Arctic whaling

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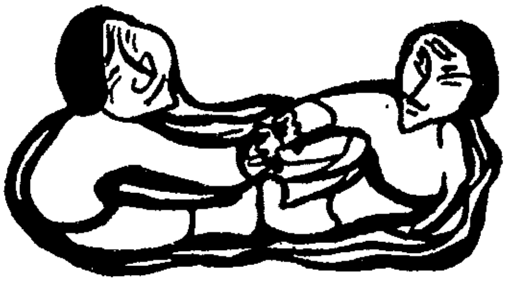

ARCTIC CENTRE

University of Groningen Netherlands

cover: vignette of the Arctic Centre, designed by Aka Hoegh

ARCTIC WHALING

Proceedings of the International symposium

Arctic Whaling February 1983

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PREFACE

In February 1983 the Arctic Centre of the University of Groningen held its sixth international symposium. This time it was devoted to Arctic whaling. It is a pleasure to present herewith the proceedings of this meeting. The Arctic Centre was happy to notice that the participation of scholars from abroad had increased considerably. We could welcome speakers and visitors not only from the Netherlands, but also from the Scandinavian countries, Belgium, Germany, Great Britain, Canada and the U.S.A.

The papers in this collection all deal with different aspects of the main theme. Dr. D.M. Hopkins (Menlo Park, U.S.A.), dr. P.M. Kelly (University of East Anglia, U.K.) and dr. T.E. Vinje (Norsk Polarinstitutt, Norway) approached the physical geographic context of whaling in the Arctic. The biological component of the Arctic ecosystem was focused by dr. P.J.H. van Bree (University of Amsterdam, the Netherlands) and dr. E.D. Mitchell Jr. (Ste-Anne de Bellevue, Canada). Under the heading "Patterns and Processes in Arctic Whaling" the history of autochtonous and foreign whaling in different parts of the Arctic was treated by prof. A.P. McCartney (Fayetteville, U.S.A.), prof. A.A. Dekin Jr. (Binghamton, U.S.A.), dr. R.C. Kugler (New Bedford, U.S.A.), prof. dr. R. Vaughan (Arctic Centre, Groningen, the Netherlands) and drs. L. Hacquebord (Arctic Centre, Groningen, the Netherlands). The connected problems of present whaling were discussed by drs. J.G. van Beek (Arnhem, the Netherlands). A brief summary by Deborah Gottheil (U.S.A.) of the Forum discussion is added to the proceedings. The theme of the discussion was "The confrontation and conflict between native subsistence and commercial whaling". The Arctic Centre is much obliged to dr. M. Tillman (U.S.A.) for his valuable contribution to this discussion as joint member of the panel of symposium speakers.

Within the framework of the meeting a series of highly interesting films and video displays were shown, which were provided by speakers and different institutions. In connection with the symposium, findings from the Arctic Centre-Carl Denig-Spitsbergen expeditions 1980-1982 were presented at the first comprehensive exhibition in the Noordelijk Scheepvaart Museum.

To conclude, I wish to express the Arctic Centre's most sincere thanks to all those persons, institutions, foundations and firms who contributed to the succesful realization of the symposium.

Prof. dr. A. van Marken
Chairman of the Arctic Centre

CONTENTS

WHALE BIOGEOGRAPHY AND THE HISTORY OF THE ARCTIC BASIN

by

D.M. Hopkins and Louie Marincovich Jr.

Introduction

Whales are the oldest surviving stock of marine-adapted mammals. They evolved in the rather unique and highly productive environment of tropical Tethys, a seaway that lay between western Eurasia and the encroaching Indian subcontinent. The early records of fossil cetaceans are entirely southern; whales first appear in the North Atlantic and the North Pacific in the Miocene.

The oldest known cetacean remains from the shores of Arctic Ocean consist of vertebrae, otherwise unidentified from the early and middle Pleistocene members of the Pliocene(?) and Pleistocene Gubik Formation of Alaska. Fossil remains identifiable at the generic level are known only from upper Pleistocene and Holocene deposits. These include what is probably the complete skeleton of a gray whale *(Estrichtius)* and scattered remains probably of a beluga *(Delphinapterus?)*, found by L.D. Carter in the youngest part of the Gubik Formation near Teshekpuk Lake, northern Alaska (Repenning, 1983), and numerous remains of bowheads *(Balaena mysticetus)* in raised beaches of early Holocene age on southern Ellesmere Island (Blake, 1975a). One of us (DMH) considers this part of the Gubik Formation to represent isotope stage 5c or 5a, which implies an age of 80,000-100,000 years. The oldest bowhead remains at Cape Storm evidently are about 9,500 years old (Blake, 1975a).

The lack of a lengthy fossil record may indicate that cetaceans were absent from the Arctic Basin until quite recently. More likely, the sparse record reflects the lack of collecting in Cenozoic marine sediments around the shores of the Arctic Ocean.

The remainder of this report reviews present knowledge of whale evolution and then considers the limited information available concerning the paleogeography and paleo-oceanography of the Arctic Ocean Basin and the possible impact of that history upon whale biogeography and whale evolution. Our intention is to stimulate discussion and a more intensive search for fossil cetacean remains at high latitudes.

Whale evolution

The earliest known cetacean fossil is *Pakicetus inachus,* recently discovered in Pakistan in fluvial sediments of early Eocene age, 50-55 million years (m.y.) old. *Pakicetus inachus* evidently was amphibious and lived in an estuarine environment marginal to the Tethyan Sea. The animal "was well equipped to feed on fishes in the surface waters of shallow seas, but it lacked auditory adaptations necessary for a fully marine existence" and seemingly spent time on land (Gingerich and others, 1983). By middle Eocene time, 40-50 m.y. ago, all known whales had a fishlike body and evidently were fully marine. Middle and late Eocene whales of the primitive suborder Archaeoceti are known from Egypt, Nigeria, Texas, and India (see papers quoted in Gingerich and others, 1983). The Archaeocetes persisted through Oligocene and into early Miocene time.

The earliest known representatives of the two living Cetacean suborders, the *Odontoceti* (toothed whales) and the *Mysticeti* (baleen whales), occur in middle Oligocene rocks about 30 m.y. old (Whitmore and Sanders, 1976). Oligocene Cetaceans were widely distributed, but diversity was low. Fossils are known from New Zealand, Australia, Italy, and Germany, from Tethyan deposits in Austria and the Ukraine, and from South Carolina on the Atlantic coast and Oregon and Vancouver Island on the Pacific coast of North America. Most and perhaps all of the Oligocene *Odontoceti* were moderate-sized inhabitants of coastal waters. Mysticete fossils from Europe and New Zealand establish that the baleen-whale mode of feeding had fully evolved by middle Oligocene times; the Mysticetes had evidently already adapted to a pelagic life on the high seas. Most of the modern Cetacean families appeared during the Miocene, and most of the modern genera during the Pliocene Epoch. Modern whale species, like the modern species of most other mammalian groups, first appear in Quaternary deposits and thus are less than 2 m.y. old.

Although very few Cetacean fossils are known from the shores of the Arctic Ocean, historically known distributions indicate that dispersals through the Arctic have played a definite role in present-day whale biogeography. The narwhal *Monodon monoceros* is nearly confined to the Arctic Ocean. The harbor porpoise *Phocoena phocoena,* the beluga *Delphinapterus leucas,* the finback whale *Balaenoptera physalus,* the little piked whale *Balaenoptera acurorostrata,* the gray whale *Estrichtius gibbosus,* and the bowhead *Balaena mysticetus* all have paired North Atlantic and North Pacific populations that must once have merged in the Arctic Ocean (Scheffer, 1967).

History of the Arctic Basin

The deep Arctic Ocean Basin has two major subdivisions, the Siberian-American Sector, adjoining northeastern Siberia and northwestern North America, and the Eurasian Sector, adjoining Greenland, Svalbard, and the shelf seas north of Europe and western Siberia. Both sectors have oceanic crustal structure. They are separated by the Lomonosov Ridge, a long, narrow slice of continental crust (Fig. 1).

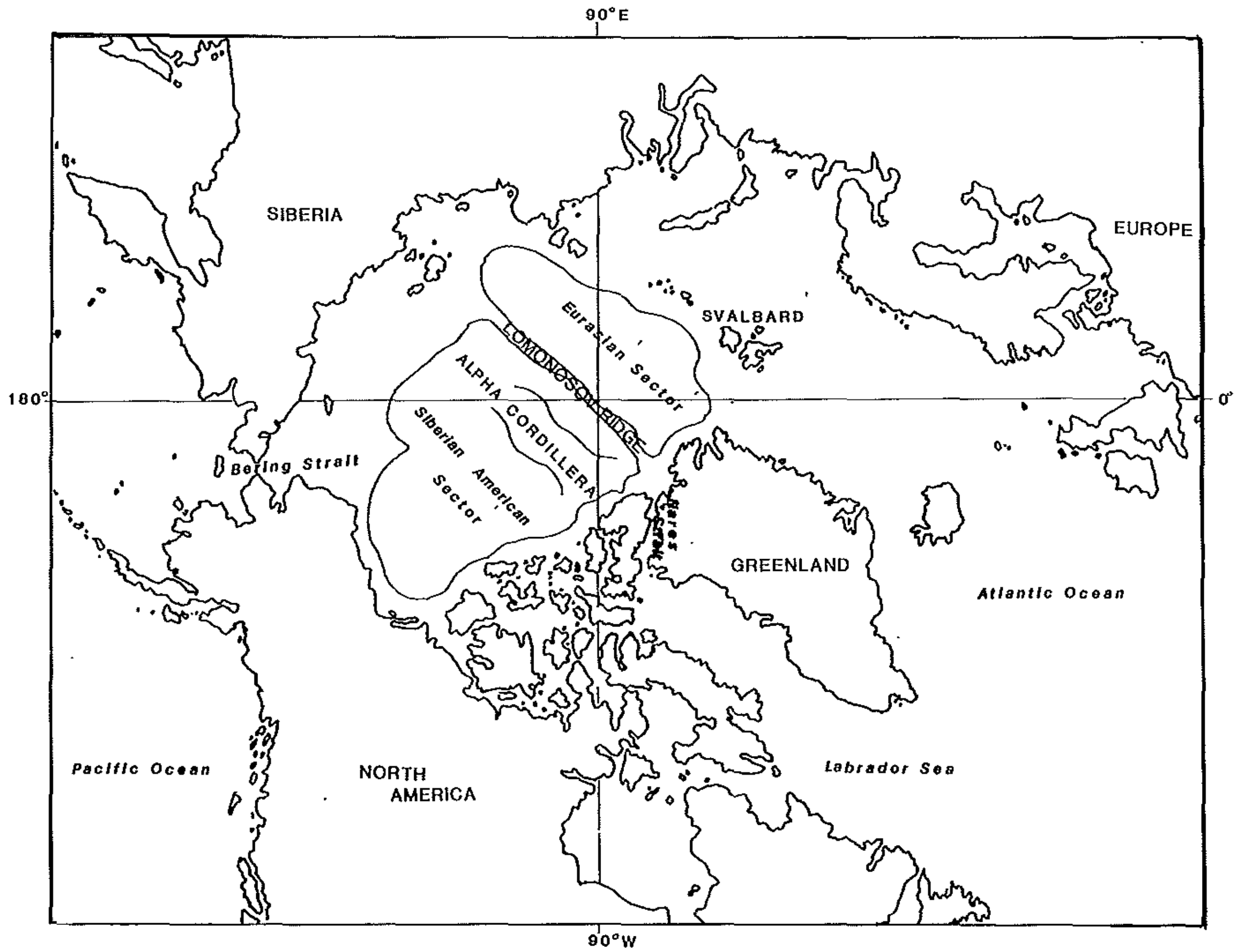

Fig. 1. Location map

The Siberian-American sector is the older and in part represents the remnant of an oceanic area that was broadly connected to the Pacific Ocean prior to closure by continental plate movements near the end of the Cretaceous period, some 65 m.y. ago (Churkin and Trexler, 1981; Fujita and Newberry, 1982). Deep-water connections with the Pacific Ocean were never reestablished, and shallow-water connections were not reestablished until the submergence of Bering Strait during the Pliocene Epoch between 3.0 and 3.5 m.y. ago.

The Eurasian sector originated as an ocean basin when the Lomonosov Ridge separated from Eurasia near the beginning of the Eocene Epoch about 55 m.y. ago (Vogt and others, 1979). Some investigators (e.g., Gradstein and Srivasta, 1980) believe that the resulting complex of Arctic Ocean basins was connected with the North Atlantic Ocean throughout Paleogene (Paleocene, Eocene, and Oligocene) time by way of a seaway through Nares Strait and the Labrador Sea, but evidence of peculiar hydrology and biologic endemism, discussed below, is more consistent with the concept that the Arctic Ocean remained almost completely isolated throughout much of Paleogene time.

Nannofossils in Cretaceous and Paleogene sediments recovered in cores from the Alpha Rise (Kitchell and Clark, 1982) (Fig. 2) show diminishing diversity with decreasing age, which Bukry (1982) interprets as indicating a progression toward either hypersaline or brackish sea-water chemistry. We believe that these cores record the gradual reduction of circulation from the Pacific Ocean as plate tectonic movements gradually isolated the Arctic Basin.

Isolation from the world ocean is also suggested by the high degree of endemism in Arctic marine shelf faunas of Paleocene or Eocene age. Foraminiferal faunas recovered from Paleocene or Eocene beds penetrated by boreholes onshore and offshore in the MacKenzie River delta region of northwestern Canada, for example, consist largely of new species and are difficult to correlate with faunas from lower latitudes (Young and McNeil, 1982, p. 24).

