9. The diets are different from those north of 62°N for both species. For post-smolt this is probably partly related to their smaller size, but more important are probably the time of the year and the different planktonic community in the southern area.

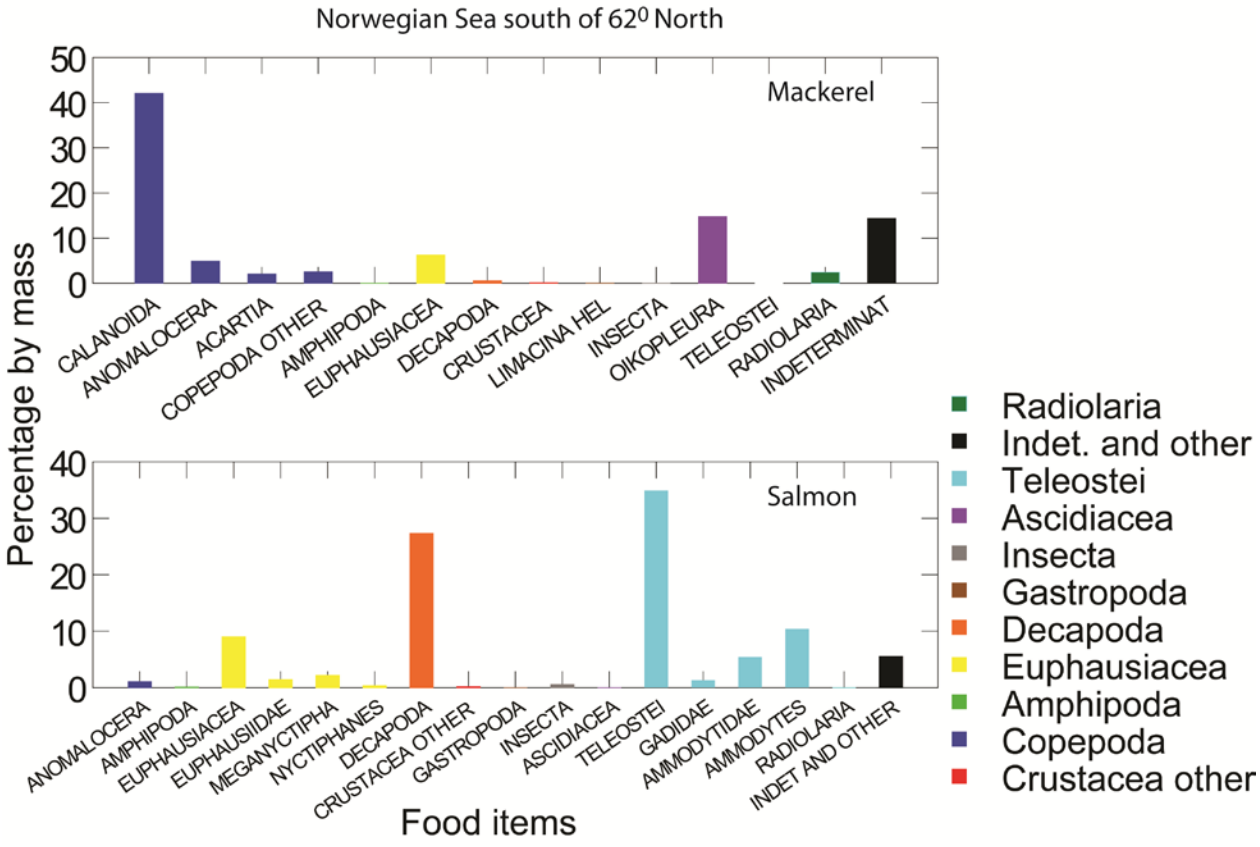

Figure 9. The diet of herring and mackerel south of 62°N.

The forage ratio of salmon of salmon was higher than the other two species all years north of 62°N, while the FR of mackerel was highest in the south (Fig. 11). FR of salmon was highest in 2002, somewhat lower in 2003 and lowest in 2008 and 2009 (probably no significant difference between the latter years). FR for herring was higher in 2008 compared to 2009, while the opposite was the case for mackerel.

