Overview of the special issue "Studies of white whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) in Greenland and adjacent waters"

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Reeves, R. R., Dietz, R. & Born, E. W. 1994. Overview of the special issue "Studies of white whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) in Greenland and adjacent waters". – Meddr Grønland, Biosci. 39: 3–11. Copenhagen 1994-04-22.

This overview introduces the collection of papers on the Distribution and abundance; Exploitation and status; Habitat use and behaviour; and Life history, stock identity and toxicology of white whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) in Greenland and adjacent waters. It includes brief summaries of the 19 included papers and calls attention to ongoing and future studies on the same or related subjects.

Key Words:
White whale, beluga, *Delphinapterus leucas*, narwhal, *Monodon monoceros*, Greenland, eastern Canadian Arctic, Svalbard.

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Introduction

This special issue of *Meddelelser om Grønland, Bioscience* is devoted exclusively to two arctic species: the narwhal (*Monodon monoceros*) and the white whale or beluga (*Delphinapterus leucas*). Both have a vast range in the Arctic. The narwhal occurs mainly in the arctic regions appended to the North Atlantic Ocean while the white whale's distribution is disjunct circumpolar and extends to subarctic waters in some areas.

The main purpose of this book is to provide a benchmark in our understanding of the populations of white whales and narwhals in waters adjacent to Greenland. The stocks of both species that migrate along the eastern and western fringes of Greenland are believed to move seasonally into international waters or, in some cases, into the coastal waters of other states, particularly Canada and Norway (Svalbard). Contributions have thus been solicited mainly from investigators who study these "shared" stocks of whales in Greenland, eastern Canada and Norway.

The central importance of narwhals and white whales in the traditional Greenlandic culture and economy provides an organizing theme for this compilation of papers. Whale hunting has long contributed to the subsistence of Inuit. Today it provides both food and cash income in the hunting areas. Whales also have symbolic importance to people both inside and outside Greenland. For these reasons we consider it important that hunting be managed to ensure sustainability and that other human activities (*e.g.* marine traffic, pollution, commercial fishing) be managed to minimize their impacts on the stocks of whales. It is the role of scientists to define stock boundaries, assess populations, measure production and recruitment, and identify factors which could affect a whale population's health and productivity. None of these tasks is easy, and there is a continuing need to improve estimates and eliminate uncertainty.

Since Kleinenberg *et al.*'s monograph on the white whale was published in 1964 (English version in 1969), there has been a rapid advance in knowledge about both the white whale and the narwhal. The concise reviews of the white whale by Stewart & Stewart (1989) and Brodie (1989) and of the narwhal by Reeves & Tracey (1980) and Hay & Mansfield (1989) are already "out-of-date" in many respects. Recently Smith *et al.* (1990) provided a collection of papers that demonstrated progress in the

systematics, population assessment, behavioural ecology, physiological ecology, age estimation, immunology and health evaluation, and toxicology for the white whales in Alaska and Canada. No similar compilation was available for narwhals or for the white whales in Greenland. We were aware that new literature on both species was appearing every year and that there was a wealth of data in reports ("gray literature") and in the files of government biologists and academics that had not yet been properly analyzed and published. Especially in view of the clear need on the part of managers for better scientific information about white whales and narwhals, we were convinced that a book such as this one, with its geographic emphasis on the waters bordering northeastern Canada, Greenland and Svalbard, should be published. Canada and Greenland established a Joint Commission on the Conservation and Management of Narwhals and Belugas in 1989. Several of the papers published here have already been used (in draft form) by this commission's Scientific Working Group and by the International Whaling Commission's Scientific Committee. We hope that the special issue will become a standard reference for these and other bodies involved in the conservation of arctic whales and their habitat.

Organization and chapter summaries

This collection of papers has been organized into four thematic sections: Distribution and abundance; Exploitation and status; Habitat use and behaviour; Life history, stock identity and toxicology. The matter of placing individual papers into one section or another was not always straightforward. Some contributions contained valuable information relevant to more than one of the sections.

