Migrations of cetaceans and seals in the Northeast Atlantic in relation to hydrography

NORÐURLANDA HÚSIÐ Í FØROYUM

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ABSTRACTS

This collection of abstracts is from the third seminar on fisheries and hydrography in the Nordic House in Tórshavn, Faroe Islands. The first of these seminars was held in 1983 in connection with the inauguration of the house, the second in 1985 and this, the third seminar was during the period August 29th to September 2d in 1988.

The Nordic House in Tórshavn was built and is financed by the Nordic countries and the Faroese government. Its aim is to promote cultural exchange between the Faroes and other countries especially the Nordic ones.

The Faroese society is to a very large degree dependent upon the sea. The export is completely dominated by fish products and the sea enters into all aspects of daily life from transportation to folklore. It was in recognition of this dependency that the board of the Nordic House already in the planning stage for the house decided to put a relatively large part of its resources into promotion of the knowledge on the sea around the Faroe Islands and its interaction with the creatures living in it. Acknowledging that science is one of the major cultural activities of a society the Nordic House has by hosting these seminars aimed at contributing to a firmer foundation for this knowledge. This not only for its purely scientific aspects, but also in the recognition, that mans activities are influencing the sea and its creatures to an ever increasing degree and that knowledge is the most necessary prerequisite for evaluating mans use and abuse of the sea.

As a cultural institution the Nordic House has also seen a challenge in promoting scientific discussion across traditional boundaries and the seminars have brought together people not usually attending the same meetings to stimulate interchange of information and ideas between ocean physicists and ocean biologists. At the same time the meetings have centred on problems of actual or potential importance for the Faroese sea area. Thus the second of these seminars focused on the effect of physical changes in the ocean (of temperature, current etc.) on the migration and recruitment of fish stocks, especially those of economical interest to the Faroes.

The collection of abstracts presented here reflect a similar purpose. The third seminar did not concern fish, but rather another major group of sea animals, the sea mammals, with special emphasis on the cetaceans, notably the pilot whale, which through centuries has been one of the major food resources of the Faroes. Although the abstracts cover a wide range of subjects, both physical and biological, it will be seen that taken together the subjects have been chosen to a large extent to illuminate the theme defined in the title of the seminar: *How does the migration of sea mammals, especially the pilot whale, depend upon physical processes in the sea? and can ocean variability explain some of the changes seen in the whale catch in the Faroes?*

In the general discussion concluding the seminar the participants as a whole acknowledged the value of the results presented. On the hydrographic problem the results tend to confirm the overall flow patterns suggested early in this century, but at the same time they demonstrate very clearly the dominance of variability on all temporal and spatial scales. Results presented by various authors from experiments within the NANSEN project show that much new information has been accumulated, but the variability introduces so much noise into measurements that we still are some way distant from a complete understanding of the flow patterns in this region. It was felt, however, that the upcoming WOCE project might change this picture dramatically.

The knowledge on sea mammals, especially cetaceans has also increased dramatically with the cooperative effort spent on this problem in the last years. For the pilot whale, notably, we have today much better information on biology, feeding, distribution and stock size, and preliminary results of recent investigations suggest that more information will be available soon.

The coupling between hydrography, squid and pilot whale also received much attention and although the picture so far is rather hypothetical it was possible to construct a consistent scheme with the squid Todarodes sagittatus being advected more or less passively by the North Atlantic Current from a spawning area close to the mid-Atlantic Ridge towards the Faroe Islands and Norway. In Faroese waters the pilot whale seems to follow the squid to a considerable degree and it was suggested that changes in the whale catch could partly be due to changes in the North Atlantic Current. As yet the limited basic knowledge on the hydrography and the biology of the squid do not allow us more definite conclusions, but this was seen as a promising subject for further research.

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Water masses and circulation in the eastern north Atlantic

by

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A review of the extensive literature on the hydrography and circulation of the Eastern North Atlantic gives examples of the distribution of the main water masses, their origin, and their pathways to the Iceland Basin. It is shown that the upper layers in that region are dominated by the advection of the warmer, saline water of the North Atlantic Current brances. In intermediate depths the influence of Labrador Sea Water, Mediterranean Overflow Water, and Iceland-Scotland Overflow Water prevails. The latter deepens southwards from the Faroe Bank Channel to about 2500 m at the Charlie-Gibbs-Fracture Zone and it is typically found near 2750 m in the northern North Atlantic. A fraction of Antartic Bottom Water reaches as far as 60°N, and is involved in the forming of the bottom water of the Eastern North Atlantic. This overview is complimented by data and first results, gathered during intensive hydrographic surveys carried out in the Westeuropean and Iceland Basin between 1983 and 1988.

On the circulation around the Faroe Islands and the adjacent continental slope
- Experiments with a three-dimensional barotropic model -

by

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Model experiments carried out with a three-dimensional, nonlinear, barotropic and all open boundary model are presented. The regional model includes a realistic topography. In a number of case-studies it was used to investigate the following questions: - what is the local topographic response to winds of different directions in the absence of any other (far field) forcing ? - what is the response of the Faroe Islands plateau and the continental slope region if a global sea level gradient is prescribed, which accelerates the flow towards the north ? - what flow patterns emerge if the above forcing conditions are acting together ? This preliminary model study is based upon the argument that barotropic processes in a region with a highly structured and pronounced topographic signal may cause a fairly high amount of the observed spatial and temporal variability of the flow. Presently, these experiments are confined to nontransient barotropic dynamics; they make use of the advantage of dynamical models to study single processes either isolated or dynamically coupled. A detailed analysis of the recently carried out model simulations, which are charted in a technical report of the Institut fur Meereskunde Hamburg, has as yet not been carried out. However, even a short inspection of the results will reveal that some of the simulations reflect to a rather high degree the dynamical features of the region, which are known from observations.