All fish were assigned to their river or region of origin by genetic methods (see reports on genetic work). We were not able to see any trends or differences in diet among the genetic groups (Fig. 10). Neither in stomach content or in diet. Figure 10 shows that within the same year there are clear differences in whether the salmon are eating fish or Themisto, but we were not able to explain this by the genetic properties of the fish.

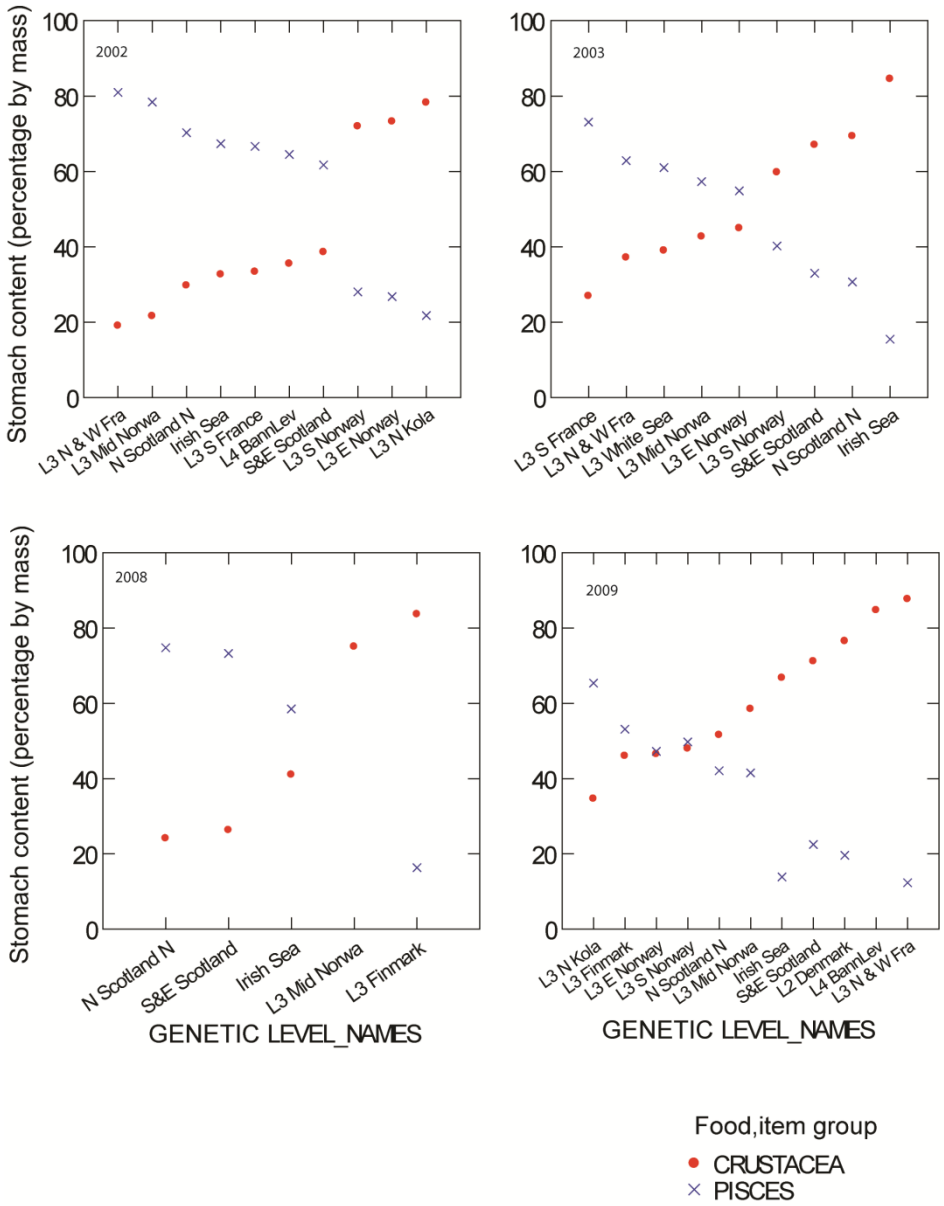

Figure 10. Stomach content, percentage by mass, of salmon during the years 2002, 2003, 2008 and 2009, by river or region of origin as assigned by genetics level 4.