Mollusk, ostracode, and foraminifer faunas from Paleocene marine beds at Ocean Point on the lower Colville River in northern Alaska also display a high degree of endemism (Marincovich and others, in press (a) and (b)). The age of the Ocean Point Paleogene sequence is known only within very broad limits. Zircon grains from a tephra (volcanic ash) layer that underlies the fossiliferous beds have yielded a fission-track age of 50.9 m.y. ± 7.7 m.y. (Paleocene to Middle Eocene) (Carter and others, 1977). The mollusk fauna is most similar to the fauna of the Cannonball Formation of North and South Dakota, thought to be of Paleocene age (Cvancava, 1966). Although lacking close affinities with any known Paleogene faunas at lower latitudes, the Ocean

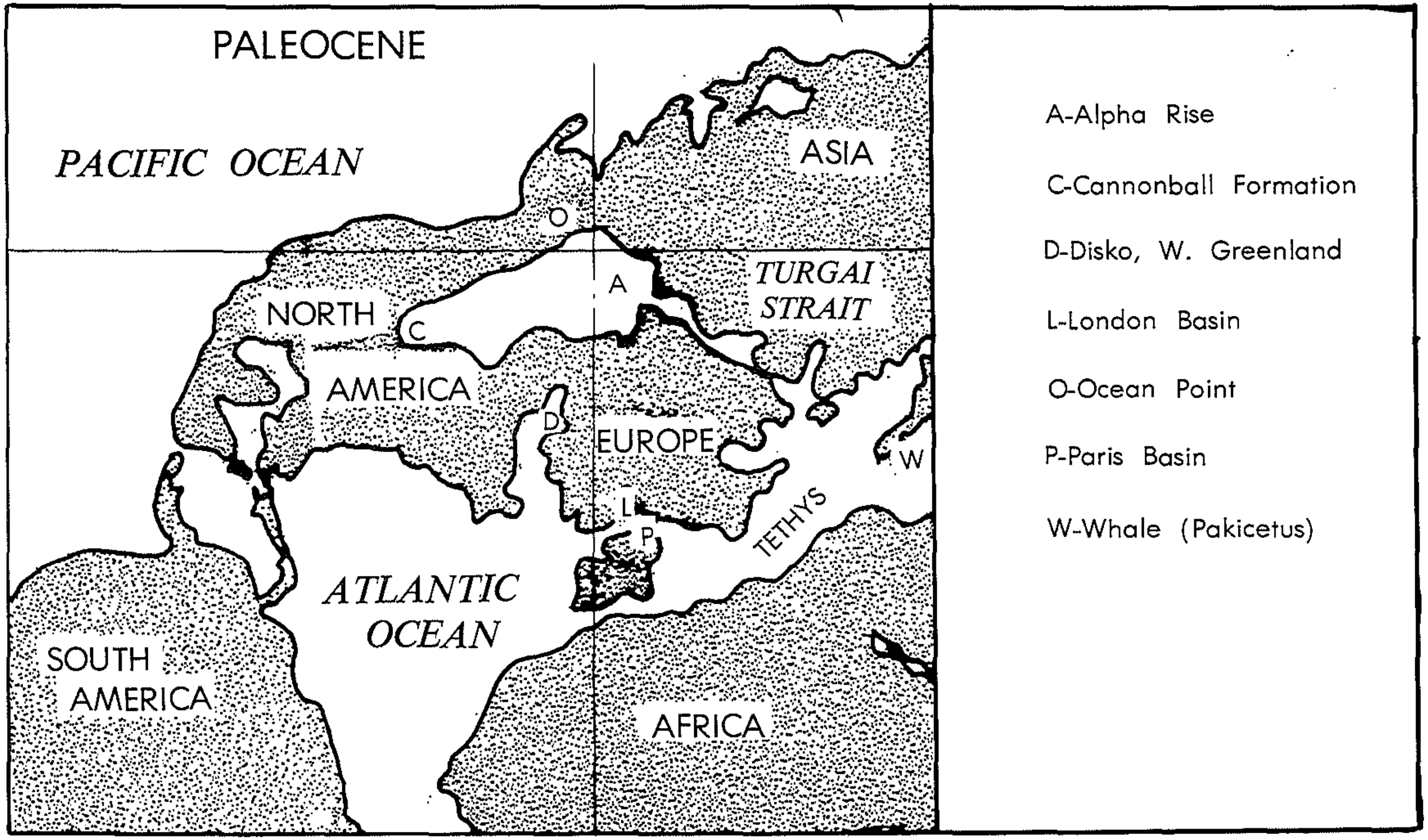

Figure 2. Paleogeography of the Arctic Basin, 38-55 m.y. ago (Paleogene)

Point and Cannonball mollusk assemblages share enough taxa with Paleogene faunas in the London and Paris Basins to suggest a remote connection.

It is most unlikely, however, that there was any direct marine connection between the Arctic and Atlantic Oceans during Paleocene and Eocene time. European and North American land-vertebrate faunas and floras display sufficient affinities to indicate the presence of a land connection across the Atlantic during Cretaceous, Paleocene, and much of Eocene time. The recently discovered Paleogene fossil vertebrate and plant assemblages in the Eureka Sound Formation on and near Strathcona and Bay Fjords, Ellesmere Island (Dawson and others, 1976; Estes and Hutchison, 1980; McKenna, 1980; Hickey and others, 1983), provide confirming evidence of the former existence of a high-latitude North American-European land connection.

It seems, then, that the Arctic Ocean and its epicontinental embayment that extended southward across western Canada to the Dakotas was isolated from the Pacific and remote from the Atlantic Ocean during much of Paleocene time. Nevertheless, some sort of indirect marine connection is indicated by the Atlantic affinities of the Arctic marine mollusk faunas. The exterior connection, as Kitchell and Clark (1982) suggest, probably lay southward to Tethys by way of the Turgai Seaway across West Siberia. Thus, primitive Eocene whales, which certainly were present between Asia and India in the shrinking Tethyan Seaway, might have had access to the Arctic Ocean but there would have found themselves in a cul-de-sac without access to the Pacific Ocean (Fig. 2).

The Paleocene nannofossil faunas indicate an open, ice-free Arctic Ocean (Kitchell and Clark, 1982). The Ocean Point Paleocene mollusk fauna conveys little paleoclimatic information, although temperate rather than tropical water temperatures are suggested by low diversity; the broadly coeval Disko Bay fauna of West Greenland displays much higher diversity and probably represents tropical conditions (Rosenkrantz, 1970; Henderson and others, 1976). The vertebrate faunas from Ellesmere Island suggest an equable temperate climate without winter freezing (Estes and Hutchison, 1980); the gymnosperm and angiosperm floras consist entirely of deciduous species and suggest winter darkness and dormancy (L.J. Hickey, personal commun., 4/83).

Sea-floor spreading opened a deep passage separating Greenland from Svalbard in Oligocene time, 32-34 m.y. ago (Eldholm and Thiede, 1980). The initiation of a direct connection to the Atlantic probably is signaled by the shift from endemic to Atlantic foraminiferal faunas within the Kugmallit Formation (Oligocene) of the Mackenzie Delta region (Young and McNeil, 1982).

A widespread and probably synchronous sea-level transgression in the

Arctic Basin is recorded by Neogene marine beds in the Beaufort Formation on Meighan Island, Canadian Arctic Archipelago (Matthews, 1976), by the Mackenzie Bay Formation of the Mackenzie Delta region (Young and McNeil, 1982), by the Nuwok Member of the Sagavanirktok Formation of northeastern Alaska (MacNeil, 1957; Detterman and others, 1975), and by a thin sheet of Miocene marine sediment recently discovered at Skull Cliff in northwestern Alaska (J.K. Brigham and K.A. McDougall, personal commun., 1983) (Fig. 3). Age estimates for these beds range from Oligocene (Young and McNeil, 1982) to Pliocene (Bergquist in Detterman and others, 1975), but plant and insect remains in associated nonmarine beds suggest that the marine tongue in the Beaufort Formation is of middle or late Miocene age and older than 8 m.y. old (Hills and Matthews, 1974; Matthews, 1976). If we are correct in assuming that these widely distributed Neogene marine deposits are synchronous, then they probably represent the peak Miocene transgression of Vail and Hardenbol (1979) which took place about 13 m.y. ago.

The Arctic Miocene mollusk faunas are Atlantic in character and indicate that a connection to the Pacific Ocean by way of Bering Strait had not yet come into existence. Furthermore, the western islands still must have been connected to the mainland (e.g., by Contra Kerr, 1980) judging from the presence of pebbles derived from the Canadian Shield in alluvial gravel in the Beaufort Formation (Tozer and Thorsteinsson, 1964; Contra Kerr, 1980).

Middle and late Miocene climates around the shores of the Arctic Ocean were relatively mild. Middle Miocene forests of *Picea, Pinus* (two species), *Tsuga, Metasequoia, Juglans cineria, Carya, Tilia,* and *Alnus* in the Beaufort Formation at Lat. 74^0 N. on northwestern Banks Island gave way in the late Miocene to a more taiga-like assemblage consisting of *Picea, Pinus, Larix* and *Tsuga* interspersed with abundant *Ericaceae* (Hills and Matthews, 1974). The taiga-tundra ecotone lay on Meighen Island at Lat. 80^0 N. (Matthews, 1976).

The perennial ice cover had not yet developed, and it is unlikely that the Arctic Ocean was even seasonally frozen. A small species of the bivalve *Arctica* characterizes the molluscan fauna of the Nuwok Member of the Sagavanirktok Formation (MacNeil, 1957), and the same species, or one very similar, dominates the small molluscan assemblage examined by one of us (LM) from the marine tongue in the Beaufort Formation at Lat. 80^0 N. on Meighen Island. *Arctica* now reaches its northern limit at Lat. 67^0 N. in the ice-free waters of the northwestern Atlantic Ocean. The Arctic Ocean was certainly accessible to and habitable by North Atlantic whale populations in the late Miocene, but it continued to be a biogeographic cul-de-sac. Dispersals between the Atlantic and the Pacific Oceans took place elsewhere, e.g., by way of the Panamanian Seaway, which continued to separate North and South America until about 3 m.y. ago (Fig. 3).

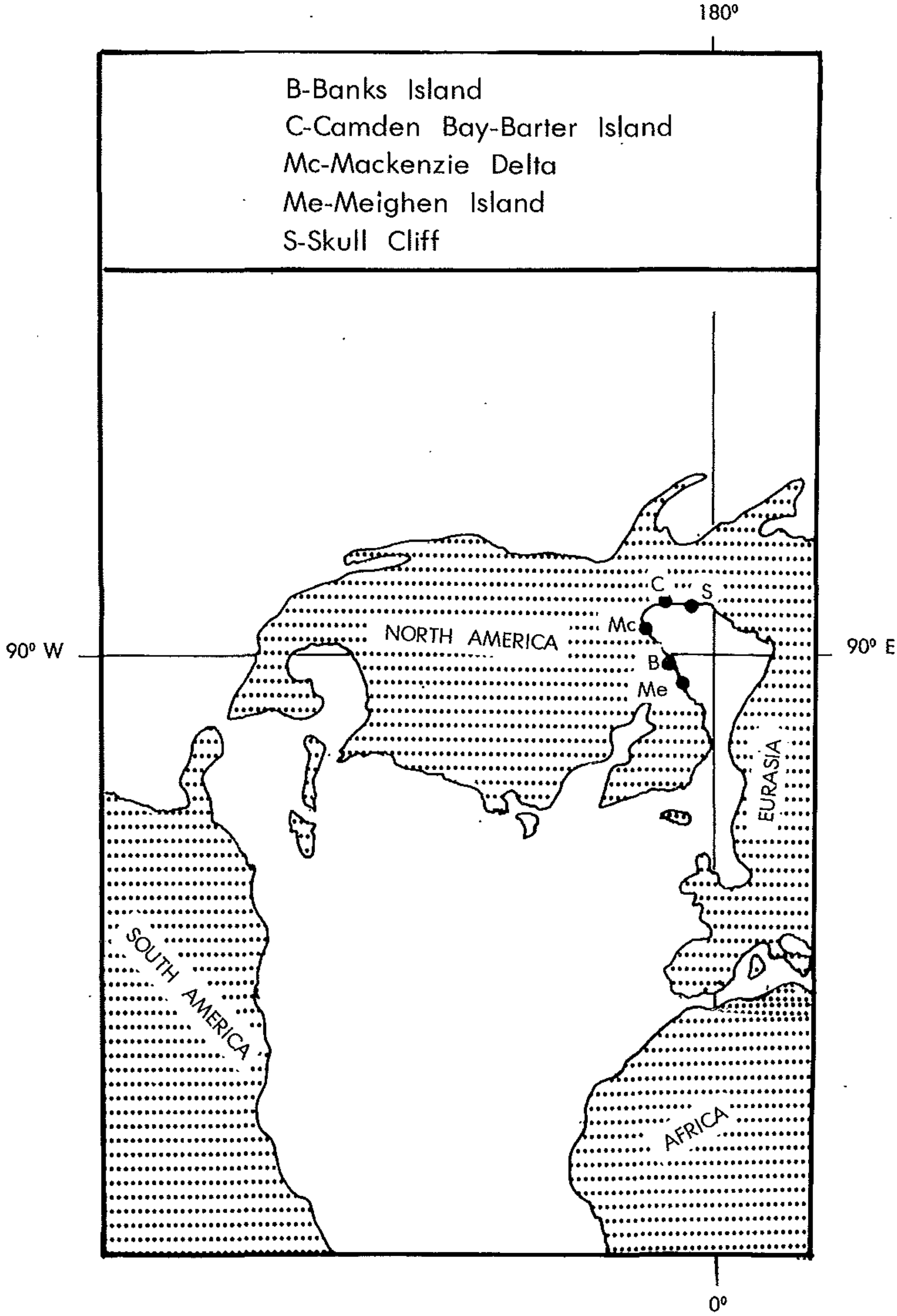

Fig. 3. Paleogeography of the Arctic Basin 13 m.y. ago (Miocene)

The isolation of the Arctic Ocean from the North Pacific came to an end with the submergence of the Bering Land Bridge between 3.0 and 3.5 m.y. ago. By this time, rifting seems to have separated all of the islands of the Canadian Arctic Archipelago. Before another half million years had passed, the Isthmus of Panama became completely emergent, cutting off low-latitude connections between the Atlantic and the Pacific Oceans. From this time forward, Bering Strait, and the Arctic Ocean became the unique but intermittent avenue for marine dispersals between the North Atlantic and the North Pacific Oceans.

An estimate of the time of opening of Bering Strait depends upon several lines of indirect evidence:

(1) Marine sediments of the Yakataga Formation on the Pacific coast of southern Alaska have yielded fossil remains of *Pusa,* an arctic seal of Tethyan and ultimate Atlantic origin. The seal remains were found 180 m below beds containing a diatom flora estimated to be between 1.8 and 1.1 m.y. old (Repenning, 1983).