Preliminary Results for the NANSEN project

by

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NANSEN is a project sponsored by The International Council for the Exploration of the Sea (ICES) to look at the exchange of water between the North Atlantic and the Norwegian Sea. Previous ICES surveys (Overflow 60 and 73) concentrated on the flow of deep, cold Norwegian Sea water and paid less attention to the warm shallow Atlantic water. NANSEN involves measurements by Icelandic, Faroese, Norwegian, Swedish, FRG and UK scientists and is likely to continue for the next 5 years. Recent results have shown that there is a significant inflow of Atlantic water passing north of the Faroes and also that the Atlantic inflow over the West Shetland Slope has a strong seasonal signal with the maximum inflow in winter. New techniques using ship-mounted Acoustic Doppler Current Profilers give the promise of better routine determinations of flow throughout the water column. Recent results from the ADCP will be presented.

Hydrographic conditions north and east of the Faeroe Islands 1986-87

by

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Problem: How strong is the influx from the Atlantic north of the Faroe Islands (if any), and what is the subsequent fate of the inflowing water? In order to try to solve this problem, programs of current measurement and hydrographic stations were carried out in June 1986 and July 1987. The current measurements along a line northwards from the Faroe Islands in 1986 made possible a direct calculation of the flow, and by means of measurement of temperature and salinity along the same line the geostrophic current could be compiled. In 1987 we occupied the same north-south section of temperature and salinity 4 times. Current measurements on this section were made on one selected station only. We hoped that this station might be representative of the section as a whole, but it is difficult to say if it is so. The transport values from the current measurements in 1986 agreed reasonably well with those calculated geostrophically. Also, the geostrophically computed transport from the 4 sections in 1987, were in good agreement both internally and with the 1986 values, considering the limitations of the accuracy of the geostrophic method. They all center around 4×10^6 m^3/s, which is also consistent with Hermann´s earlier results. The 1987 program also included a coverage of the area east of the Faroes with hydrography and current measurements. Although conditions were rather variable, it seemed that the old Helland-Hansen picture would generally apply, with a colder and less saline tongue to the south, indicating that the Atlantic flow would not take the direct path into the Norwegian Sea. The currents measured on the shelf break NE of the Faroes generally followed the bottom topography (tow. E); more variable currents were observed farther east.

Persistence and variability in the ocean between Scotland and Rockall

by

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The migrations of cetaceans and fish west of Europe must be greatly influenced by the variability of the oceanographic features of the area. Persistent features offer a more reliable aid to navigation or for the survival of year-classes than patterns which result from dominant component of large variations. For instance, although the Alantic Current through the Rockall Channel is of major importance to the climate and physical oceanography of the European seas because large volumes of water are in motion within it, great temporal variability is observed at fixed stations due to atmospheric, topographic and long-distance influences. By comparison, currents upon the shelf and over the slope zones appear to be steadier in direction although carrying much lesser volumes of water. Other features, such as boundaries between mixed and stratified water and the persistence of winter-formed water upon the outer shelves and banks may also provide sensory clues to location for cetaceans. With these aspects in mind, the general oceanographic features of the area to the west and northwest of Scotland will be examined.

Short term fluctuations of hydrographic conditions in the deeper parts of the Faroe Bank Channel

by

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The outflow of deep water through the Faroe Bank Channel into the North Atlantic is a permanent phenomenon.Various field investigations show, however, that the hydrographic conditions may exhibit considerable variations over short time scales (1 day-1 week). In 1983 a survey, supported by the Nordic Council, was carried out in this area in order to estimate the discharge of deep water. Several hydrographic cross sections were worked in the Faroe Bank Channel. Current measurements were also carried out. Large changes of the position, as well as the shape, of the isotherms were found. Also the thickness of the thermocline varied significantly. A brief follow-up of the field program mentioned above took place in 1986. This time hydrographic measurements were made at two stations at the most narrow section of the Faroe Bank Channel. The two stations were investigated alternatively during 24 hours, at approximately two hours interval. A current meter was furthermore deployed midway between the stations. In the talk the results from these two surveys will be presented, with emphasis on the fluctuations of the hydrographic conditions.

Some oceanographic features of the Southern Norwegian Sea

by

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The Norwegian Sea is part of the Arctic Mediterranean Sea which comprises the deep basins to the north of the Greenland-Scotland Ridge, including the Arctic Ocean. While the deep basins in the Arctic Mediterranean are connected through deep passages, they are isolated from the Atlantic by the Greenland-Scotland Ridge where the sill depth in the Faroe Shetland Channel and the Denmark Strait is approximately 850 m and 600 m respectively. This bottom topography is of decisive importance for the water masses in the whole area, and recirculation is probably a dominant process in the deeper layers. Even in the Southern Norwegian Sea the deep water is characterized by the connection with the Arctic Ocean. Three main water masses have traditionally been defined in the area; Atlantic water with $S > 35.00$, $T > 4°C$, Arctic water with $S < 34.90$, $T < 4°C$ and the homohaline Norwegian Sea Deep water with $S = 34.92$, $T <= 0°C$. The surface circulation in the southern Norwegian Sea is characterized by the Norwegian Atlantic Current and the East Icelandic Current. The Atlantic water mainly flows in through the Faroe Shetland Channel and to a considerable extent also to the north of the Faroes. The water to the north of the Faroes mainly follows the bathymetry, but east of the Faroe plateau it frequently forms eddies before it joins with the Atlantic water which has come through the Faroe Shetland Channel. Off the Norwegian coast the Atlantic water has a narrow east-west extent in the southern Norwegian Sea. The reason for this is the East Icelandic Current which brings Arctic water from the Iceland Sea toward the Faroes. This also includes Arctic intermediate water which has a much wider distribution than the surface current. It is now evident that the Arctic intermediate water is of greater importance than previously recognized. Although its characteristics may be subject to long-term fluctuations, at least two types may be defined. North Icelandic winter water, $S= 34.85 - 34.90$, $T= 2-4°C$, is formed on the shelf north of Iceland during winter. It spreads towards the Faroes along the northern side of the Faroe-Iceland Ridge. Another type of Arctic intermediate water $S= 34.87 - 34.90$, $T= -0.5°C$ to $+1°C$, comes from the central Iceland Sea. This water intrudes into the Norwegian Sea between the Atlantic water and the Deep water. It spreads over the entire basin and may be traced even along its eastern slopes. Traditionally it has been assumed that the Deep water in the Arctic Mediterranean Sea is formed in the central Greenland Sea and the slightly higher salinity of the deep water in the Norwegian Sea was associated with the Atlantic water above. The intermediate salinity minimum which is established by the Arctic intermediate water, indicates that this can not be the case, and there is now evidence that the deep water in the Norwegian Sea is a mixture of deep waters coming from the Greenland Sea and the Arctic Ocean.