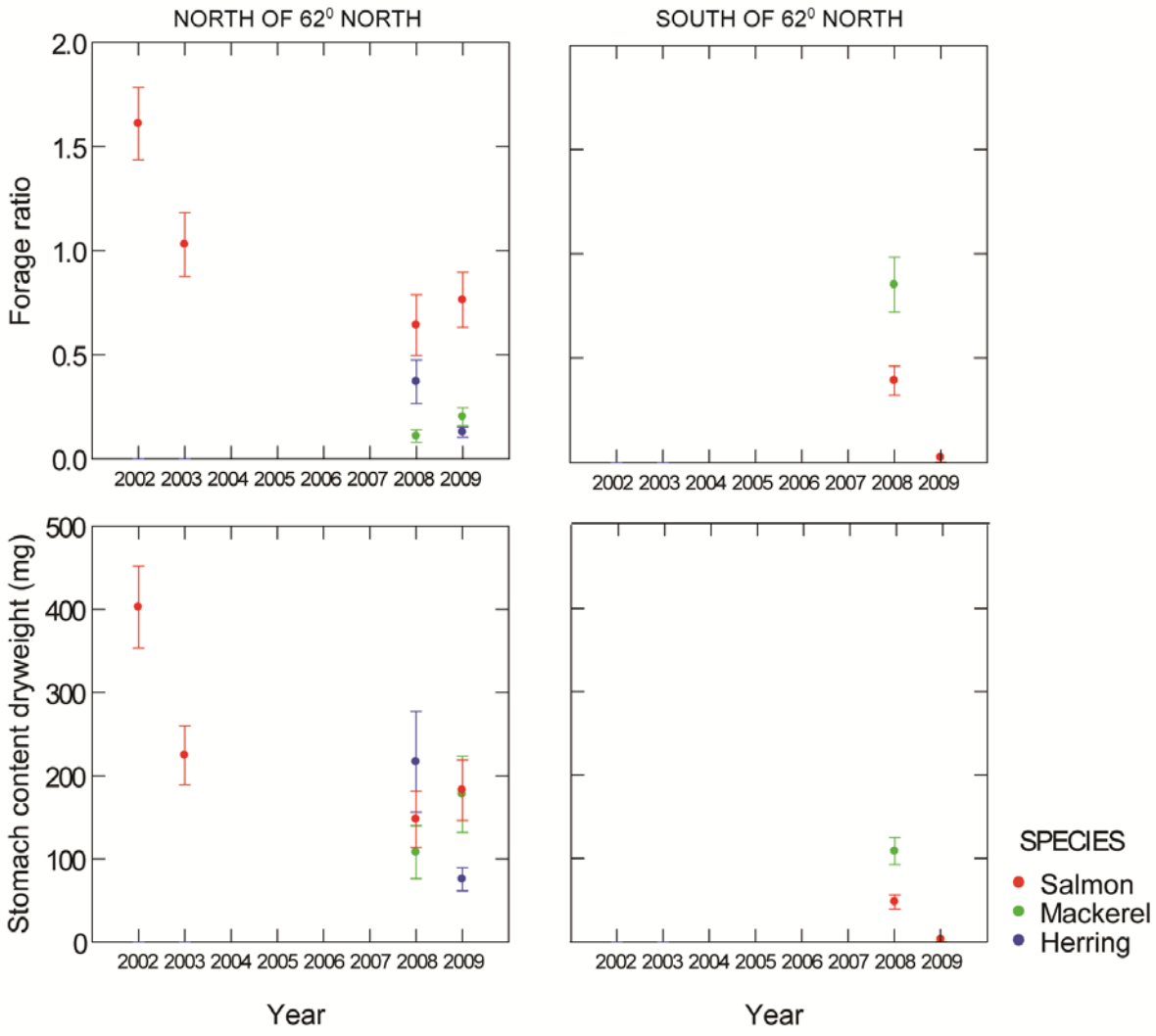

Figure 11. Forage ratio and stomach content of salmon, herring and mackerel in 2002, 2003, 2008 and 2009, north and south of 62°N.