(2) The presence of similar mollusk faunas in deposits of the Beringian transgression at St. George Island and Nome to the south and at Kivalina and Skull Cliff to the north indicates that Bering Strait was open at least 2.2 m.y. ago (Hopkins, 1967) (Fig. 4).

(3) A flood of marine mollusks of boreal Pacific ancestry appear at Tjörnes, northern Iceland, in beds about 3.5 m.y. old (Einarsson and others, 1967; Gladenkov, 1979). The precise nature of the events at Bering Strait that led to this event in Iceland has yet to be worked out. Clues are provided by marine geological studies indicating that the Norton Basin to the south and the Hope Basin to the north were sites of ongoing tectonic down-warping throughout much of Tertiary time (Fischer and others, 1982; Eittreim and others, 1979). Bering Strait, floored by hard, crystalline rocks (Grim and McManus, 1970), clearly was and still is tectonically relatively high. A possible scenario might involve the development, during Miocene and Pliocene time, of a major stream valley draining from the Hope Basin across this tectonic high to a lower-lying Norton Basin. Tectonic movements in concert with the peak Pliocene marine transgression, which, however, Vail and Hardenbol, 1979, place at about 5 m.y. B.P., may have submerged this ancestral valley to form the Bering Strait.

Whatever the cause, the Arctic Ocean has functioned during the last three million years as the sole avenue of marine communication between the North Pacific and North Atlantic Oceans. It has functioned only at times when sealevel was high enough to drown Bering Strait, thus presumably only during interglacial episodes. Glacial episodes have been intervals of lowered sea level, re-establishment of the Bering Land Bridge, and interruption of

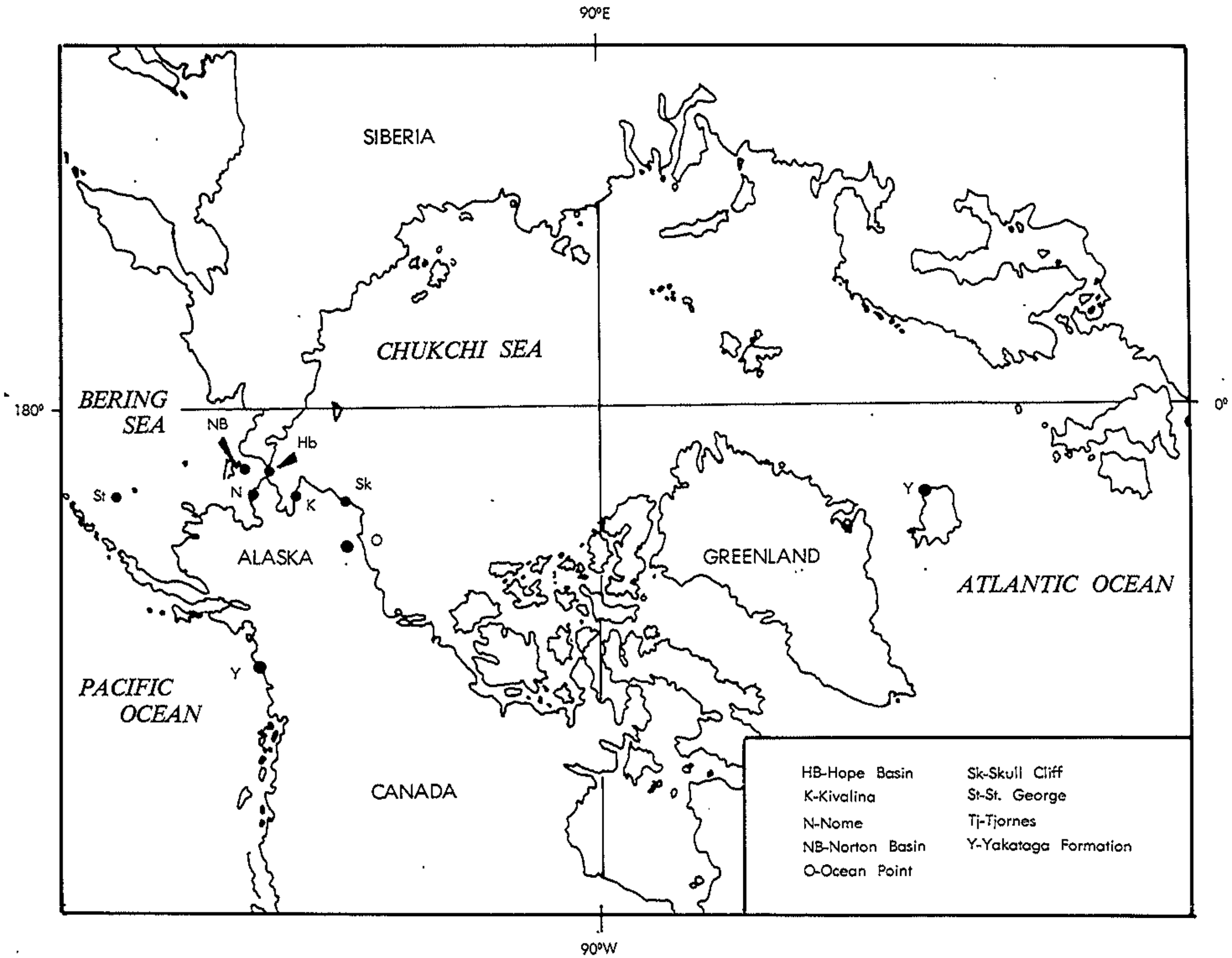

Fig. 4 Paleogeography of the Arctic Basin 3.5 m.y. ago

North Pacific-North Atlantic marine communication.

How many of these high-sea-level episodes occurred when the Arctic Ocean was free of perennial sea ice? Opinions differ drastically, reflecting the dubious geochronology, the sparse faunas, and the ambiguities of lithologic interpretation of the few, decades-old deep-sea cores that have been available. D.L. Clark and his co-workers stoutly maintain that their study of the cores indicates that the Arctic Ocean has remained frozen for a period much longer than 3 m.y. (e.g., in Clark, 1982); Y. Herman and her co-workers maintain with equal vehemence that analysis of the cores shows that the Arctic Ocean has been perennially ice covered only during the last 0.7 m.y., that the ice cover was seasonal between 0.7 an 2.5 m.y. ago, and that the Arctic Ocean was open prior to 2.5 m.y. ago (e.g., Herman and Hopkins, 1980).

Both Clark and Herman base their age estimates mainly upon inadequately documented and very noisy paleomagnetic data thought to show that the cores provide a 5.5 million-year record of Neogene sedimentation. Research in progress by G.L. Miller (University of Colorado) and Hans-Petter Sejrup (Bergen University) on amino-acid ratios in planktic foraminifera tests from the Arctic Ocean cores cast doubt upon this chronology. Racemization ratios for monospecific samples consisting of several tens of individual tests vary erratically rather than increasing down-hole, suggesting that large numbers of redeposited foraminifera may be present in these glaciomarine sediments. The most highly racemized samples studied thus far have racemization ratios that suggest ages no greater than a few hundreds of thousand and possibly as little as a few tens of thousands of years (G.L. Miller and H.-P Sejrup, personal commun., 1983). Perhaps we will find that the Arctic Ocean cores provide a highly detailed history of events during the last glacial cycle rather than a very compressed record of events that spanned the entire Pliocene and Pleistocene epochs.

Although the Arctic Ocean cores available at present may provide little information about the long-term history of the Arctic Ocean ice cover, some inferences can be drawn from onshore paleobotanical studies and studies of glacial geology. A lack of evidence, as we interpret the literature, of extensive middle and late Pleistocene glaciation over the northwestern Canadian Arctic Archipelago and the evidence of pronounced asymmetry of middle and late Pleistocene glaciation on the north and south flanks for Alaskan mountain ranges indicates that the Arctic Ocean was an insignificant moisture source and thus probably perennially frozen during most, if not all, of the last several hundred thousand years. At some earlier time, however, continental glaciers covered northern Greenland (Hjort, 1981; Schytt and others, 1982), large areas on Ellesmere Island (England and Bradley, 1978), and most of Banks Island (Vincent, 1982, 1983) (Fig. 5). An ice cap over the Chukotka Peninsula,

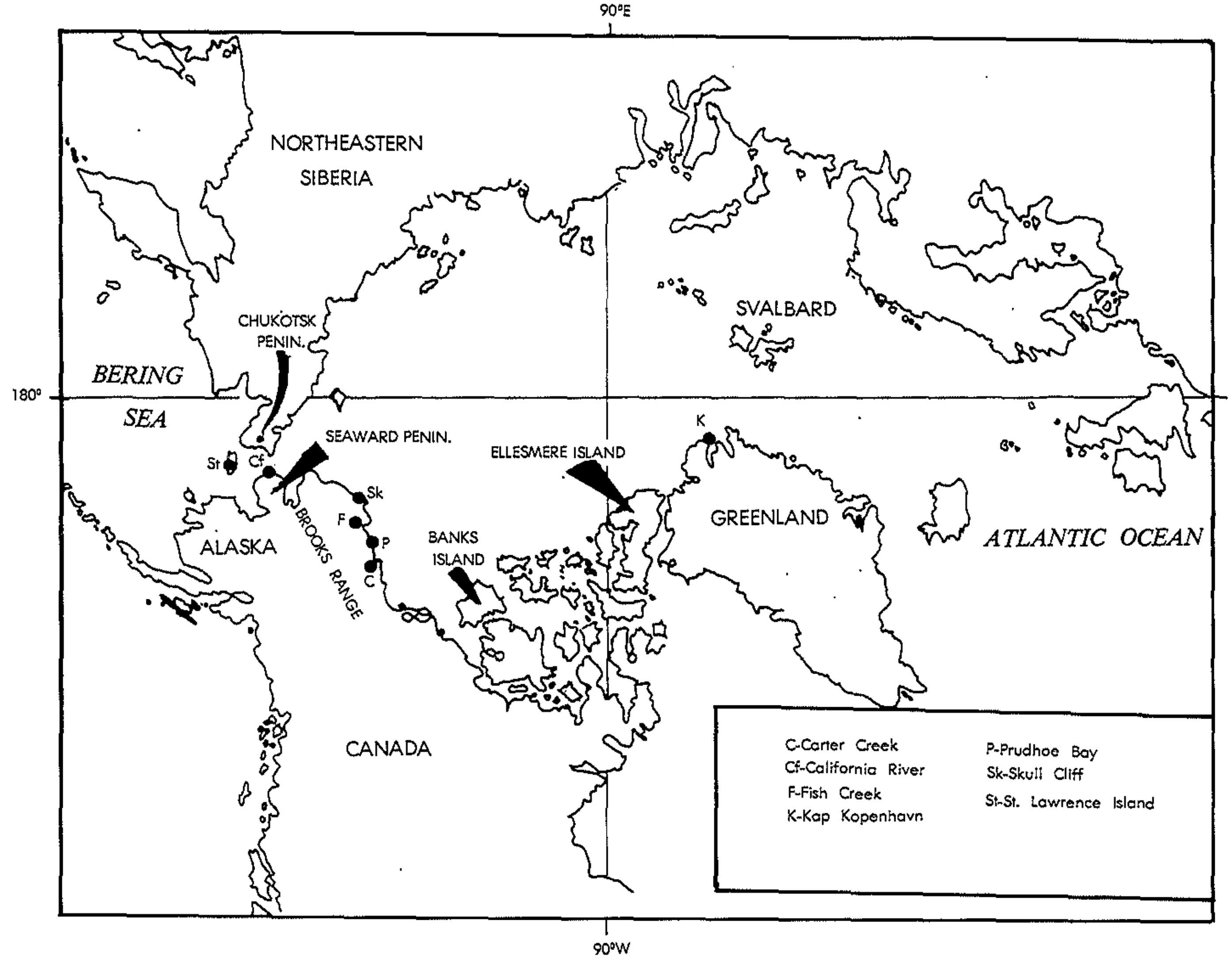

Fig. 5. Important Early Quaternary Arctic glacial and interglacial localities

northeastern Siberia, extended westward across Anadyr Strait to St. Lawrence Island (Hopkins and others, 1972) and across northwestern Bering Sea to within 100 km of the Seward Peninsula coast of mainland Alaska (Nelson and Hopkins, 1972). Alpine glaciers extended north of the Brooks Range in northern Alaska (Hamilton and Hopkins, 1982). Northern glaciers of these magnitudes seem to require a northern moisture source; they suggest that prior to middle Pleistocene time, the Arctic Ocean was at least seasonally open, even during glacial intervals.

The state of the ice cover during interglacial intervals is, however, of greater potential significance for whale biogeography. It seems likely that a perennial ice cover has been present over the central Arctic Ocean throughout Holocene time. Arctic land climates were warmer, however, between 13,500 and 8,500 years ago in Alaska and northeastern Siberia, areas were not influenced by the Laurentide ice cap persisting over northern Canada (Hopkins, 1982). Massive, pumice-rich storm beaches in the Canadian Arctic Archipelago (Blake, 1975B) and Spitsbergen (Blake, 1961) seem to record more open water and thus greater wave fetch during summers 6,500 to 5,000 years ago. Abundant driftwood on uplifted beaches 6,500 to 4,000 years old have similar implications (Blake, 1972; Stewart and England, 1983).

The last interglacial interval, about 125,000 years ago, was also a time of less ice-bound coasts and warmer summer water temperatures, judging from the abundance of extralimital mollusk species in fossil faunas of Eemian age from northern Russia, northwestern Siberia, and northern Alaska (Troitskiy, 1974; D.M. Hopkins, unpublished data). Middle Pleistocene marine mollusk faunas, however, suggest a water and ice regime much like the present one.

Marine ostracodes and benthic foraminifera now confined to North Atlantic waters have been recovered in boreholes on the Beaufort Sea shelf near Prudhoe Bay (P.A. Smith, K.A. McDougall, and E. Brouwers, personal commun., 1983). The Atlantic micro-organisms appear in marine silt and clay dating from both the last and from earlier interglacials. These finds may indicate that during certain interglacials, the cold, saline Atlantic water mass lay nearer the surface than at present. If so, then the surficial low-salinity layer, which is in part an effect of the sea ice, may have been thinner. Possibly the sea ice, itself, was either thinner, more restricted in distribution, or of seasonal occurrence during the Eemian and some earlier interglacials.