Survey of meteorological parameters on the Faroes 1875-1986

by

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The investigation is based mainly on time series of daily measurements in Tórshavn in the period 1875-1986. Also data from other places have been used, among them Akraberg and Mykines. The meteorological parameters included are air, temperature, pressure, wind (direction and speed), and for some subperiods also precipitation, "sunny days", and sea surface temperature. Focus is set on long term and seasonal variations. Summary results are given for the period 1875-1960, while the period 1961-1986 is studied in more detail.

The flow of Atlantic water around the Faroes.

by

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Except for the northeasternmost part the upper layers of the sea area around the Faroes are dominated by water of Atlantic origin. This water derives from a branch of the North Atlantic Current which impinges on to the Rockall Plateau at its western edge. From the edge it flows towards the Faroe Bank region where a branch of it turns northwards just west of the Iceland Faroe Ridge and flows towards Iceland before turning east again to flow over the ridge. Thus the Atlantic water flowing over the ridge eastwards does not come from the Iceland Basin but rather from the northern edge of the Rockall Plateau, but large parts of it make a detour to the north instead of flowing directly over the ridge. Having passed the ridge the Atlantic water meets colder and fresher water from the East Icelandic Current and flows towards the southeast so that due north of the Faroes the Atlantic water forms a wedge shaped boundary current against the Faroe Plateau. At least part of this current deflects into a southwards flowing branch which follows the eastern slope of the Faroe Plateau into the Faroe Shetland Channel, although this flow varies on short timescales. It has been speculated that this branch should continue westwards south of the Faroes and recirculate around the Faroe Plateau, but except for the shallower regions the upper water in the western Faroe Shetland Channel and in the Faroe Bank Channel appears to have a western origin. The Atlantic water in the eastern Faroe Shetland Channel which has come from the north must therefore to a large extent turn east and join the eastflowing Atlantic flow through the Faroe Shetland Channel. Over the shallow parts of the Faroe Plateau (as over Faroe Bank) there is a partly closed anticyclonic circulation around the islands associated with a well-mixed hydrographic regime on the shelf. There are some indications of a seasonal variation in this flow with strongest residual currents in late summer. The eastflowing branch of the anticyclonic shelf gyre is situated north of the islands while the westflowing return branch is not only south of the islands, but between them also. Thus the water reaching the coast comes from the east, rather than from the west and recent investigations indicate that there is also a westgoing flow further east on the Faroe Plateau. The input of Atlantic water to the shelf gyre may therefore also occur mainly in the northeastern corner of the Plateau which might explain why squid almost invariably are first sighted close to land in this part of the islands.

A proposal of a connection between ocean current status and the distribution and abundance of the squid Todarodes sagittatus in the Northeast Atlantic.

by

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Based on one record of a juvenile finding and due to comparison with other close related squid species one could propose a possible spawning area for the squid Todarodes sagittatus. If true, spawning areas for this species must be in the same region as where the North Atlantic Current reach the European continent. It is therefore reasonable to believe that spawning success and larval survival might be influenced by the status of the ocean current system in the region. Available data on yearly variations in salinity of the North Atlantic Current are used as a parameter describing the changes in intensity of this current. Norwegian fishery statistic on yearly catches of the squid T. sagittatus are used for describing abundance in the Norwegian waters. Although this comparison might be speculative, there are indications on some correlation between current intensity and abundance of T. sagittatus in Norwegian waters. Particularly the mid seventies anomalies of the North Atlantic Current seem to have had severe effects on the abundance of T. sagittatus in Norwegian waters.

Distribution and abundance of squid as whale food

by

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Squids in the food of cetaceans live either in midwater or close to the bottom. The bottom living species and some of the midwater species are muscular, negatively buoyant and have high calorific values. Many other species, common in cetacean diet, live off the bottom in oceanic water, have ammonium concentrations in their tissues to make them neutrally buoyant and have much lower calorific values. Recognition of the different types of squid in the diet is invaluable in studies of distribution, abundance and biomass of squids and helps in studies of whale migration, diving habits and energy transfer. Lower beaks provide the best method of identifying squids in the diet but other useful information can also be obtained from flesh, eye lenses, statoliths and gladii. The number of cetacean species in each family including squids in their diet will be discussed. The relative importance of the various squid families will be reviewed and the inferences which may be drawn from these data concerning feeding habits of the whales will be summarised. Conclusions drawn from the most widely studied cetacean, the sperm whale, will be outlined. Squids in the diet of Globicephala are probably not as diverse as in sperm whale diet and some differences will be considered.