Distribution and abundance

The six papers in this section mainly concern narwhals. Distribution and abundance of the stocks of white whales centered in Baffin Bay and Davis Strait have been reviewed elsewhere recently (Richard *et al.* 1990, Richard 1991a, Heide-Jørgensen *et al.* 1993, Doidge & Finley in press). Richard (1991b) provided a population estimate and a discussion of stock identity for the narwhals in northern Hudson Bay, Foxe Basin and Hudson Strait.

Two papers in the present volume are based on the results of aerial surveys in the eastern Canadian Arctic. Koski & Davis (1994) analyzed data from visual surveys conducted in 1978–1979 and 1981–1982 as part of environmental impact assessments related to oil and gas development. They found considerable variation in the numbers of narwhals entering a given summering ground from one year to the next. They also found narwhals to be widely dispersed in the offshore pack ice in Baffin Bay and Davis Strait during late winter and spring. Their surveys between 12 May and 2 July 1979 resulted in an estimate of somewhat more than 34 000 (SE 8200) narwhals in the Baffin Bay-Davis Strait region. This estimate has very wide 95% confidence limits (approximately 21 600 and 54 600; Burnham *et al.* 1987) and does not include a correction for animals outside the survey area or submerged out of sight as the aircraft flew past. Koski & Davis also estimated the calving and first-year mortality rates of narwhals in this region (0.29 calves/adult female/year and approximately 17%, respectively).

Richard, Weaver, Dueck & Barber (1994) reported on photographic surveys of the major narwhal summering grounds in the Canadian High Arctic. For reasons similar to those mentioned above in relation to the estimate by Koski & Davis (1994), the estimate of 18 000 (90% CI 15 000–21 000) narwhals by Richard *et al.* is probably an underestimate of the true population size. Richard *et al.* identified and discussed various biases that could have affected their results. They also conducted an experiment using life-sized models of adult, juvenile and neonatal narwhals and white whales, placed at different water depths, to evaluate detection probabilities on aerial photographs.

Inglefield Bredning is an important summering area for narwhals. Born, Heide-Jørgensen, Larsen & Martin (1994) conducted a series of census surveys, both from a high-elevation shore site and from airplanes, with the objectives of estimating the size of the summering population and learning about the relative age and sex composition of this population. Their paper presents the results of land-based surveys in 1985 and 1988 and aerial surveys in 1985 and 1986. They concluded that annual differences in the abundance and behaviour of narwhals might be explained at least partly by natural fluctuations in prey populations. The direct count of 4043 narwhals in Inglefield Bredning in August 1984 reported by Born (1986) remains as the highest minimum estimate of this summering population of narwhals.

Relatively little information has been available on narwhals and white whales in East Greenland. Two papers in this volume significantly improve the situation. Dietz, Heide-Jørgensen, Born & Glahder (1994) reviewed historical literature and archival sources for a synthetic appraisal of distribution and relative abundance. Recent catch records and direct observations were also considered. The authors concluded that while narwhals are widespread and common in parts of East Greenland, white whales are largely absent, perhaps due to a lack of suitable habitat. The second paper on East Greenland, by Larsen, Heide-Jørgensen, Martin & Born (1994), gives the results of aerial surveys conducted in Scoresby Sund in September 1983 and 1984. This study, which covered the largest of several fjord systems regularly inhabited by

Fig. 1. White whales were hunted in southwestern Greenland during the 19th and early 20th centuries. This picture was taken in Nuuk around 1915. Photo: Unknown. Copyright Arktisk Institut, Denmark.

narwhals during the open-water season, provided the first quantitative information on narwhals in the Greenland Sea.

The short paper by Gjertz & Wiig (1994) summarizes what is known about white whales in Svalbard. More than 3000 were taken by Norwegian whalers at Spitsbergen between 1945 and 1960, suggesting that there was a fairly large population of white whales at Svalbard in the early 1940s. The white whale is now protected in Norwegian waters, but no population estimates have been made for the Svalbard region. The narwhal's distribution and relative abundance around Svalbard were recently reviewed by Gjertz (1991).

Exploitation and status

This section consists of three papers. Savelle's (1994) examination of archaeological and ethnographic evidence led him to the somewhat unexpected conclusion that prehistoric and early historic Inuit of the eastern Canadian Arctic may not have hunted white whales or narwhals to any great extent. He suggested that the overriding importance of bowhead whales (*Balaena mysticetus*) in the ancient economy of the Thule people may have caused them to pay relatively little attention to the smaller odontocete cetaceans. Hopefully other scholars will accept Savelle's challenge and further explore the interesting questions raised in his paper.