Arctic and Subarctic marine faunas of Pliocene and early Pleistocene age suggest a considerably less severe ocean climate and a much more moderate sea-ice regime. *Littorina,* an intertidal snail now limited to ice-free waters, is found in marine deposits of early Pleistocene age at Nome, California River, Skull Cliff, Fish Creek, and Carter Creek in western and northern Alaska. *Macoma balthica* is found far north of its present range in interglacial deposits probably of early Pleistocene age at Kap Kopenhagen, northernmost Greenland (Schytt and others, 1982).

At Ocean Point, northern Alaska, marine deposits dating from late Pliocene or earliest Pleistocene times have yielded the remains of a primitive *Enhydra* (sea otter) and *Pagophilus* cf. *P. groenlandica* (North Atlantic Harp Seal) (Repenning, 1983). The living sea otter lacks adaptations for surviving in ice-covered waters and established populations now live only to the south in areas where near-shore waters remain open throughout the year. The Ocean Point fossil may represent an individual that strayed from more southern waters or it may represent a not-yet fully-marine ancestral otter that foraged on land in winter. However, the presence of the harp seal, now confined to North Atlantic waters, suggests that when the bone-bearing beds at Ocean Point were accumulating, passages through the channels in the Canadian Arctic Archipelago were more open and less ice-bound than at present. Pollen in the bone-bearing Ocean Point sequence records a *Pinus-Picea-Populus* forest in what is now a region of low-arctic tundra (Nelson, 1981), confirming that the nearby Arctic Ocean must have been at least seasonally ice-free.

These paleoclimatic and paleo-oceanographic inferences suggest that the Arctic Ocean probably offered an equable avenue of dispersal between the North Atlantic and the North Pacific Oceans during non-glacial and interglacial intervals between 3.5 and 1.0 m.y. ago. One might expect that in the time that has elapsed since the dispersals that were possible at these early times, descendant populations should have evolved into sympatric pairs of species within single genera. Because all of the closely related cetacean populations in the two oceans are, in fact, conspecific, they must have continued to maintain intermittent contact during middle and late Quaternary time. Whales have evidently continued to disperse between the North Atlantic and North Pacific Oceans during the last interglacial, 125,000 years ago, and probably also during the earliest, warmest part of the present interglacial, about 8,500 to 13,000 and 6,500 to 4,000 years ago.

Acknowledgments

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ARCTIC CLIMATE: PAST, PRESENT AND FUTURE

by

P.M. Kelly, J.H.W. Karas and L.D. Williams

Introduction

The Arctic is considered to be particularly sensitive to climatic variation. Changes in climate occur on all time scales and the variability of many climatic parameters is at a maximum in higher latitudes. Variations in the character of both the atmospheric and oceanic circulations occur and are accompanied by changes in atmospheric and sea-surface temperatures, precipitation, salinity, sea-ice conditions, and so on. These fluctuations have long been known to those who live or seek a livelihood in polar regions. Varying environmental conditions can favour or hamper human activity directly or indirectly, through their impact on the flora and fauna. At the present time, increasing interest in the exploitation of Arctic mineral resources is stimulating much research concerning the polar environment.

In this paper, a brief summary of the factors which shape the weather and climate of the Arctic is given and the use of historical whaling records to reconstruct past sea-ice conditions is discussed. A chronology of the major high-latitude climatic events of the present millenium provides a context for studies of the historical development of whaling. Finally, the potential for long-term climate prediction is assessed. Environmental considerations, including the possibility of climate change, should influence management decisions concerning Arctic resources such as the whale.

Arctic climate

The climate of the Earth is shaped by regional, mostly latitudinal, imbalances in the input of energy from the Sun and by the redistribution of this energy by the circulation of the atmosphere and oceans. Greater heating at low latitudes results in a pressure gradient between low and high latitudes. This causes a tendency for poleward flow of air which is distorted by the Earth's rotation, inter alia, such that in middle latitudes the flow is largely zonal, from west to east. This westerly flow is disturbed by mountain barriers and other features of the Earth's surface and takes the form of a series of waves at height in the atmosphere. The winds meander around cold troughs extending south from polar regions and relatively warm ridges which push northwards. It is the upper air flow which steers the surface cyclones and anticyclones which are responsible for much of the character of the weather and climate in middle and higher latitudes.

The radiational imbalance between the equator and poles is then the driving force behind the atmospheric circulation which, with the current system of the oceans, attempts to redress the energy imbalance by the transport of heat and moisture. Within this general framework, each region has its individual climatic character. The main factors which shape the climate of a region such as the Arctic can be conveniently summarised as geography, the nature of the local energy balance, and the local atmospheric and oceanic circulations.

As far as the climate of the Arctic is concerned, the main geographical feature of note is the largely ice-covered sea, surrounded on most sides by land. The ice pack has a high reflectivity so that, depending on the time of year and other factors, some 60 to 90 per cent of the incoming radiation is reflected away. Over open ocean, the proportion lost is generally much less and the lack of ice cover also means that heat can be made available to the atmosphere from the ocean itself. A significant amount of heat enters the Arctic Ocean via ocean currents and, in effect, through the transport of ice out of the Arctic Ocean. The ice cover of the Arctic varies greatly, from year to year and on longer time scales. These changes are accompanied by pronounced alterations in the local energy balance and contribute to the sensitivity and high variability of high-latitude climate. During certain times of the year, there is a strong thermal contrast between the ice-covered ocean and the adjacent landmasses. The land heats up rapidly during the summer months whilst the ocean remains relatively cold and the resulting thermal gradient stimulates the development of cyclonic storms. Finally, the height of the Greenland ice mass is an important geographic feature as this and, to a lesser extent, other mountainous areas affect the flow of the winds in the lower layers of the atmosphere.

In the early years of the present century, it was believed that the atmospheric circulation of the central Arctic was usually dominated by an area of radiationally-maintained high pressure. As the polar observational network improved, it was realised that this was not the case; the area often being invaded by cyclones from middle latitudes. These advect warm air and some moisture into the Arctic and variations in their frequency of occurrence can be responsible for major changes in polar climate. Ocean currents, which are largely wind-driven, also bring heat into the region, particularly in the North Atlantic sector and, to a lesser extent, through the Bering Strait. The main flow of water and ice out of the Arctic occurs east of Greenland. The presence of both cold southward-flowing and warm northward-flowing currents in the relatively restricted area of the Greenland and Barents Seas makes this region very active climatologically. Variations in the strength or location of these currents may be responsible for changes in sea surface temperature patterns and these may affect the local atmospheric circulation. The sea-ice distribution in this area is also very dependent on the character of these ocean currents.

Variations in climate occur when the Earth's energy balance is disturbed by external forcing, such as changes in the amount of solar energy reaching the top of the atmosphere, or by internal mechanisms, such as alterations in the pattern of snow and ice distribution which may affect the amount of heat available to the atmosphere at the Earth's surface. This topic is discussed further in a later section.

Evidence of past climatic change

The main concern of this paper is with recent climatic change, that is, that which occurred during the present millenium. The evidence of the great climatic shifts from glacial to inter-glacial conditions will not be considered. Instrumental observations of weather and climate have only been collected for some two to three centuries and relatively long records are only available for a few locations. The global observational network only extends back four to five decades. Information concerning climatic change during the pre-instrumental era can be reconstructed from a variety of geological, chemical, biological and historical sources (Wigley et al., 1981). Glacial deposits can be dated and reveal information about the advance and retreat of the glaciers that formed them. Much work has been done on the chemical composition of high-latitude ice cores, particularly from Greenland. Tree rings provide a valuable source of well-dated evidence of past climatic conditions. Pollen profiles, taken from sediments on land or under water, reveal periods of past vegetation change which, with care, can be interpreted in terms of climatic fluctuation. Historical, or documentary, evidence is a rich source of information about the climate of the era immediately prior to the development of the modern instrumental network of weather stations.

All indirect or proxy measures of past climate are prone to error and misinterpretation and should be used with care. One source of error lies in the difficulties that are frequently encountered in dating proxy data accurately. Moreover, such data may only be representative of conditions in their particular region and will almost certainly only represent a narrow facet of climatic change. For example, many of the types of proxy data cited above are only indicative of summer conditions, usually temperature. It is, therefore, unwise to accept the results of climate reconstruction exercises uncritically. A review of the different types of indirect climatic indicators, their applications and limitations, has been given in Wigley et al. (1981) which also contains much discussion of the use of historical sources of climatic information.

One particular example of the use of historical information will be given here. Whaling records provide a wealth of material concerning variations in many aspects of the climate system. Perhaps the most reliable data, because of its intrinsic relationship with the success and survival of the expeditions, concerns sea ice. Kugler (this volume) reports on an extensive investigation of records for the Alaskan sector which has resulted in a valuable extension of the sea-ice record for this area back into the nineteenth century. Dunbar (1967, 1972) has used whaling records to derive information about sea-ice limits west of Greenland and in the Bering Sea for various intervals during recent centuries.

Comparing Baffin's progress northwards up the west Greenland coast in 1616 with whalers' reports from the nineteenth century and modern aerial observations, Dunbar (1972) finds that the nineteenth century estimates of clearance dates are two to three weeks later than Baffin's earlier dates (after correcting for the change in the calendar) and about one month later than more recent estimates. Inevitably, there are difficulties in such comparisons: different types of ship were involved, the interests of the expeditions were different, and so on. Nevertheless, analyses such as these do suggest that significant changes in ice conditions have occurred in that area.

In an earlier study, Dunbar (1967) considered varying sea-ice conditions in the Bering Sea. During the second half of the nineteenth century, whales were caught at the ice edge in this area and in open water within the ice pack. The whalers would follow the ice margin as it retreated northward during the spring and many observations were taken during these voyages. Much of this information was compiled, more or less at the time, by Dall (1882) and Page (1900). Figure 1 shows a comparison of April ice limits for the 1870s and 1890s based on whaling observations, and for recent decades based on modern observational material. Unreliable information noted by Dunbar has been omitted from the chart. Two limits are presented for the recent period: the extreme southward extent and the average limit of ice of concentration 1/10. We have used unpublished limits prepared in the Climatic Research Unit rather than those used by Dunbar.

The nineteenth century data bracket the recent southward extreme but lie south, for the most part, of the recent average limit. Dunbar (1967) describes the nineteenth century limits as average positions rather than extremes and, given this interpretation, the whaling data suggest more severe conditions during the late nineteenth century, particularly during the 1870s. April marks

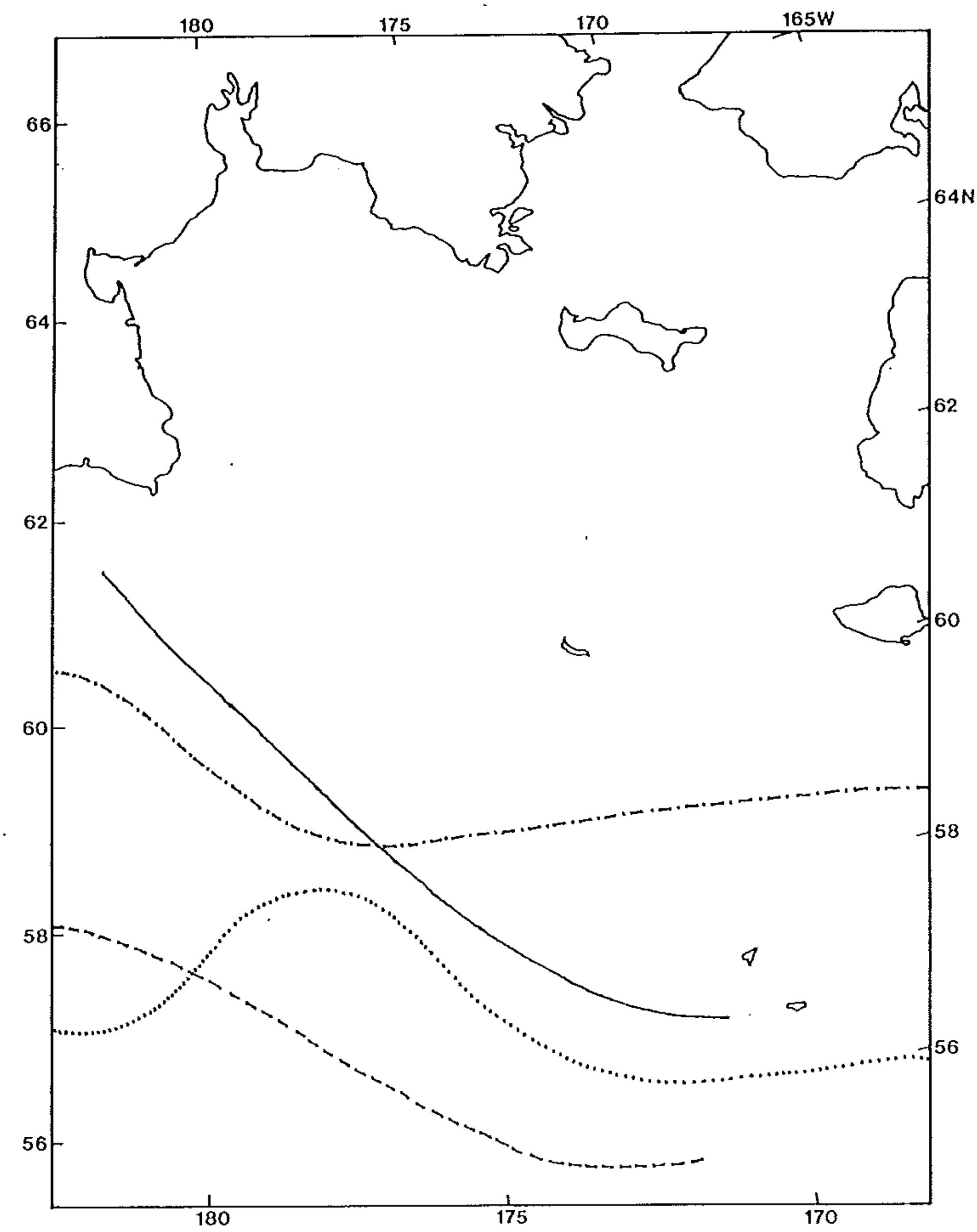

Fig. 1 Comparison of April ice limits in the western Bering Sea based on late nineteenth century whaling records and modern observations. Limits for the 1870s (broken line) and 1890s (solid line) were extracted from Dunbar (1967). The recent average (chained line) and extreme (dotted line) limits are based on unpublished data for the period 1953-1982.

the end of the ice season and the start of ice break-up in this area in recent years, and these results suggest that break-up occurred later during the late nineteenth century, most notably in the east of the region. This is evidence of a shift in the seasonal characteristics of the ice cycle of formation and decay and, as such, indicates an important change in the energy balance of the area and, quite likely, its climate.