The squid Todarodes sagittatus in Faroese waters.

by

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The squid Todarodes sagittatus has been caught for many years in Faroese waters usually in fjords or very close to land by small boats. Catch statistics exist from 1973 and show very large variability in the yearly catches. Thus the catch was very small in the first years after 1973 until 1979. This is consistent with catches in Norway and Iceland and has been related to the mid-seventies anomaly affecting the water masses of the eastern North Atlantic. The catch is very seasonal, peaking usually in August and lasting only for about three months each year. The T.sagittatus always arrives first in the northeastern part of the islands and this region has the highest catches. On the southernmost island T.sagittatus is only caught in exceptional cases. Length distributions of the catch show that the August peak in the catch is composed of animals significantly shorter than caught previously in the year indicating that the peak is due to an influx of a new yearclass. Statolith investigations yield an age for these new animals of about 8 months. This is not inconsistent with the hypothesis of passive advection of newly spawned Todarodes sagittatus by the North Atlantic Current from the region of the Mid-Atlantic Ridge, which has been proposed as a spawning area with peak spawning in mid-winter. This current would advect the juvenile T.sagittatus over the Rockall Plateau which is consistent with the fact that T.sagittatus has frequently been sighted over the Rockall Plateau, but is very seldom found close to the British mainland. When the North Atlantic Current approaches the Faroes it turns northwards before crossing the Iceland Faroe Ridge and then approaches again the Faroe Plateau in a southeasterly direction hitting the Plateau in the northeastern corner and new hydrographic information indicates that there at least occasionally is a westgoing flow from this area going towards the coastal region where T.sagittatus is caught in largest quantities. The large variability in the catch could to some extent be due to variability of the flow in the region northeast of the Faroes, and recent hydrographic investigations support this hypothesis indicating that there is a large amount of eddying and mesoscale variability in this region. This might also to some extent explain the apparent negative correlation between catches of T.sagittatus in the Faroes and in Norway. Among the local population the occurrence of the pilot whale Globicephala melaena has for a long time been linked to influx of T.sagittatus: *The whale follows the squid*, and Hoydal has shown a positive correlation between yearly catches of squid and number of pilot whales landed each year. New data on catches of squid and pilot whale extend this correlation and in addition it is shown that the seasonal distribution of whale landings is different in years with squid than in years without it. Thus, although the number of whales caught every month generally peaks around August, the relative magnitude of the peak is much larger in years where squid is caught in large quantities.

Hydrography and differentiation of some toothed whale stocks in the Western North Pacific

by

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Strong warm Kuroshio Current and cold Oyashio Current meet in the western North Pacific, and form a distinct frontal zone bounded by parallel Kuroshio and Oyashio Fronts. The Kuroshio Current, its eastern extension and the counter current form a large warm water gyre in the subtropical and temperate waters (Subtropical Gyre). To the north of it there are several cold water gyres, i.e. Western Subarctic, Okhotsk Sea, Bering Sea and Alaskan Gyres. Distribution of toothed whales in the Western North Pacific shows three types of surface water temperature preference. Warm water species inhabit waters over 15°C, cold water species those below 19°C, and omnithermal species between 5° and 29°C. Overlap of the thermal ranges between the first two groups is of particular interest for some toothed whales as detailed below. Pantropical distribution of short-finned pilot whales suggests its origin in tropical waters, but they have expanded the range to the waters between the Kuroshio and Oyashio Fronts. This has been accomplished by developing a morphologically distinct local form in the frontal zone. Augmentation in body size and alteration of mating season have possibly contributed to improve survival of neonates born in winter and successful switch of major nutrition from milk to squid in summer when food is most abundant. However they are still unable to expand the range further to the north of the Oyashio Front. To the contrary cold water toothed whales of large (Bairds beaked whale) and small (Dalls porpoise) body size have expanded the range to the south of the Oyashio Front and developed a local stock in the coastal waters of the frontal zone, but they are yet unable to extend the range into the Subtropical Gyre. The latter species is known to have developed several stocks each breeding in the Alaskan Gyre, Bering Sea Gyre, Western Subarctic Gyre, Okhotsk Sea Gyre, and presumably in some other coastal waters. These suggest that limited amount of movement was usually possible for many toothed whale species across fronts or boundary between gyres and thus resulted in the formation of stocks, but the expansion across the strong frontal zone between the Kuroshio and Oyashio Currents was not possible for these species. An apparent violation to this hypothesis will be the sperm whale distribution. This species has at least three breeding populations in the North Pacific each in the Subtropical Gyre, Alaskan Gyre and the Western Subarctic Gyre, although adult males of these populations may segregate seasonally outside the corresponding gyres. There is a hypothesis to assume that the species has expanded the range from one gyre to another in the above order, thus avoided the expansion across the Kuroshio/Oyashio frontal zone. In the Japanese waters the finless porpoise is a typical omnithermal species living in the coastal waters under the influence of the Kuroshio Current. Such wide thermal tolerance was probably acquired as the adaptation to the sedentary life in the seasonally variable coastal environment. Individuals in the Japanese population are larger than those in southern warmer environment, suggesting similar selection as assumed for short-finned pilot whales. Although killer whales appear to be an offshore omnithermal species, no data are currently available to indicate local stocks in the western North Pacific.