Reeves & Heide-Jørgensen (1994) addressed a problem that brings present-day narwhal hunting and product use into an international context. As narwhal tusks and the craft items made from narwhal ivory are exchanged in a worldwide market system, they become subject to trade agreements and treaty obligations. The character and volume of trade may influence the hunting in various ways. This paper should facilitate two kinds of evaluation – on the one hand how commercial incentives may affect hunt intensity and selectivity, and on the other hand how external trade regulations may affect local economic and cultural development.

The paper by Heide-Jørgensen (1994) provides an overview of recent hunting and population status in West Greenland. According to Heide-Jørgensen the range of white whales in southern and southwestern Greenland has diminished within the present century, presumably due to overexploitation (see Fig. 1). The population that winters off West Greenland has been heavily exploited and appears to have declined substantially since the early 1980s (also see Heide-Jørgensen *et al.* 1993). Among the

problems met by the author in trying to evaluate the status of stocks was the lack of complete and reliable catch statistics. He used mattak purchases to document catches in some municipalities, and in the case of Avanersuaq (Thule) this information was used to estimate the landed catch. Simple projections using estimated population sizes in the late 1970s and early 1980s, a range of net rates of annual population increase (0.02–0.04) and known or estimated catches were used to evaluate several different scenarios. According to Heide-Jørgensen the white whale stock off West Greenland would have had to be much larger than 18 600 (the upper limit of the 1981 population estimate – Smith *et al.* 1985) to sustain the catches during the 1980s and early 1990s. The situation for narwhals appears to be less critical. A 1979 population of 34 000 (Koski & Davis 1994) could have sustained the catches; however a 1984 population of 22 000 (Born 1986, Richard *et al.* 1994) could not have.

The population estimates used in the above projections (from Smith *et al.* 1985, Koski & Davis 1994 and Richard *et al.* 1994) are uncorrected to account for whales that were submerged or outside the surveyed areas, but the catch estimates are also uncorrected to account for hunting loss and under-reporting. These countervailing biases are important because their net impact can determine whether catch levels are or are not sustainable. Further information on how the biases have been addressed can be found in Anonymous (1992, 1993) and IWC (1993).

The final paper in this section discusses the interesting question of the extent to which windfall catches made at "sassat", or ice entrapments underneath the dense landfast ice, represent natural mortality vs. hunting mortality (see Fig. 2). The finding of more than 30 dead narwhals in the Uummannaq area in late April 1984 confirms that some entrapped whales are doomed regardless of whether or not they are found and killed by hunters. Siegstad & Heide-Jørgensen (1994) concluded that ice entrapment may have effects on white whale and narwhal populations similar to the effects of mass strandings and epizootics on populations of other marine mammals in tropical and temperate regions. Such "unpredictable catastrophic mortalities" should be considered in stock assessment and management.

Habitat use and behaviour

Although several papers in other sections of the book address similar questions, habitat use and behaviour are central concerns of the two papers in this section. Kingsley, Cleator & Ramsay (1994) studied narwhals in the Eclipse Sound/Milne Inlet/Koluktoo Bay/Tremblay Sound complex, an important summering area in the Canadian High Arctic. Their repeated helicopter surveys between 1987 and 1993 were designed to examine how ice cover, water depth, seafloor relief and shelter from wind might affect narwhal movements and distribution. The whales seemed to remain in the relatively exposed waters of Eclipse Sound only if extensive ice cover was present there. Otherwise they showed an affinity for deep, steep-sided basins. Fortuitously the authors made useful observations of narwhals' responses to forays into these waters by killer whales (*Orcinus orca*).

Smith, Hammill & Martin (1994) reported some of the results of their long-term study of white whale behaviour at Cunningham Inlet in the Canadian High Arctic. Observations were also made of white whales in a small subarctic estuary on the east coast of Hudson Bay (*cf.* Caron & Smith 1990). In both areas the distribution of whales was influenced by tidal processes and to some extent by the date and the volume of river outflow. Adult females, calves and juveniles predominated in the estuaries. The authors argued that the strong philopatry and physiological dependence of white whales on seasonal access to estuaries means that such sites should be carefully protected (see Fig. 3).