The interpretation of the nineteenth century data is, however, problematic. The observations were not taken regularly or systematically. They must have been scattered in both space and time and it is debateable whether or not such data can be used to derive meaningful average sea-ice limits. It is quite likely that the observations are biased towards severe, rather than light, ice conditions as these would have been of greater concern to the whalers. According to Dunbar, all the available data were averaged to produce the limits shown in Figure 1. We suspect, however, that, contrary to Dunbar's interpretation - although in keeping with the cautious tone of her discussion -the nineteenth century limits may be more indicative of extreme rather than average conditions. In which case, there is little difference between the recent and nineteenth century limits. To resolve this problem, it is necessary to return to the original data sources.

As Dunbar notes, data such as these need to be handled carefully to minimise the effects of the errors and ambiguities which can plague this type of anecdotal evidence. It is, however, clear that much valuable information exists in the mass of whaling records. The time and patience needed to extract all references to sea-ice conditions, and weather and climate in general, from surviving whaling records is great. It may be that undertaking regional studies designed to address particular questions rather than access all environmental information would be the most efficient approach.

Climatic change during the present millenium

Much of the information presented here concerning the climate of the earlier centuries of this period is taken from a recent review of the subject undertaken by Williams and Wigley (1983). They concern themselves, for the most part, with the record of summer temperature for the North American, North Atlantic and European sectors of the Arctic. The reader is referred to Williams and Wigley (1983) for a detailed discussion of their sources of data. The record of Arctic climate during the period of instrumental climate records since about 1881 is extracted from Kelly et al. (1982). Further details have been taken from Lamb (1977) which contains much background information.

During the tenth, eleventh and twelfth centuries, climate improved throughout much of the North American and Greenland sectors of the Arctic. This was part of a more widespread episode of climatic amelioration that affected a fair proportion of the Northern Hemisphere and reached its peak in the medieval warm epoch or "Little Optimum". Regional patterns of climatic change were more complicated during the following three to four centuries. There is some evidence of cooling but the most certain feature of this period is warmth in the eastern Canadian Arctic during the fifteenth and early sixteenth centuries. Archaeological data from Greenland suggests that this warmth extended eastwards affecting the burial conditions of Viking settlers there. There is also evidence, based on the ability of Russian ships to sail along the northern European coast to the Kara Sea, of warmth in the European and western Siberian sector of the Arctic during the sixteenth century (Lamb, 1977, p. 465). The remainder of North America and much of Europe was, however, notably cold or cooling during this period. Sailing routes in the North Atlantic sector were increasingly affected by ice and shifted south (Lamb, 1977, p. 453).

General cooling led up to the most severe phase of the "Little Ice Age" which reached its peak during the seventeenth century in most areas. In the North American and Greenland sectors, a double minimum in summer temperature occurred between 1620 and 1710. This was a time of generally harsh climatic conditions although, even so, warm years and decades did occur. For example, Ogilvie (1983), in a re-assessment of the historical data base for Iceland, has shown that the period 1640 to 1670, immediately prior to the most severe phase of the Little Ice Age in Europe (the 1690s), was notably mild with relatively little sea ice. The spatial patterns of climatic change can be complex. Climatic variation may affect different regions in different ways and at different times. It is, therefore, dangerous to rely on a simple hemisphere-wide, or even Arctic-wide, model of climatic history.

The eighteenth and nineteenth centuries were, it is believed, times of slow climatic amelioration punctuated by short, and sometimes, severe cooling episodes. A particularly harsh period occurred in northern Europe about 1800. The final phase of the recovery from the Little Ice Age is shown in figure 2. Surface air temperatures in Arctic regions rose during the early decades of the twentieth century, reaching a peak around 1940. The warming was most marked in winter and in the regions of the Kara Sea and northwest Greenland. Succeeding decades were characterised by cooling in many areas and temperatures reached a temporary minimum in the 1960s. Since that time, they have begun to rise again reaching values typical of the late 1950s in recent years. This second warming, although not yet sufficiently well-established to be considered a major long-term climatic change, has been most marked in the Kara Sea and Alaskan regions.

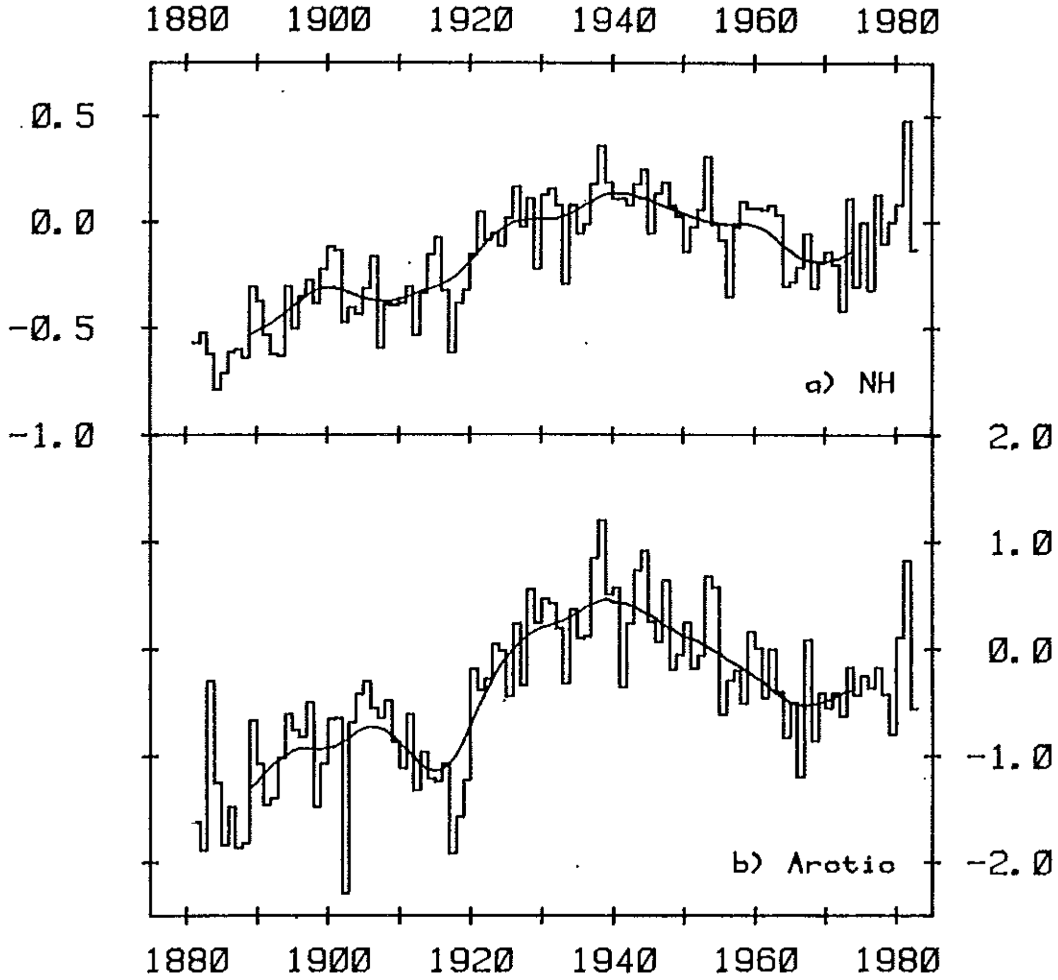

Fig. 2 Annual temperatures (degrees Celsius) for a) the Northern Hemisphere and b) Arctic regions. The data are expressed as departures from the 1946-1960 reference period means and have been smoothed to reveal the long-term variations. These large-scale averages are mostly representative of conditions of the landmasses of the areas and the reliability of the estimates decreases in the earlier years. The sources of these data and their limitations have been discussed by Kelly et al. (1982).

Variations in Arctic-wide sea-ice extent during recent decades have been considered by Walsh and Johnson (1979). Their analysis shows minimum ice extent in the early 1960s then a rapid increase during the mid-1960s, following the general course of the atmospheric temperature trends. A decline in extent occurred during the 1970s. For earlier periods, it is necessary to resort to the use of regional or point estimates of sea-ice conditions; none of which can be considered to be necessarily representative of conditions elsewhere in higher latitudes. The spatial patterns of change in sea-ice extent are complex, being affected by the characteristics of the seasonal movement of the ice margin. Perhaps the best-known of the longer, historical records is that for Iceland compiled by Thoroddsen (1916/17), Koch (1945) and later revised and updated by various investigators. The more reliable portion of this record (Fig. 3) shows the retreat of the seasonal ice margin away from Iceland during the early twentieth century at the time of atmospheric warming and its return during recent decades. A similar, although shorter, period of relatively ice-free conditions occurred in the mid-nineteenth century.

The Future

The record of climatic change during the current interglacial suggests that the variations of the present century, in particular, the marked warming seen in figure 2, could well be without parallel during the last 5,000 years or so. Data for recent decades indicate that the warming of the early twentieth century may not be over, as many scientists believed during the cooling of the 1950s and 1960s. Are we seeing a temporary halt in the cooling which will soon be re-established or will the warming continue? To answer this question it is necessary to consider the state of knowledge concerning the causes of climatic change, for reliable prediction must be based on thorough understanding of the physical processes that are involved.

It is generally accepted that a proportion of the variations seen in the temperature records shown in figure 2 was caused by variations in the degree of explosive volcanic activity. Explosive eruptions input a large quantity of dust and gas into the upper atmosphere and this may remain for months to years. This dust and the aerosols which develop from the gas injection can significantly alter the energy balance of the Earth producing warming in the upper layers of the atmosphere and cooling at the Earth's surface (Newell and Deepak, 1982). The volcanic "veil" reduces the amount of solar energy reaching the Earth's surface. Empirical studies, confirmed by theoretical modelling experiments, have shown that individual eruptions can cause a hemispheric cooling of some 0.2 to 0.3 degrees Celsius lasting for two to three

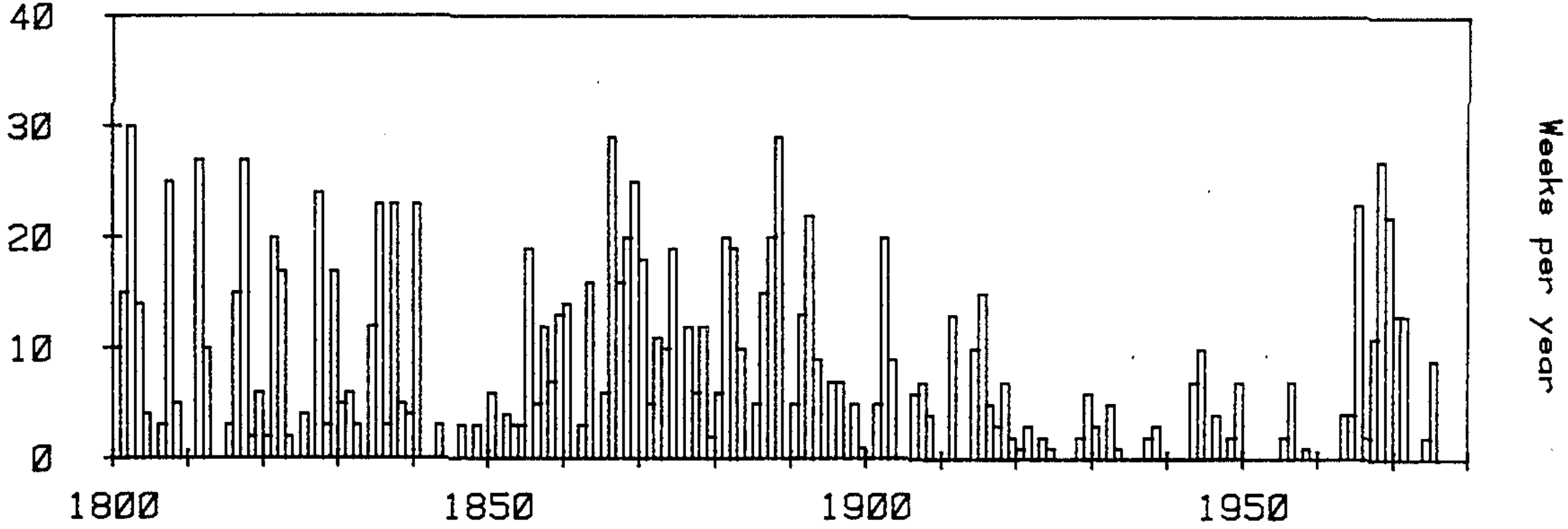

Fig. 3 The number of weeks per year when ice affected the coast of Iceland. Data from Lamb (1977).

years. Although the evidence is less convincing because of the limited amount of data available, it is believed that changes in the frequency of large explosive eruptions may produce longer lasting effects. For example, the warmth of the early twentieth century occurred at a time of low volcanic activity apparently unparalleled in recent centuries.

The warming of the 1920s and 1930s and of recent years could also be a result of Society's actions in polluting the atmosphere with carbon dioxide, deforestation and changing land use. In this way, Mankind is causing a notable rise in atmospheric carbon dioxide levels which threatens to result in a major climatic change (Kellogg and Schware, 1981). Numerical models of the climate system predict that if the amount of atmospheric carbon dioxide doubles then the world will warm by 2 to 3 degrees Celsius. This is because carbon dioxide allows solar energy to pass through the atmosphere to the Earth's surface, while trapping the longer wavelength terrestrial radiation which would otherwise have escaped to space. As carbon dioxide levels rise, this "greenhouse" effect is increased and warming occurs at the Earth's surface. The uncertainty surrounding estimates of the magnitude of the "carbon dioxide problem" is great, but most climatologists agree that it is a cause for concern. Recent work has shown that a combined model of changes associated with the varying level of volcanic activity and atmospheric carbon dioxide can provide a reasonable simulation of the observed temperature record for the past 100 years (Hansen et al., 1981). The model suggests that the observed record should be interpreted as slow carbon-dioxide-induced warming punctuated by periods of volcano-induced cooling (Fig. 2).