Abundance and migration of whales in Norwegian waters

by

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About 20 species of whales have been recorded in Norwegian waters. Some (Blue Whale, Greenland and Black Right Whales) were heavily depleted by former exploitation and have not shown any signs of recovery, with the exception of the Blue Whale. Although a classification scheme will be somewhat arbitrary, some species have only been observed occasionally (Sei Whale, Narwhal, Sowerby's Beaked Whale, Common Dolphin Bottlenose Dolphin), while others are rather abundant (Minke Whale, Fin Whale, Sperm Whale, White-Beaked Dolphin, Killer Whale, Common(Harbour) Porpoise, Humpback Whale, White Whale, Bottlenose Whale, White-Sided Dolphin, Pilot Whale). So far our knowledge of abundance and migration of whales in the Northeast Atlantic has relied on catch statistics, incidental sightings, tagging experiments (with Discovery tags) and in recent years sightings surveys. The data presented here are mostly from the sightings surveys conducted in 1987 and 1988. The northern part of the Norwegian Sea, the continental shelf west of Svalbard and the western Barents Sea, including the coastline from Kola to Lofoten were covered both years, but in 1987 the Greenland and Barents Seas west and north to the ice edge were also included. The larger whales in Norwegian waters (with the exception of the Greenland Right Whale) are summer guests with a northwards feeding migration in summer and a southwards migration to winter grounds in autumn. Minke whales are the most abundant of the rorqual whales, sighted all over the Norwegian Sea south of the ridge between Jan Mayen and Svalbard, at the continental shelf west of Svalbard, in the western Barents Sea and on the banks along the Finmark and Kola coasts. From the 1987 survey an uncorrected estimate was calculated of about 15,000 Minke whales in these areas. Catch statistics indicate that occasionally Minke whales may be abundant also in the northeastern Barents Sea area and along the coasts of Novaya Zemlya. They are thought to migrate into the Barents Sea northwards along the Norwegian coast as inferred from recaptures of Discovery tags and segregational behaviour as revealed by catch statistics, but they may as well enter the Barents Sea area from the west as seen by their presence in the Norwegian Sea between Jan Mayen and Norway. Fin whales seem to be especially abundant in the Jan Mayen area, but also in the Norwegian Sea and west of Svalbard. Sperm whales are especially abundant at the edge of the continental shelf west of the Lofoten-Troms area in northern Norway. Killer whales are seen along the Norwegian coast all year around, at times concentrating in the Møre and Lofoten areas, but otherwise observed in the western Barents Sea and the Norwegian Sea. The abundance of small toothed whales of the family Delphinidae, in Norway collectively known as "springere" but in most cases referring to White-beaked Dolphins, are relatively unknown but they have been recorded from the greater part of the Barents Sea with concentrations along edges and coastal banks. The common (Harbour) Porpoise is abundant along the Norwegian coasts but is also observed in the Barents Sea.

Seasonal changes in body fat condition in pilot whales

by

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Pilot whales taken in the Faroese drive fishery between July 1986 and October 1987 were routinely examined for carcase composition to estimate the importance of the dynamics of body fat in ecological energetics. Body weights, whole and a few piecemeal, were obtained for foetuses through to adult bull size for more than 630 whales of both sexes and all ages, throughout the 18-month period. In addition, length, girths and blubber thickness measurements were collected. Body tissues (blubber, muscle, visceral organs and fats) were sampled and analysed for biochemical composition. The main pattern emerging was an increase in body fat content during the winter months from November onwards. This was observed as an increase in wet weight lipid content from ca 1% to >25% in tail muscle, 50->70% in visceral fat, and actual weight increases in fat depots around visceral organs such as intestinal mesenteries and kidneys which comprised >40% organ weight during January. This fat build up was observed in all reproductive classes of whales regardless of sex. The lipid content of blubber remained stable year-round at ca 78-85% wet weight. Morphometric data indicated that blubber thickness expanded in the winter, thus increasing the overall body fat reserves. The relationship between body weight (W in kg) and length (L in cm) could be described by the formula $W=0.00005xL^{2.706}$ for foetuses >30 cm length, and by $W=0.00026xL^{2.484}$ for males and $W=0.00020xL^{2.521}$ for females. For both sexes, incorporation of a mid-girth measurement increased the logarithmic weight/length correlation r^2 value from 0.951 to 0.964 in males and from 0.927 to 0.936 in females. Using three girth measurements, posterior to flipper insertion, anterior and posterior to the dorsal fin, the logarithmic weight/length/girth correlation was further increased, although the correlation was less close in females, indicating greater variability caused perhaps by body changes due to the reproductive condition of the whale. Muscle constituted about 25% body weight, more in adults and most in bulls, and blubber about 23% body weight. During winter, the fat increase within the muscle comprises about 6.25% body weight, around the viscera, about 1.5% body weight, and the blubber weight increases constitute about 5% body weight. Overall this represents about 10% body weight of lipid. Such an energy reserve (about 100 kg or $9.45x10^5$ kcal in a fully adult female) is significant, and because of virtual depletion by May, must be assumed to be associated with seasonal changes in prey availability.

Factors influencing the metal contamination in pilot whales

by

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The ecotoxicology of trace-elements takes place in the comprehensive investigations about the biology of the Longfinned Pilot Whales (Globicephala melaena) caught in the drive fishery of the Faroe Islands. As, Cd, Cu, Hg, Se and Zn have been analyzed in individuals from five grinds covering different seasons over a one year period : September 1986, December 1986, April 1987, July 1987, October 1987. The liver in which bioaccumulation is important, has been analyzed for every pod, muscle and kidney have been analysed in one pod. In each pod, the influence of different factors on the bioaccumulation of trace elements, such as body lengths, sex, reproductive status of females has been studied. Cd and Hg concentrations are always significantly correlated to the body lengths of the whales. This is a very general observation in marine mammals which occupy the highest levels of marine food chains and are long-lived species. Both these factors are responsible of the cumulative characteristic of Hg and Cd. The mean Cd, Hg and Se concentrations seem to be higher in mature females than in mature males. But since the elements are cumulative, it will be necessary to know the ages of the whales to confirm this hypothesis. Differences in ecotoxicological parameters are observed between females. The reproductive status and/or the stage of lactation or pregnancy will be examined since they could influence the metabolism of the trace elements. The analysis of foetuses and milk give more informations about this aspect. The levels of Hg and Cd in individuals from different grinds are examined in order to reveal the potential existence of sub-populations. But so many factors can influence the bioaccumulation (ages, reproductive status) that the structure of the pod must be considered in interpreting the data.