Life history, stock identity and toxicology

This section contains a diverse set of papers, all of which are based on analyses done in laboratories using tissue samples collected from whales killed in Greenland or northeastern Canada.

Age estimation is a basic tool for studying animal biology. Although a reliable method for estimating absolute age in narwhals has yet to be developed (*cf.* Hay 1980), a basic method of sectioning white whale teeth and "reading" the growth layers in the dentine and cementum has been available for more than 20 years (Sergeant 1973). Heide-Jørgensen, Jensen, Larsen, Teilmann & Neurohr (1994) sectioned teeth from a large sample of white whales killed by hunters in West Greenland. They found that the lower-jaw teeth of whales from Greenland become significantly worn at a much earlier age than those of white whales from Hudson Bay and the White and Kara seas. Teeth from a captive white whale originally caught in western Hudson Bay exhibited a layering rate of approximately two growth-layer-groups per year, thus reinforcing the conclusions of previous calibration studies (Goren *et al.* 1987, Brodie *et al.* 1990).

Heide-Jørgensen & Teilmann (1994) analyzed tissues from a large sample of white whales from West Greenland to study growth, maturation, reproduction, diet and age structure (see Fig. 4). Their major conclusions were as follows: 1) White whales from West Greenland grow to greater lengths than the whales in all other areas studied. 2) Males reach sexual maturity at 6–7 and females at 4–7 years of age. 3) Mating takes place in May or perhaps later. 4) The gestation period is at least 330 days, and calves are born mainly in April and May. 5) The autumn drive fishery in Upernavik takes mainly