The Arctic is likely to experience the greatest climatic impact caused by carbon dioxide increases and may be affected by another societal action. In order to reduce water shortages in Kazakhstan and Central Asia, the USSR plans to divert substantial quantities of water away from the Arctic Ocean by transfers from major northern Eurasian rivers (Kelly et al., 1983). Because the freshwater injection from these rivers plays a major part in determining the current structure and water-mass characteristics of the Arctic Ocean and its marginal seas, any discharge reduction could affect the oceanography, ice cover and, possibly, climate of the region. While substantial transfers are many years away and assessment of the environmental risks involved is nowhere near complete, this possible source of climatic change adds another element of uncertainty in attempts to predict climate.

In fact, it is unlikely that understanding of the causes of climatic change will ever be sufficient to support reliable climate prediction on the 10 to 50 year time scale. Indeed, when it is realised that such forecasts will probably require prior predictions of the level of explosive volcanic activity, inter alia, the magnitude of the problem is clear. Nevertheless, useful information can be provided concerning the potential range of future climatic variation. By examining the longest possible climate records, the range of conditions experienced in the recent past can be determined. Given the rate of current climatic change, it is reasonable to assume that this range will encompass the fluctuations likely to occur over the next 10 to 50 years. The longer the records that are available, the more likely it is that estimates made in this way will be reliable. The importance of extending climate records back in time, using sources such as historical whaling material, is clear.

Acknowledgements

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ON THE PRESENT STATE AND THE FUTURE FATE OF THE ARCTIC SEA ICE COVER

by

Torgny E. Vinje

The present sea ice conditions in the Arctic are discussed with particular reference to the Atlantic approach. Various features are considered against the background of previous and new observations. Measurements suggest an average thickness between 4 and 5 meters of the sea ice passing through the Fram Strait. Buoy drift data from the strait over the past six years suggest an average outflow of ice of about 0.8 mill. km^2 per year.

The fate of the Arctic sea is briefly discussed. Models suggest that a series of simultaneous changes in the atmospheric and oceanographic circulation patterns would be necessary for a natural removal of the ice cover. Most model simulations suggest a global average temperature increase of 0.5^0 to 3^0C when the carbon dioxide concentration is doubled. Similar global temperature increases, however, existed for long parts of the interglacial periods without any drastic effect on the multiyear ice cover in the Arctic Ocean.

Interannual variability

Within the frame of natural variations of the climate there seems to be room for a considerable interannual variation in the sea ice extent. This is indicated from proxy data as well as from aircraft and satellite observations during the last decades. Walsh and Johnson (1979) investigated the temporal and spatial fluctuations of sea ice for a period of 25 years (1953-1977). They found that the general minimum of iciness in the early 60's was followed by a fairly sharp increase during the mid-1960's. They concluded that the trend of the total Arctic ice extent computed from the 300-months sample is positive, equal to 3.14×10^3 km^2 $year^{-1}$, and statistically significant. The only area in which the ice extent has decreased substantially is the Barents Sea. They also found that the dominant spatial mode of ice variability is an asymmetric mode in which the North Atlantic anomaly is opposite to the anomaly over the remainder of the polar cap. Sanderson (1975) considers the variation of the Arctic sea ice for the period 1966 to 1974. He finds, for instance, that in practically every region, heavy ice conditions are associated with winds from a north or north-westerly direction. The variability of the total area is usually less than 10%. Vinje (1977a and 1981) has studied the variability in the Greenland, Iceland and Barents Seas for the period since the coming of the satellites. He finds a close relation between the deviation from the monthly mean ice distribution and the corresponding deviation from the monthly mean air pressure in all parts of the region. The fairly rapid improvement of the sea ice conditions north and east of Iceland from 1968 to 1971, for instance, corresponds with a marked intensification of the Icelandic Low over this period. A similar connection between the ice conditions north of Iceland and the low pressure centre to the south has for previous periods been demonstrated by Bjørnson (1969) and Jakobsson (1969).

The surface circulation in the Greenland Sea Gyre may at times be reflected in the sea ice distribution in a very spectacular way (Fig. 1). This was the case in March-April 1970 and 1979 and in January-February 1981. It is found that the extra-ordinary distribution for all years is coincident with a marked intensification of the cyclonic atmospheric circulation in the Norwegian-Greenland Seas. This suggests simply that extreme developments of the sea ice distribution in this area may occur when the cyclonic circulation in the Gyre is stimulated by an intensification of a similar circulation in the atmosphere (Vinje 1983). It has been shown by Aagaard (1970) that wind transport computations for the Greenland and Norwegian Seas during 1965 result in an annual mean oceanic circulation scheme which quantitatively resembles the known circulation in this area.

Thickness distribution

The structure of the sea ice cover in the Arctic undergoes large seasonal variations, particularly in the marginal seas. The subsurface morphology has been observed from submarines (e.g. Swithinbank 1972, Hibler 1979 and Wadhams 1981a). An example of the under surface profiles given by Swithinbank is reproduced in figure 2, and a compilation of sea ice thickness as observed from submarines is reproduced in figure 3. The observed distribution of the sea ice thickness (Fig. 3) indicates a relative accumulation of ice north of Greenland and the Canadian Archipelago and this reflects the effect of the average drift of ice across the Polar Ocean towards these areas (Fig. 5).

There are few measurements of the ice thickness distribution in the Greenland Sea. According to a submarine transect in October 1976 (Wadhams 1981a) the mean thickness (ice draft × 1.12) varied from 6-7 m near the coast of Greenland to 3.45 m in the marginal area of the Fram Strait.

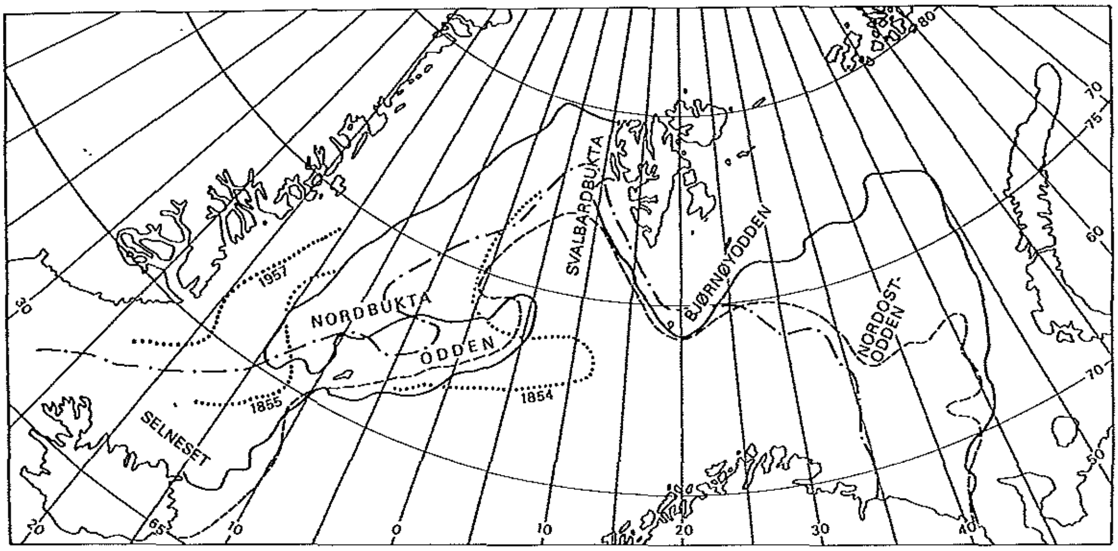

Fig. 1 Maximum and minimum sea ice distribution in the Iceland, Greenland and Barents Seas as observed during the two periods 1853-1875 and 1953-1975. (After Vinje 1976). -.- : 10-20 April 1966, ---- : 10-20 April 1968, ___ : 1-10 April 1970 and ..... : Ship observations in April.

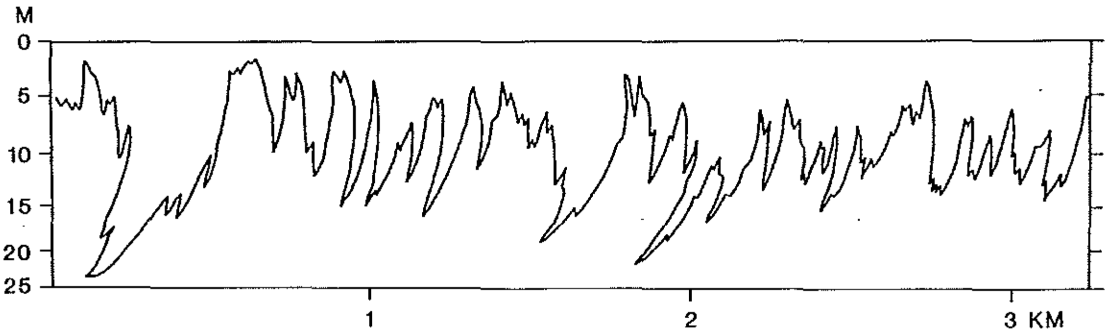

Fig. 2 Features of the underside of the ice as observed from a submarine at 87°N,06°E. (After Swithinbank 1972).

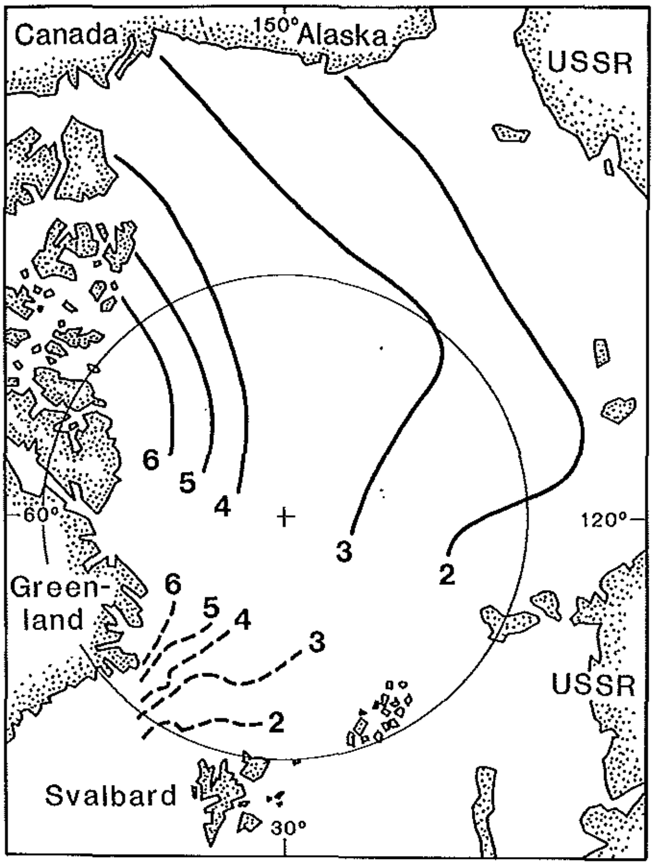

Fig. 3 Ice thickness contours (in metres) as obtained from submarine observations. Solid lines are from composite analysis of both summer and winter data, whereas the dashed contours are from April 1977. (After Hibler 1980).

Measurements from LANCE in July 1981 and in 1982 of even ice in the sea ice margin in Fram Strait yielded averages of 3.7 and 3.2 m based on 23 and 110 drillings, respectively. Statistical calculations indicate standard deviations of 0.5 and 0.2 m, respectively, while sonar profiles may have an uncertainty of 0.2 to 0.4 m according to Rothrock (1981). The contribution to the mean ice thickness from ridged ice, h_e, can be estimated from

$$h_e = 10\pi\mu\overline{h_s^2}$$

(Hibler et al. 1974) where μ is the number of ridges per km and $\overline{h_s^2}$ is the mean square sail height of the ridges. We apply a median value of $\mu = 10\ km^{-1}$ as observed during the U.S. Birds Eye Project (Vinje et al. 1981), and an average ridge height of one metre which is in fair accordance with field observations. This rough correction gives ice thicknesses for 1981 and 1982 of respectively 4.0 and 3.5 m which can be compared with 3.45 m obtained by Wadhams in 1976.

A mean thickness of 3 m is traditionally assumed for the ice moving through the Fram Strait (Zubov 1943, Vowinkel 1964). According to submarine observations, which show that there is a considerable variation of The ice thickness cross stream (Wadhams 1981a and Hibler 1980 (Fig. 3), and the drillings in 1981 and 1982 in the marginal area, an average thickness between 4 and 5 metres seems more likely.

Measurements in the northern Barents Sea reveal great interannual variations. Observations from the Swedish ice breaker YMER in 1980 gave an average thickness of even ice of about 1 metre (Overgaard et al. 1982), corresponding to an average mean sea ice thickness of 1.40 m when corrected for ridging using the formula of Hibler et al. (1974). Observations made in 1981 and in 1982 during the Norsk Polarinstitutt's cruises with LANCE yielded a mean ice thickness of 2.4 with a standard deviation of 0.3 m according to Rothrock (1981). Ridging has then been corrected for by using the above formula and applying the most frequent ridge density, 9 ridges per kilometre, as observed during the Birds Eye Project and assuming an average ridge height of one metre. The considerable interannual variation in the ice thickness as observed in the northern part of the Barents Sea is in all probability due to the variation of the inflow of ice from the Arctic Ocean as well as the degree of maintenance of the local ice cover from one year to another.