Molecular approaches to the study of pilot whale populations

by

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Recent developments in molecular biology have opened up new pathways for gaining insight into the population structure and breeding systems of natural populations. In particular, the technique of DNA fingerprinting has caught the limelight. In humans it has already been used for individual identity in murder trials and to confirm paternity in immigration test-cases. Samples from the Faroese pilot whale catch have been analysed using DNA fingerprinting and other genetic techniques. In comparison with other organism and even other whales, pilot whales show very little variability. However, paternity assessment was nonetheless possible, albeit with lowered confidence when compared with human studies. In the preliminary analysis 4 pods of whales were examined. An average rate of intra-pod mating was determined of 19% (n=31 mother-foetus pairs) with 55% of matings being by males not in the pod when it was killed. The remaining 27% of assessments were unclear. In cases where more than 1 paternity assignment was made within one pod more than one male was responsible. Interestingly 2 unassigned paternities have rare features strongly indicating that the same male was the father for both. These foetuses both were nearterm, suggesting a "visit" or death from an unknown male. Comparisons were also made between individuals from different pods using several molecular techniques and it is shown that, as expected, individuals within pods are more similar than between pods.

Reproduction and foetal growth in the pilot whale Globicephala melaena around the Faroe Islands

by

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Complete pods of whales were sampled in all months of the year in the Faroese drive fishery. Age at first ovulation in the female is estimated at 9-10 years and corpora are accumulated at an average rate of about one every 2.9 years thereafter. The maximum number of corpora found in any pair of ovaries was 14, suggesting that at least some females may be reproductively active at 50 years of age. Many older females appeared to have ceased ovarian activity. Annual reproductive output was estimated at 10-11% using a novel technique which overcomes temporal sampling bias within the study period, but would be sensitive to any synchronized cycle in pregnancy rate within the population over a period of many years. The average inter-birth interval is 3.5 years or 42 months, but it is likely that most females adhere to a reproductive cycle of either 3 or 4 complete years. Conceptions and births are broadly seasonal but may take place in almost any month of the year. Assuming a gestation period of 14.5 months, conceptions peak between April and mid-July while births occur most often between mid-July and mid-October. Calves are born at 1.75-1.80 m on average and a weight of about 70-80 kg.

Diet of the Pilot Whale, Globicephala melaena, around the Faroe Islands.

by

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The diet of the Pilot Whale was studied from the Faroese whale drive fishery. Pods of whales were sampled in all months of the year, from July 1986 to December 1987. The stomach contents of around 20% of the whales within target pods were examined both qualitatively and quantitatively. This gave a total of 720 stomachs of which 77% contained food remains. The list of items identified included 9 genera of cephalopods, 14 genera of fish, plus shrimps and miscellaneous other items. These prey were of different ecological or behavioral types, but all of them were fairly common species in the locality of the catch. The Pilot Whale is mainly a squid eater around the Faroes with Todarodes sagittatus and Gonatus sp. as the main prey. Pilot Whale diets varied according to the length of the animal, the season and the year. When T. sagittatus was available, the diet was nearly exclusively of this prey, despite the availability of the other usual prey. If not available, the diet was supplemented with a large range of items including fish, suggesting an opportunistic foraging behaviour. This feature appeared clearly from the comparison of the diet in the summers 1984, 1986 and 1987.

Effects of man-made noise on marine mammals

by

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Marine mammals use sound for orientation and communication. The use of sonar is known from dolphins, and the social structure of groups of marine mammals is believed to be mediated by sound. The range of their acoustic systems is limited by the sound transmission properties of the sea, and by the background noise. The latter has increased by one order of magnitude with the introduction of propeller driven crafts, the figure being an average over time and area of the oceans. The increase is mainly at frequencies below 200Hz. Is this change in the environment likely to have impacts on the conditions for marine mammal life? A general answer to this question is not possible. Marine mammals form a diverse assemblage of species with different demands to the acoustic environment. Also, noise exerts its effects in different ways: as a signal, as a masker, and, if excessive, as a cause of hearing loss. To be answered, the question therefore should be restricted to the level of the species, and some information about its behaviour and acoustic habitat should be known. The bulk of the specific answers are those addressing the acoustical part such as the properties of the noise, its propagation, and its masking potential. When it comes to the biological side of the question, answers are mainly anecdotal, if at all available. This reflects the lack of adequate techniques for observing the behaviour of marine mammals when submerged and the consequent lack of known standards of normal behaviour and of information about priorities and options of the marine mammals. Some of the answers from the acousticians are surprising. Underwater sound can be channelled and may travel with vanishingly small losses, making across-the-ocean propagation possible. In the Arctic, channelling occurs in the surface layers, and a ship may be audible at ranges in the order of 100 miles. For a species like the Narwhal, which reportedly is shying human activities, the signal effect of the noise from shipping could conceivably cause stress, analogous to that seen in terrestrial mammals such as moose exposed to the "harmless", but repeated disturbances by crosscountry runners. Other species, e.g. the Common Dolphin, are often attracted by ships and observed riding the bow wave. The masking effect of ship noise is differentially affecting the various species of marine mammals. The biosonar known from smaller odontocetes operates at ultrasonic frequencies and is not likely to be impeded by ship noise. The vocalisations of pinnipeds are at intermediate frequencies, and are affected to some extent. The calls of baleen whales share frequencies with the ship noise; the range of such calls can be significantly reduced. A procedure to predict a range reduction factor for marine mammal calls exposed to ship noise will be presented, using Baffin Bay conditions as an example.

Is school identification of long-finned pilot whale (Globicephala melas Traill) possible with morphological characters ?

by

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From July 1986 to July 1988 all landed schools of pilot whales G. melas were examined by an international team to study as many aspects of the biology as possible. In total, 43 schools containing 3,613 pilot whales have been examined. Measurements of dorsal fins, flippers and flukes were taken from 29 different schools and from every month in order to study the possibilities of using these in offshore school identification. The colour patterns of 2 whole schools were noted in order to clarify how the white to gray dorsal spots were distributed within the schools, and in case there was also any possibility for using this for school identification. Two distinct colour patterns were found: a postdorsal fin saddle and a postorbital eye blaze. The occurrence of the eye blaze pattern was significantly more frequent in males than in females and not related to body length. The saddle pattern only occurred beyond a certain body length and had the same frequency in males and females. The dorsal fin length and height were proportional to body length, and this material showed no signs of sexual dimorphism. The ratio of flipper length to body length showed a longer range than has been previously found, with an overlap to the range of G. macrorhynchus, even with only a few whales. Sexual dimorphism was shown for both flipper and fluke, in the sense that males had longer flippers and longer and wider flukes than females of the same body length. Both immature males and immature females had significantly smaller flipper length in proportion to body length than mature animals of both sexes. It was concluded that school identification was not possible using either the colour patterns or morphological characteristics of flippers or flukes, at least for pilot whales at sea. But for the length of the dorsal fins, there was a highly significant difference visible both between the different schools and according to the season but a significant, positive correlation between the seasonal change in fat condition, and both dorsal fin length, and fluke span and length invalidate these interschool differences.