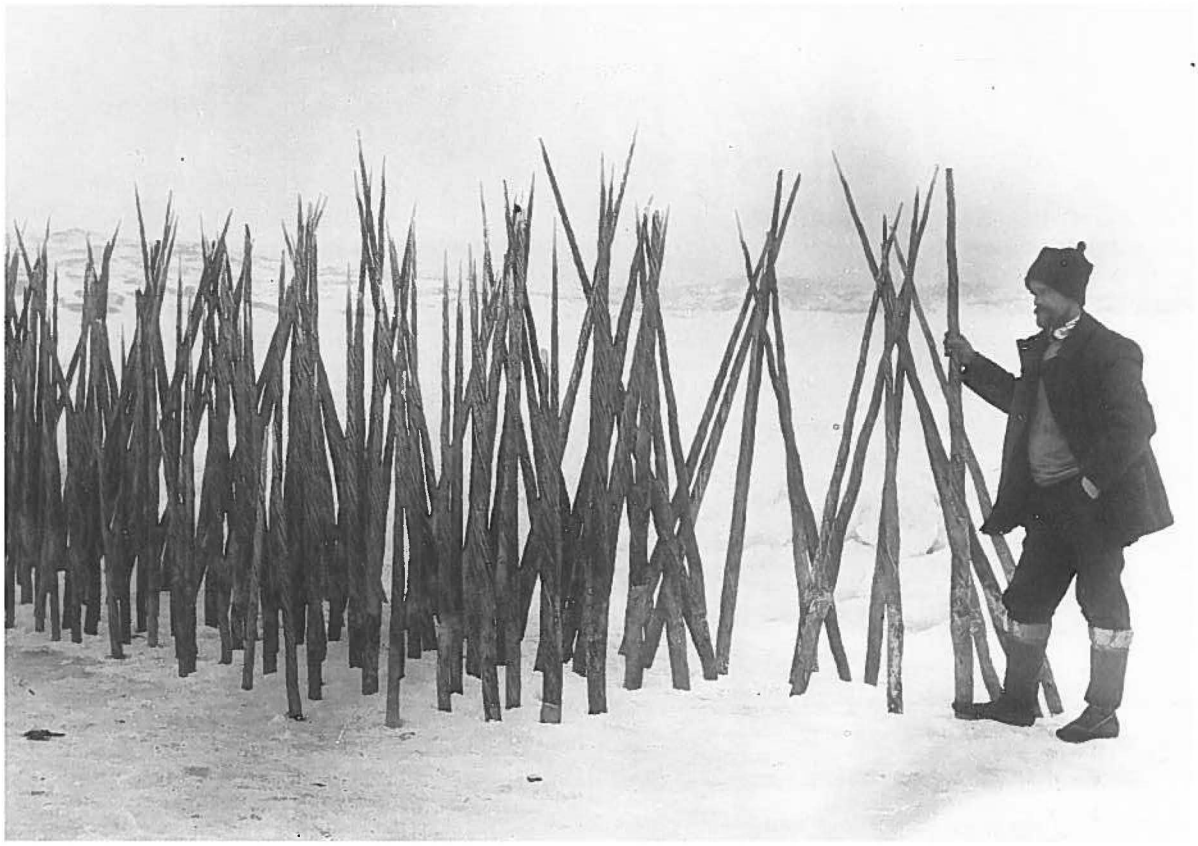

Fig. 2. A display of narwhal tusks obtained from the large ice-entrapment ("sassat") in Disko Bugt, February 1915. Photo: M. Porsild. Copyright Arktisk Institut, Denmark.

juveniles and adult females with calves while the spring hunt in Disko Bugt generally takes a higher proportion of adult whales. 5) The white whales caught today off West Greenland are significantly smaller (in length) than those taken in the drive fishery in southwestern Greenland in the 1910s and 1920s (*cf.* Degerbøl & Nielsen 1930).

The stomach contents of 35 narwhals obtained from the hunt in Inglefield Bredning in the open-water seasons of 1984 and 1985 were sampled and analyzed by Heide-Jørgensen, Dietz & Leatherwood (1994). Arctic cod (*Arctogadus glacialis*), polar cod (*Boreogadus saida*) and other unidentified gadids were found to be the principal prey. The lack of Greenland halibut (*Reinhardtius hippoglossoides*) in this sample of stomach contents was unexpected as both Vibe (1950) and the Inughuit (Thomsen 1993) have reported halibut as important prey of narwhals in northwestern Greenland.

The "stock" is usually regarded as the fundamental unit within a species' total population. However scientists and managers have often had difficulty defining stocks in practical terms. New genetic techniques promise to sharpen our understanding of the stock concept (Dizon *et al.* 1992), but traditional analytical methods can nevertheless provide useful insights. In his paper on size-at-age relationships Stewart (1994a) concluded that white whales from western Hudson Bay were significantly shorter as adults than whales from Cumberland Sound and Jones Sound. This finding is generally consistent with the preliminary results of genetic studies of white whales (Helbig *et al.* 1989, Brown & Clayton 1993, Brennin *et al.* in press). While acknowledging the "waning importance" of morphometric comparisons to questions of stock identity, Stewart pointed out that the variation in body size between populations of white whales remains an interesting biological phenomenon that raises questions related, for example, to differences in marine productivity.

Høier & Heide-Jørgensen (1994) analyzed the steroid hormone and prolactin levels in samples of blood and urine from 131 white whales killed off West Greenland between 1989 and 1992. They confirmed that progesterone levels, measured in either serum or urine, and urine oestrogen levels were reliable indicators of pregnancy in females, and that testosterone levels could be used to judge whether males were or were not sexually mature. Their attempts to use oestrogen content for distinguishing reproductive classes of females (pregnant, nonpregnant, lactating etc.) and to use prolactin for determining lactation were inconclusive. While the authors suggested that

Fig. 3. Large groups of white whales congregate during summer at river outfalls along the coast of Somerset Island, Canadian High Arctic, in this instance near Wadworth Island in Peel Sound, summer 1992. Photo: J. M. Savelle.

the threshold values established in their study could be useful for evaluating the reproductive status of white whales, they also urged caution in applying their results to animals sampled under dissimilar circumstances. The stress from being chased and hunted immediately prior to death could have had a major effect on hormone levels in the white whales used in this study.

Stewart (1994b) measured progesterone levels in the blood serum of 63 female white whales killed in the eastern Canadian Arctic. He concluded that serum progesterone levels of 3 ng/ml or higher provide a reliable indication of pregnancy. He also found that progesterone concentrations were not significantly correlated with ovary, corpus luteum or fetus mass. Female white whales from the three sites sampled by Stewart became sexually mature at 4–7 years of age.