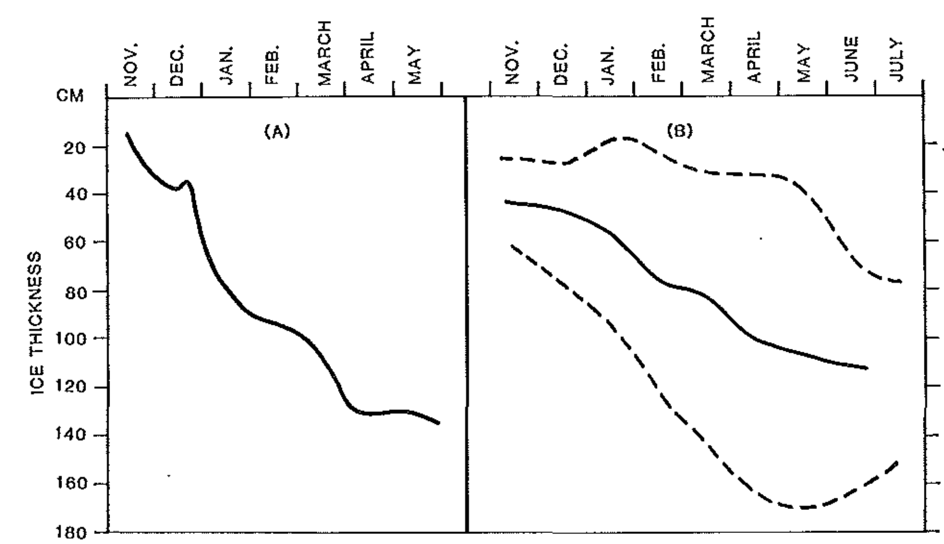

Fig. 4 Left: The annual course of the thickness of the fast ice as measured 1964-1965 at Edgeøya at 77.4°N,22.5°E. (Odd Lønø, pers.comm.). The average air temperature for this season was about 2°C below the long term mean.
Right: Maximum, minimum and mean thickness of fast ice at Hopen (76.5N,25.1°) based on weekly drillings through nine seasons between 1966 and 1982 with a permanent fast ice cover. The maximum thickness was observed in the 1968-1969 season when also extreme low average temperatures were observed (Det norske meteorologiske institutts Årbok).

Measurements of the thickness of land-fast ice at Hopen (Fig.4) show an extreme thickness of 1.73 m in 1969. During this winter season there also occured an extreme low mean temperature in the Barents Sea area. (Det Norske Meteorologiske Institutts Årbøker.) Statistics based on twelve years of ice observations at the Norwegian Arctic meteorological stations reveal a marked peak in the frequency distribution of the ice thickness in the interval 0.9 to 1.5 m at Hopen in march. Further south at Bjørnøya which lies closer to, or in, the ice margin, this frequency distribution becomes flat, with no preferred ice thickness (below 1.5 m) (Vinje et al. 1981).

Drift features

Based on drift data from the period 1893-1965, Volkoc and Gudkovic (1967) find that in areas with a good data-base there is no apparent difference in the average drift speed for the summer half-year (April-September) compared with the winter half-year (October-March). The average drift speed in the Transpolar Ice Drift Stream is nearly constant over a distance of 2000-2500 km out from the Siberian coast, and close to 2,8 cm s^{-1}. The drift speed is accelareted when the Fram Strait is approached where an average drift speed of 7.2 cm s^{-1} has been observed from buoy observations (Fig. 6). The axis of the Transpolar Drift Stream is subject to slow lateral displacements between the Eurasian and the American side of the Arctic, probably because of change in the atmospheric circulation. The direction of this axis will to a great extent determine the sea ice conditions north of Canada, Greenland, Svalbard and the northern part of the Barents Sea. A lateral displacement will also be of importance for the magnitude of the outflow through the Fram Strait, between Greenland and Svalbard. The extension of the Beaufort Gyre is of importance with regard to the inflow of multiyear ice from the Beaufort Sea to the Transpolar Drift Stream. Gudkovic (1966) estimated the area encompassing the anticyclonic drift centered in the Beaufort Sea to vary between 2.5 and 3.5 mill km^2 suggesting a marked interannual variation also in the exchange of ice between the two main ice creams in the Arctic Ocean. According to the drift pattern given by Gordienko (1958), as well as that observed under the Arctic Basin Buoy Programme after 1979 (Fig. 5), the center of the Beaufort Gyre is found in the vicinity of 80°N and 150°W.

Buinitskii (1951) found that for long periods (a season or a year) the currents account for about two-thirds of the total ice drift, while the remaining one-third is due to wind drift. Thus, for example, current drift comprised respectively 70%, 68% and 80% of the total drifts of the *Fram,*

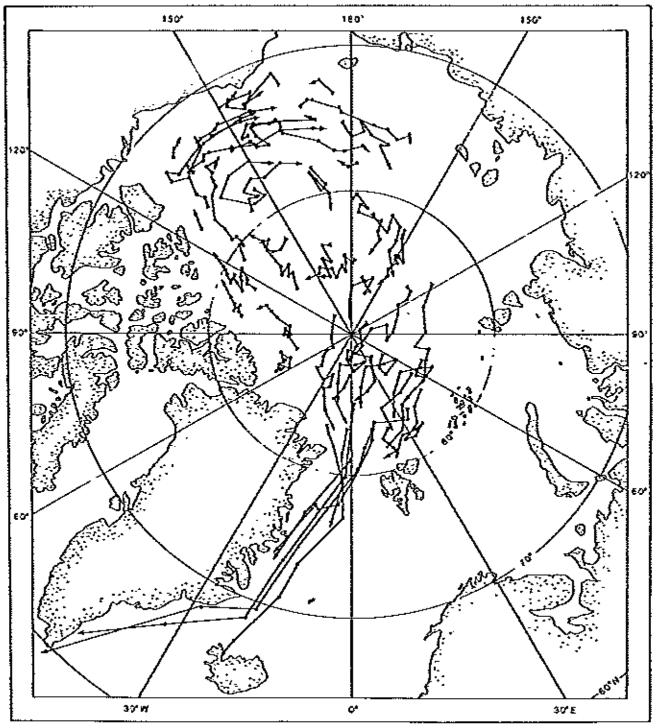

Fig. 5 Drift tracks of selected buoys deployed under the U.S.Arctic Basin Buoy Programme since 1979. Norwegian and Canadian contributions have been made annually since 1981 with buoys and deployments. The position at the beginning of each month is indicated by a filled circle.

Sedov and the Russian manned station North Pole 1. Thorndike and Colony (1982) found that about 50% of the ice drift in the central part of the Arctic Ocean over periods of several months is directly related to the geostrophic wind, while 50% is related to o cean circulation. On shorter time scales in all seasons they find that the percentage share of the total ice drift related to ocean circulation is reduced to less than 30%. There is thus a marked increase, with longer periods of time, of the influence of the ocean currents on the ice drift.

The export of ice through the Fram Strait has been estimated in several different ways. Based on drift observations in the Arctic Ocean, Volkov and Gudkovic (1967) for example estimated an outflow of 0.9 mill km^2 per year for the period 1954-1964. Estimations based on the drift of automatic stations deployed north of the Fram Strait under a Norwegian Ice Drift Experiment (ICEX) which started in 1976 (Fig. 6) suggest an annual mean speed (averaged across the Strait) of 7.2 cm s^{-1}. The annual maximum, the median and the minimum width of the ice stream was 420, 350 and 230 km, respectively, for the ten-year period 1971-1980 (Vinje 1982). The corresponding average values of the sea ice outflow through the Fram Strait then become 0.95, 0.79 and 0.52 mill km^2 year^{-1}.

Zacharov (1976) reports on calculations made for the period 1942 to 1968. He used the observed constant speed of the ocean current (not given) and calculated the wind drift in the Fram Strait. He found a seasonal variation with a maximum in the winter half-year and a minimum in the summer half-year. The annual average was 0.65 mill km^2 per year with a maximum of 0.92 and a minimum of 0.39 mill km^2 per year in 1961/62 and in 1953/54, respectively. Because of the different periods and approaches the various absolute values of the figures cannot be compared directly. Zacharov's figures suggest an interannual variation of 135% while Vinje's observations suggest

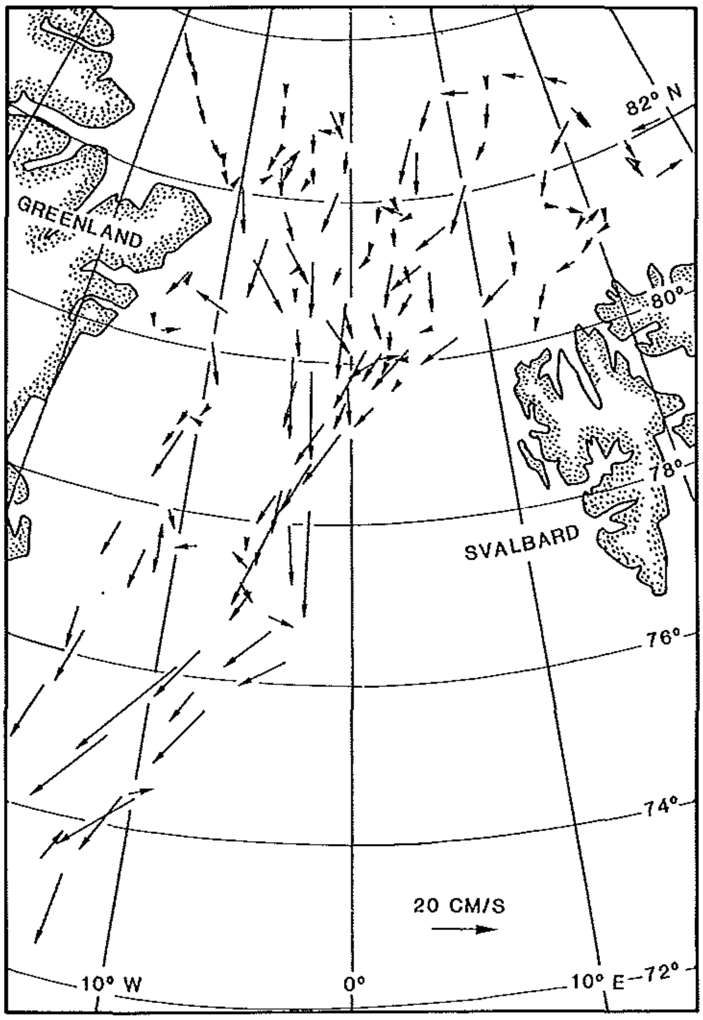

Fig. 6 Ten day averages of drift vectors as obtained from the current Norwegian Ice Drift Experiment (ICEX) performed by NP and DNMI since 1976. The average of the drift components perpendicular to the shortest line across the strait indicates an average annual outflow speed of 7.2 cm s^{-1}.

possible maximum interannual variation of 83%. The ice drift pattern in the strait caused by the oceanic surface currents has been estimated by tracing ice floes on Landsat images during two periods of together three weeks during calm-weather conditions in 1976 (Fig. 10). Assuming a small annual variation, in accordance with the Russian observations mentioned above, we arrive at a current induced ice export of about 0.57 mill km^2 per year. Compared with the above figures for the total export, this observation indicates that the ocean currents play a dominant role in the ice export through the Fram Strait.

The drift speed of the ice generally increases towards the ice edge. The main reason for this is presumeably an increase of the wind induced current in the surface layer, a reduction of the internal stress between the more spread out ice floes, and an increasing roughness because of the increasing length of freeboard per unit area when approaching the ice edge. The degree of ridging plays a very important role in the drift. This is clearly illustrated in Table 1, which is a reproduction of Table 110 in Zubov (1945).

m \ n	1	2	3	4	5	6	7	8	9
1	90	80	70	60	50	40	35	30	25
2	180	160	140	120	105	90	70	60	50
3	270	245	220	200	175	150	125	100	80
4	360	330	295	260	230	195	160	130	100
5	450	410	370	330	290	250	210	170	130
6	540	490	440	395	350	305	260	210	160
7	630	575	520	465	410	355	300	245	190
8	720	650	600	540	475	410	350	285	220
9	810	740	670	590	520	450	390	310	245

Table 1. The wind factor ($\times 10^4$) of ice drifts as a function of concentration (n) and hummocking (m) of the ice. From Zubov (1945), based on measurements made by theodolites at Cape Schmidt (1938-1940).

It is seen that the wind factor for 1/10 ice cover is about three times greater than for 9/10 and that the wind factor increases by as much as an order of magnitude when the hummocking increases from 1/10 to 9/10 of the area. The relatively high effect of roughness on the wind drift may explain why certain ice floes move markedly faster than others under similar wind conditions in an area (e.g. Vinje 1977b). Because of the linear relationship between the wind factor and the hummocking and ice concentration a non-linear change crosswind of the roughness (e.g. ridging or floe seize) or the ice concentration should result in a more or less abrupt change in the drift speed. This will cause the well known increase in the flow speed towards ice edges (e.g. Vinje 1977b and Johannessen et al. 1982).

Fig. 7 A sequence of four LANDSAT images illustrating the marked difference in sea ice margin features which may be observed in areas with variable current shears. The north-western part of Spitsbergen is seen in the lower right part of the figure. The images were obtained 22 May 1976 under a NASA project. See text for further explanation.