Abundance and migration of cetaceans in Icelandic and adjacent waters

by

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This paper reviews information on distribution, abundance and movements of cetaceans in Icelandic and adjacent waters. Results of vessel sightings surveys conducted during June-August 1987 onboard three Icelandic and one Faroese sightings vessel allocated to the joint 1987 North Atlantic Sightings Survey (NASS-87) are presented and discussed along with results from concurrent aerial survey in coastal Icelandic waters. The study covered the area between East Greenland and Iceland, around Iceland, Jan Mayen, the Faroes, southern Norwegian Sea, and deep and shallow waters west of the British Isles and Ireland. Much new information on summer distribution and abundance of cetaceans in this vast ocean area was obtained. The species encountered were blue, fin, sei, humpback, minke, sperm, pilot, killer, Northern bottlenose and North Sea beaked whales, in addition to a number of small odontocetes and a single Biscayan right whale (first record in the area in the past 16 years) that was sighted in the Irminger Sea deep west of Iceland. Of large whales, fin whale was by far the most abundant species (265 primary sightings of 430 animals), occurring in particular high numbers off west and northeast Iceland, and at East Greenland. Based on the shipboard and aerial surveys the first estimate of abundance for the entire stock range of East Greenland/Iceland fin whales (6,436) and the Central North Atlantic stock of minke whales (19,484) are given and discussed, while provisional estimates of blue, humpback, sei, sperm, Northern bottlenose, pilot and killer whales are also given for the area surveyed. The scanty information on winter distribution of almost all cetaceans in these waters is discussed. Large whale species seem to undertake the typical north-south migrations as in other oceans, although evidence of this is very limited and mainly supported by absence of observations in the high latitudes in winter and a few records of north-south long range movements of humpbacks and a single sperm whale. Seasonal movements and segregation in the East Greenland/Iceland stock of fin whales is discussed with respect to mark returns in the Icelandic fishery, historical catch records and a radio-tagged fin whale that crossed the Irminger Sea from the coast of Iceland to the East Greenland coast in a period of 10 days.

Whales and climate

by

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In an earlier submission to IWC the second author explored the properties of the time series of catch data for pilot whales in the Faroes, covering the years 1709-1984. The univariate time series was fitted to an ARIMA model. This model explained 32% of the variation in the data and it was evident that some additional explanatory variables had to be found to explain a larger part of the variation. Two data series have been added as additional explanatory variables. One is the catch series of bottlenose whales given by Muller (1884) covering the period 1709-1883. The other is the climatic series presented by prof. Dansgaard, based on measurement of the isotope contents in core samples from the Greenland ice-cap. The data for 1600-1975 were approximated by a tenth degree polynomium in time and used in the further analysis. The data are analysed by various statistical methods and it seems evident from the data that the correlation between climatic data and number of pilot whales and number of schools of pilot whales is different for the two periods 1709-1882 and 1882-1983. For the former period the relationship is highly significant, for the latter the relationship is weaker. It is also shown that there is a strong relationship between the pilot whale and the bottlenose whale series for the years 1709-1883.

Cetaceans and seabirds in an oceanographic context

by

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The distribution and ecology of both cetaceans and seabirds depend to a large extent upon oceanographic elements which affect the dispersion of their prey. Strong overlap in diet occurs between members of both groups, and we may learn a great deal about the distribution and movements of cetaceans and seabirds by looking at those oceanographic factors in further detail. This contribution will first compare aspects of feeding ecology and diet of the two groups, then review the role that oceanographic factors may play, and finally examine ways in which cetaceans and seabirds interact both at the individual and at the population level. The importance of plankton frontal systems will be emphasised, with examples from recent field studies. Consideration will also be given to those factors which might determine prey choice, and to the significance of availability of alternative prey for conservation of different cetacean (and seabird) species. Recent developments in the fishing industry in the Northeast Atlantic and North Sea will be related to potential conflicts, using overfishing of herring and sand-eels as examples.

Seals in Norway

by

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All the seven North Atlantic species of seals are also found in Norwegian coastal waters, two as resident species, the others as occasional or, in periods, regular visitors. Seals were protected in Norway in 1973, and since then increasing numbers of common seals (Phoca vitulina) and gray seals (Halichoerus grypus) have gradually interfered more seriously with inshore fisheries. The seals act on fish stocks by predation and by chasing fish from the grounds. They also damage gear and captured fish. Most serious, however, is their function as final hosts to parasitic nematodes with life-cycles which include larval stages in commercial fishes. In particular the cod-worm (Phocanema) with larvae in benthic invertebrates and fishes like cod, has a significant economic impact on coastal fisheries. Cullings through 1980-87 have not improved the situation but may have slowed down the increase in detrimental effects. An epidemic lung disease among European common seals reached Norwegian waters in early June 1988, and by 25th August a total of 735 dead common seals had been recorded in Norway. The Arctic walrus (Odobenus rosmarus), bearded seal (Erignathus barbatus) and ringed seal (Phoca hispida) are occasional visitors and do not interfere significantly with coastal fisheries. Commercial sealing in the North Atlantic is based on the pelagic hooded and harp seals (Cystophora cristata and Phoca groenlandica), which both congregate on drifting pack-ice during the breeding and moulting seasons when they are also caught in large numbers by the sealers. Both also feed on a variety of fishes and invertebrates over large areas through the rest of the year. The gregarious harp seal invaded Norwegian coastal waters in large numbers each of the years from 1978 to 1984 and from 1986 to 1988, and seriously affected the coastal spring fisheries for cod these years. A scarcity of food, a large stock of seals, in excess of one million head, and a cooling of the Barents Sea may have caused the invasions 1978-1984. There is no unambiguous explanation for the invasions the last three years, however.