Organochlorines are among the most widespread and dangerous environmental pollutants. Their accumulation in high-order predators, including narwhals and white whales (Muir *et al.* 1988, 1990), has implications both for conservation (Martineau *et al.* 1987, Muir *et al.* 1990) and for human health (Kinloch *et al.* 1992). Although body burdens of heavy metals in cetaceans from West Greenland were given by Hansen *et al.* (1990), organochlorine levels have not been reported previously for white whales from Greenland. The paper by Stern, Muir, Segstro, Dietz & Heide-Jørgensen (1994) documents organochlorine levels in blubber from 138 white whales and skin and kidney samples from 20 individuals taken in western Greenland. As is true in other mammals, substantial quantities of organochlorines are transferred from the mother white whale to her calf via the milk. Ontogenetic changes in contaminant levels led the authors to infer that lactation in white whales lasts for less than one year and that most females bear their first calf at 5–6 years of age. Organochlorine levels in narwhals from Greenland have not been studied.

Remaining gaps and continuing studies

We have no illusions that this volume is either comprehensive or definitive. It advances our knowledge of the monodontids but does not close the books on any aspect of their history, biology, behaviour or ecology. Much remains to be learned.

Of particular and immediate relevance to management is the need for better information on stock relations and diving behaviour. Uncertainty surrounding these two sub-

Fig. 4. Biological samples are obtained from the hunt at Upernavik in October darkness. Photo: M.P. Heide-Jørgensen.

jects has seriously impeded stock assessment. The attachment of satellite-monitored radio transmitters to whales has become feasible only recently. Yet it has already begun to transform our understanding of the animals' behaviour and physiology. This research "tool", along with genetic studies, is expected to clarify many of the discussions about stock identity during the coming years. It may also improve our ability to "correct" population estimates from visual or photographic surveys to account for whales that are present within the sampled area but are not detected because they are submerged when the aircraft passes overhead.

It is disappointing not to have something in the volume that compares the narwhal and the white whale, in terms of their ecological roles and biological characteristics. Qualitative comparisons by earlier workers (Sergeant 1978, Mitchell 1984) began the development of a theoretical framework, and Finley *et al.* (1990) and Doidge (1990) used field data to compare aspects of behaviour and anatomy, respectively, in the two species. Although white whales and narwhals are closely related, eat similar prey and are sympatric in a broad sense, their habitat preferences are clearly different. During the open-water season many white whales move into shallow estuaries while narwhals congregate in deep fjords. During the winter narwhals tend to be widely dispersed in heavy pack ice while white whales are more typically found in wide leads and expanses of open water. These are only central tendencies rather than strict rules, and a closer examination of the differences and similarities between the two species is needed. Hopefully the material in this volume will help stimulate and provide background for more comparative work.

We would also like to have had more coverage of Inuit perspectives in the volume. The recent studies by Remnant & Thomas (1992) in Canada and by Thomsen (1993) in Greenland are welcome additions which recognize the value of knowledge gained by the people who observe, hunt, dissect and consume narwhals and white whales as a regular part of their lives. Too often in the past this accumulated wisdom has been ignored. Thomsen's report from Greenland became available very late in the process of preparing this collection of papers, so it was impossible to ensure that its contents were consistently addressed and appropriately incorporated in all cases.

Acknowledgements

The editors thank Greenland Fisheries Research Institute and Greenland Environmental Research Institute for pro-

viding salaries and underwriting many of the other costs of preparing and producing this book. Jonas Teilmann provided editorial assistance during the final stages of manuscript preparation. An obvious debt is owed to the authors for their contributions. In addition we are very grateful to the external referees who helped ensure a high standard for the papers. They are listed here in alphabetical order: A. Aguilar, I. L. Boyd, J. J. Burns, D. W. Doidge, M. A. Fraker, K. J. Frost, I. Gjertz, L. Hacquebord, P. S. Hammond, M. P. Heide-Jørgensen, A. A. Hohn, F. O. Kapel, R.A. Kastelein, T. Kasuya, M. C. S. Kingsley, M. Klinowska, W. R. Koski, C. Lockyer, L. F. Lowry, A. P. McCartney, M. A. Ramsay, P. J. H. Reijnders, P. R. Richard, G. J. B. Ross, T. G. Smith, D. J. St. Aubin, G. W. Wenzel and T. Øritsland.

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