Figure 12 shows the condition factor of herring, mackerel and post-smolt during the four years 2002-2009 and condition factor versus forage ratio. From 2002, to 2003 and 2008 there was a decreasing trend in condition of salmon. There are probably no significant difference between 2008 and 2009 for any of the three species. There seem to be a positive relationship between FR and condition in salmon. Probably no such relationship in mackerel and herring. For all species there may also be a general positive relationship between FR and condition. If one assumes that FR is an indication of the feeding conditions of the species a given year, it can be concluded that better feeding conditions have given better growth in body weight and thus higher condition.

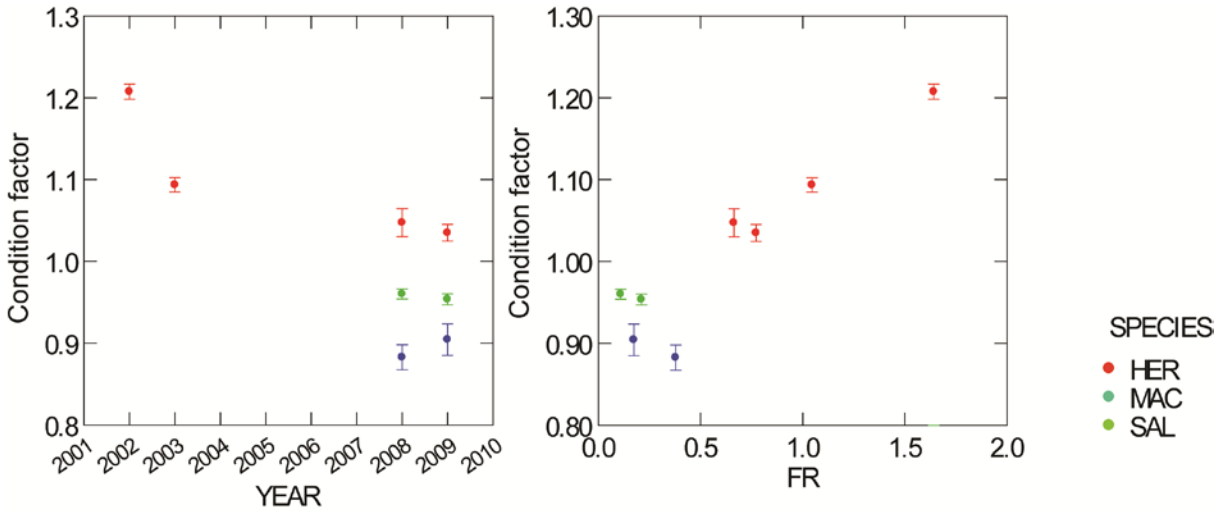

Figure 12. Condition factor of post-smolts vs. year and FR, north of 62°N. Average and standard error of the mean.

In 2002, when the post-smolt had the highest condition factor and the highest forage ratio they were feeding mostly on one species of fish (herring larvae) and one species of Themisto. It has been suggested that good growth and survival occur during years when the post-smolt can feed more or less exclusively on fish. Similarly, in 2003 the post-smolt were feeding on various fish species, only. On the other hand, in 2008 there was a similar concentration on fish larvae and one amphipod species. Therefore, data from more years are probably needed before a firm conclusion can be drawn.

Conclusions

- The main food of salmon are juvenile fish and Themisto spp.
- Salmon, herring and mackerel have overlapping diets, but there are also differences in diets within the same region.
- The diets of all three species differ among year.
- The diet of salmon, herring and mackerel in the southern region in May differ from the diets found further north.
- We could not explain the diet or feeding of salmon by their river or region of origin as assigned by genetics.
- Forage ratio and condition of the salmon was highest in 2002 and 2003. There were no clear differences in the two factors between 2008 and 2009 in salmon, herring and mackerel.
- There is a positive relationship between condition factor and forage ratio of the salmon during the years 2002-2009.
- It is still unclear whether salmon have higher forage ratio and condition during years when they are mostly feeding on fish.