Patterns of living marine resource exploitation in the western Pacific: Lessons for contemporary resource management

by

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Marine resources are as vital to the economic survival of the Pacific micro-states today, as they were to the traditional societies which first colonised these islands in the distant part. Man first colonised the western Pacific prior to 40.000 B.P and rapidly spread through the coastal envirionment of Melanesia relying at least initially on marine resources for survival. One of the longest records of marine resource use world-wide is known from New Ireland where molluscs, fish, dugong and turtles were exploited at the same site from 33.000 B.P to 10.000 B.P. Colonisation of the Central and Eastern islands of the Pacific followed much later, around 3.000 B.P and was probably dependent upon the development of strategies and technologies for the exploitation of pelagic marine resources such as tuna. At the time of European penetration into the Pacific during the last century the archipelagoes were well populated with societies demonstrating a range of skills and knowledge in subsistence agricuture, fishing and environmental management far superior to that of contemporary European societies. The dependence of insular populations on marine organisms for survival, combined with the enormous diversity of available resourses resulted in the etablishment of a detailed body of traditional knowledge concerning the behaviour, ecology and local migrations of important species. This in combination with an understanding and appreciation of the influence of the abiotic environment on the organisms has resulted in a body of "ethno-scientific" knowledge which is not constrained by scientific "discipline" boundaries. Knowledge of lunar periodicity and local hydrography is as important to succesful resource exploitation as knowledge of the behaviour and ecology of the species sought. This paper reviews the patterns of resource exploitation which have resulted in the traditional knowledge base and assesses the value of that knowledge to western science. An importent aspect of the continuity of marine resource exploitation in the Pacific Basin has been the regulation of the rate of exploitation through various social and cultural mechanisms. Successful management of resources on a long-term, continuous yield basis in the Pacific societies has been dependent upon the traditional knowledge base and it is instructive to consider the underlying principles of successful management in traditional societies and the manner in which such principles have and may be incorporated into current management practices, both in the region and elsewhere. The current dependence of Pacific microstates on living marine resources for long-term economic development has resulted in an increase in exploitation using population models and fisheries management principles derived from western scientific theory, the applicability of such practices is evaluated against the background of traditional patterns of exploitation and resource ownership.

Environmental changes, human influence and development

by

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Global environmental changes presently occurring are climatic and associated with effects of these climatic changes. These are partly induced by human activities through releases of contaminants which influence the radiation balance and the ozone layer. Model calculations show a greenhouse effect of about 0.3-0.5 °C temperature increase over the last century, in reasonable agreement with observations. Projections suggest temperature increases over the coming century of about 3°C ± 50%. Considering that the range of temperature change since the last glaciation is about 8°C such a global change is very large. Regional changes induced through human activities additionally include effects on the marine environment from manipulation of the water balance through river discharge regulations; from releases of nutrients and organic material; from changes in temperature and sea-level induced by the climatic changes; from extraction of living and nonliving resources; from releases of contaminants on local and regional scales and through long-range transport through the atmosphere. The concern in many regional seas is demonstrated through the regional conventions. The human influences are manifested on regional and global scales, long since having passed mere local scales, and they are due mainly to the growing size of the population and the increasing scales of the human activities. Several examples are given, with a gradual but parallel increase of contamination in groundwaters and sea waters, of various contaminants. Examples also show the effect of management, control actions and change of industrial processes, banning of use of certain contaminants, in decreasing environmental levels. The pesticide levels are not decreasing in those parts of the world where they are still used, and elevated levels have been found in mothers milk from such parts compared with western Europe. The increasing population pressure is also noticed in the increasing interest in recovering and controlling living and non-living marine resources. This is demonstrated both through technological/scientific activities and through the general introduction of EEZ's. Ocean island societies are playing an active role in this context. The role of good economy, or wealth, and production together with a willingness, on part of the government, to use part of the resulting wealth to clean, protect and maintain a good environment is demonstrated through developments over the last one or two decades in Japan, in parts of the USA and in parts of Europe. The willingness of governments to set aside wealth for protection of the environment is also demonstrated through the ratification of several global and regional conventions on the protection of the environment. Human development on the present scales must include actions and precautions for a good environment and protection of resources against over-exploitation, leading to sustainable development. One major present concern involves the possible sea-level rise projected to be induced through the temperature rise, and the effect of this on low-lying costal zones and islands. Projections suggest sea-level increases in the range 20-140 cm during the coming century. The sea-level can change through a change of ocean currents, through melting of small ice fields and glaciers, melting of polar ice caps, expansion of sea water due to temperature increase. An evaluation of these factors is presented, based on a recent summary by R.W.Stewart, taking into account the differentiation of the warming as a function of latitude. This evaluation suggests a 15-20 cm sea-level rise in tropical/subtropical areas and a 30-50 cm rise in temperate regions following a doubling of the atmospheric CO_2 content. The temperature change will also have a considerable direct effect on coastal zones. The belt of tropical cyclones occurrence will broaden, with associated storm surges. The time scale for the global changes is about 100-200 years, i.e. 2-3 generations. The time scales for regional changes are one generation or less, and for local changes less than a decade. Paleo-oceanographic studies confirm that large changes can occur over time periods of 100 to 200 years. The changes discussed here, very much associated with human development, and their effects will obviously also influence the hydrographic

conditions, the position of fronts, the intensity of the ocean circulation, which in turn will influence the distribution of food for marine mammals, as well as terrestrial, with adjustments of the migration patterns as at least one consequence.