Processes in marginal areas

Since the coming of satellites it has been possible to obtain overviews of the sea ice conditions in a great variety of time and space scales. This has to a considerable extent increased our knowledge of the highly variable conditions in the marginal ice zone. Very complex circulation pattern may at times be observed. In figure 7 we see several eddies along the ice edge with different spacings and shapes. High pressure conditions prevailed, indicating calm or feeble winds. Three-quarters of the right hand side of the image covers the area where the warmer West-Spitsbergen Current submerges the cold. At zero degree it is the salinity which determine the density. The polar water has less salinity and is therefore less dense. The striking difference between eddy forms and sharpness of ice edge in this submerging area as compared with the

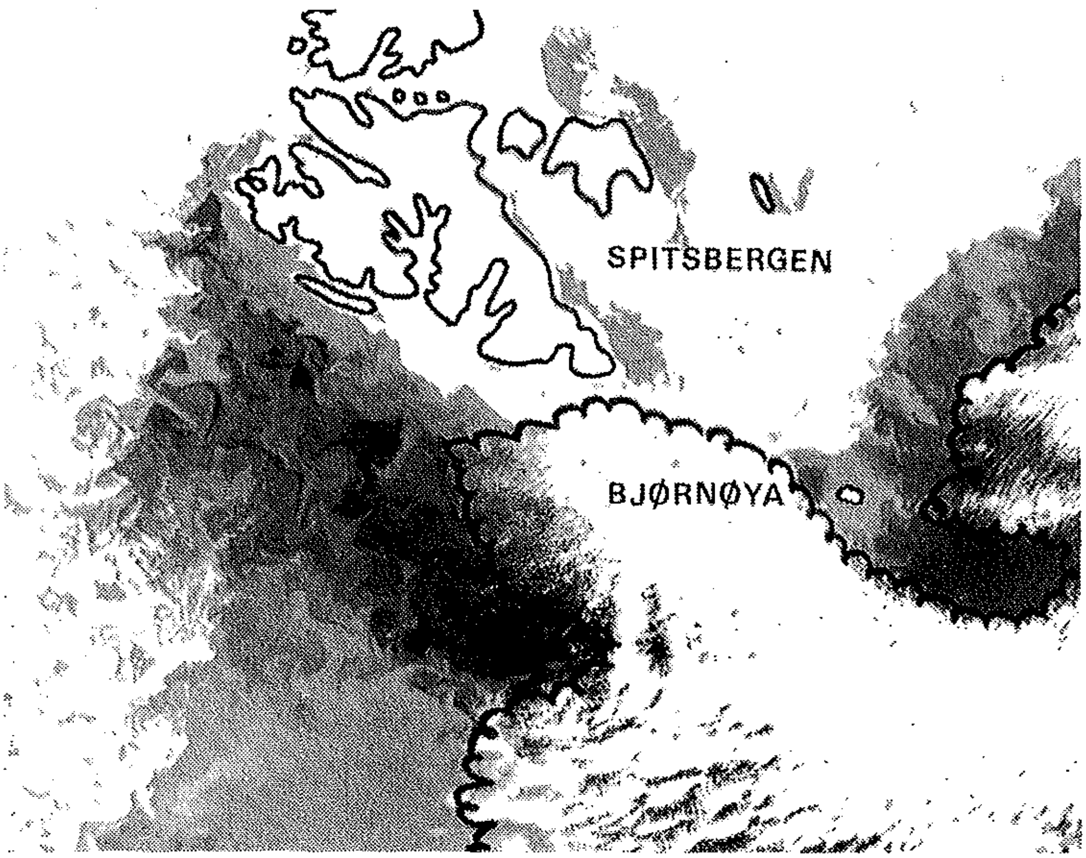

Fig. 8 composite visual and infrared NOAA image displaying the features in the ice margin and the complexity of the mixing processes between the warm and the cold water masses in the Greenland and Norwegian Seas. The maximum difference in sea surface temperatures is about 6°C according to DNMIs Ice Charts. Fairly weak, northerly winds prevailed. Received at Tromsø Telemetry Station 14 May 1981.

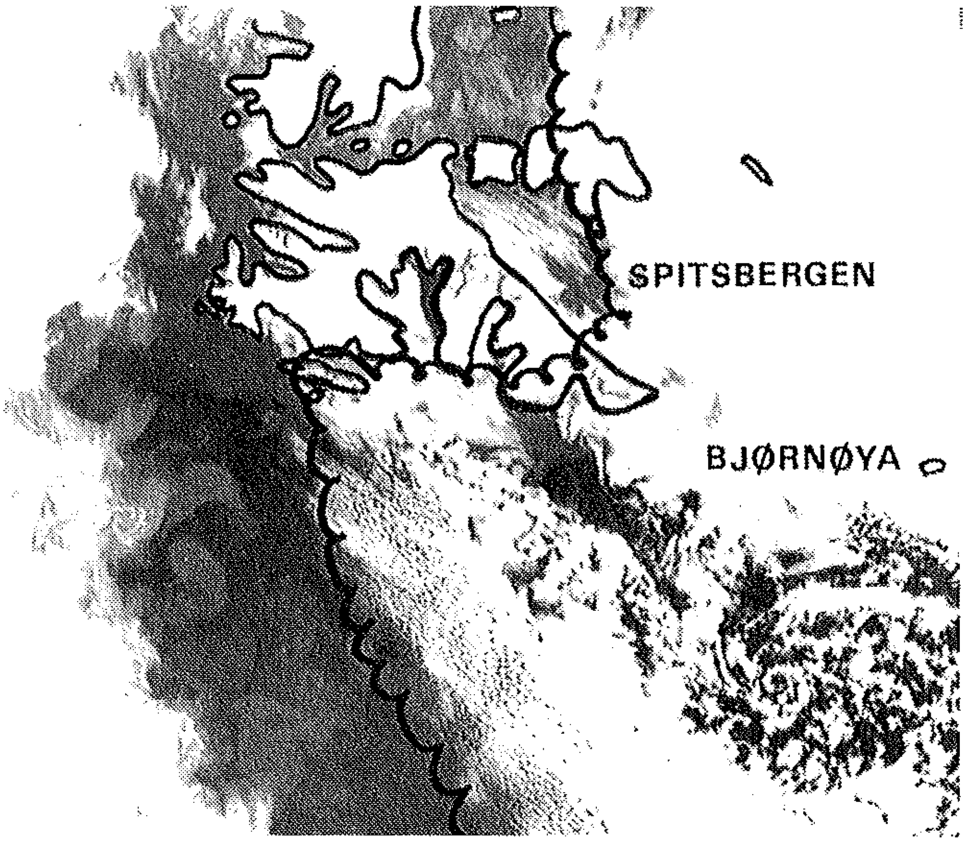

Fig. 9 A composite visual and infrared NOAA image covering the same area as Fig. 8. We note the difference in eddy forms along the ice edge in the Greenland Sea when comparing the two figures. The maximum sea surface temperature difference is about 6°C (DNMI Ice Charts). Received at Tromsø Telemetry Station 5 September 1980.

left hand side of the figure shows that the pattern of interaction between the two current systems is clearly different in the two areas.

The complicated mixing pattern between cold and warm water masses west of Svalbard is also illustrated by the infra-red images reproduced in figures 8 and 9.

We see how the ice may be extracted from the East Greenland Ice Drift Stream into the warmer water (where it disintegrates). This "leakage" seems to go on along the full length of the ice edges both in the Greenland as well as in the Barents Seas during conditions with an off-ice component in the wind. The ice extracting eddies can be observed at intervals ranging from 10 to about 70 km. It seems that the mixing activity becomes more orderly later in the season (Fig. 9) when several well developed eddies can be seen in the water with dimensions varying within a similar range as given above. The exchange of heat across an ice border is accordingly highly variable both in space and time. This shows clearly that to obtain representative averages of the fluxes of heat and mass across an ice edge it is necessary to consider a fairly large part of the ice boundary to secure a representative inclusion of the various types of heat and mass exchanging eddies.

Fig. 10 is based on the tracking of more than 100 ice floes on LANDSAT images. The figure shows the average drift pattern as observed during two periods with calm weather during May and June 1976. We see the narrow jet-like drift in the middle of the passage with a back water circulation extending over a large part of the shelf area east of Greenland. A cyclonic circulation is indicated between 79°-80°N and 0°-5°E where eddies are frequently observed (e.g. Palfrey 1967, Vinje 1982 and Wadhams and Squire 1983).

The sea ice cover and climatic changes

To cover the radiative loss of heat in the Arctic the present equilibrium state is maintained by advection of heat in the atmosphere and in the ocean plus the

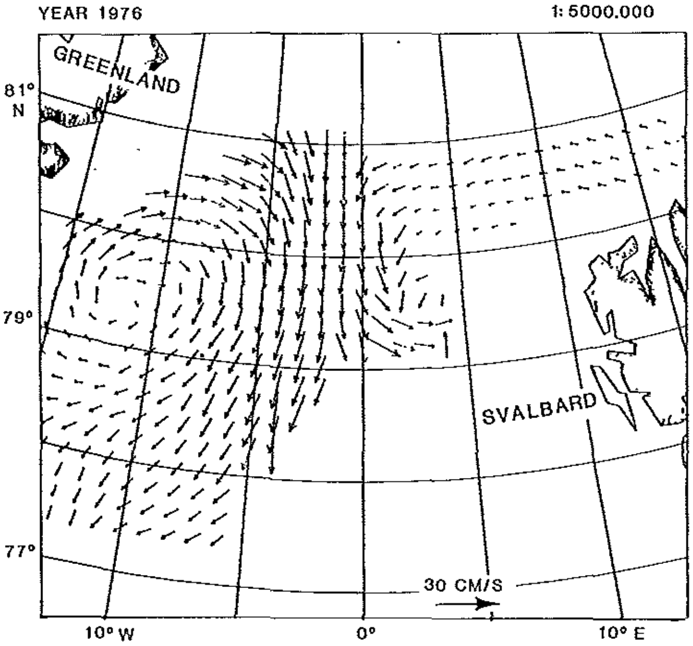

Fig. 10 Interpolated ice drift vectors based on daily observations of nearly 100 ice floes tracked on LANDSAT images during two periods with calm weather, 5-16 May and 1-12 June 1976. The images were obtained under a NASA project (Vinje 1977b). The average drift speed perpendicular to the shortest line across the strait corresponds to a current induced ice export of 0.57 mill km² per year.

heat of fusion released in regions with net production of ice. The influxes in the atmosphere and in the water are calculated to be 75 and 6 W m^{-2}, respectively. The additional gain of heat caused by the freezing of ice in the Arctic Ocean amounts to 3-4 W m^{-2} (Untersteiner 1982). Studies made by Aagaard and Greisman (1975) indicate that the heat budget of the Arctic Ocean is determined mainly by the flows of water and ice that pass through the Fram Strait. The other passages are too constricted and moreover, there are no prevailing current systems which favour exchange through these straits.

The main discussion of the stability of the Arctic ice cover started about 20 years ago in connection with the question of removing the ice cover artificially to improve the climate of the Arctic region. According to Bodyko (1962) a reduction of the albedo with 0.2 would be sufficient for a long term removal of the Arctic ice resulting in warm climatic conditions, as during the pre-glacial times. The heat balance components for the present ice cover has also been computed by Fletcher (1966) and by Donn and Shaw (1966). They found that an increase of the radiation balance in the absence of ice in the Arctic Ocean is not compensated by the heat loss through turbulent heat exchange and evaporation. The compensation could be effected by for example increasing the temperature of the water (and then ice cannot form), or, according to Donn and Shaw, by an increase of the turbulent heat exchange and evaporation in the Norwegian Sea. Doronin (1969) states that the effect or the stratification in the upper layers of the ocean, and accordingly the effect on the surface temperature, has not been considered in the above papers. Taking this into account, Doronin arrived at the conclusion that without an additional advective heat influx, the final stage of the ice regime in the Arctic Ocean and its marginal seas will be the same as at present. This conclusion is supported by Zacharov (1981) as well as by Stigebrandt's (1981) calculations. Stigebrandt presents a model for salinity and thickness of the upper layer of the Arctic Ocean. The parameters are the river runoff to the Arctic, the influx of less saline water through the Bering Strait, the export of ice and a parameter characterizing the vertical mixing. He finds that a decrease of the fresh water supply by as much as 50% would have only a small effect upon the ice thickness and the fraction of open water in the present Arctic Ocean. However, if such a decrease of freshwater supply is combined with a moderate decrease of the flow through the Bering Strait and with a similar moderate increase of the area of exported ice, the pack ice might disappear. The development of an ice free Arctic Ocean accordingly depends upon a series of relatively comprehensive, simultaneous changes both in the fresh water discharge as well as in the atmospheric and oceanographic circulation patterns. The probability of such contemporary changes seems to be extremely small because studies of cores from the Beaufort Sea and preserved marine fauna suggest that the Arctic Ocean has been covered with perennial ice throughout the last several hundred thousand years (Herman and Hopkins 1980). This means that no drastic variation has occured in spite of very great climatic changes, including exceptionally warm interglacial periods. Such a persistence suggests that an ice-covered Arctic Ocean is indeed a very stable state.

The anthropogenic effects will in the future add to the complexity of the question concerning the fate of the Arctic ice cover. We can expect increasing changes in the atmospheric composition because of increased transport of combustion products from distant areas (e.g. Rahn 1982), and if the atmospheric carbon dioxide continues to increase at the present rate, the concentration will have doubled by about the year 2030-2050 (e.g. Mason 1979). Most models suggest a corresponding increase of the global average temperature of 0.5^0 to 3^0C. mainly because of the "greenhouse effect" (e.g. Munn and Machta 1979). This increase is similar to or less than the temperature rises which took place during interglacial periods, for instance during the postglacial optimum between 6000 and 5000 B.P. (SMIC 1971). The models suggest that a doubled carbon dioxide concentration will cause large regional differences in the temperature rise with a maximum in the Arctic. The U.K. Meteorological Office 11-level global model for example suggests a moderate increase of the average global temperature of 0.4^0C with a maximum of 4^0C in the Arctic during winter (Mason 1979).

The stability and the depth of the upper mixing layer of the Arctic Ocean will be crucial in determining the ice regime. The maintenance of the present, very stable stratification is provided mainly by the fresh water discharge from the Russian rivers and the melting. Manabe et al (1981) deduced from model studies that statistically significant changes of the hydrologic variables include large increases in both soil moisture and run-off rate in high latitudes. This effect is caused by the penetration of moisture-rich, warm air into high latitudes. An increased run-off from the continents should secure a maintenance of the low salinity upper layer -and the stability- of the Arctic Ocean. This poleward transport of humid air would in addition cause a significant increase in the thickness and extension of the cloud cover over the Arctic Ocean. Since a relative large part of the incoming solar radiation is reflected from clouds, an increase in the total cloud cover will reduce the heating of the surface and could mask the effect of an increase in carbon dioxide to a considerable extent. The present models thus suggest series of physical changes, which have the potential of neutralizing the heating effect caused by an increased concentration of carbon dioxide in the atmosphere.

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ON THE BIOLOGY OF WHALES

by

P.J.H. van Bree

In discussions on whaling and on the history of whaling it is absolutely necessary to have a basic knowledge and understanding of the biology of whales. In this article I shall discuss the general biology of whales: others will treat the biology and ecology of the species hunted in arctic waters. It is understandable that in a short paper as this one, the subject only can be treated in a very superficial way. For those interested in the subject, a list of publications is given at the end of this article, so that they can study the biology of whales more in detail.

Whales, which can be divided into baleen whales, *Mysticeti*, and toothed whales, *Odontoceti*, are an order of mammals, the order *Cetacea*. Their ancestors were rather primitive non-specialized land mammals, the *Proteutheria*. From these proteutherian mammals groups specialized themselves in anatomy, morphology and biology/ecology. The group of primitive mammals which in the course of time gave rise to the Cetacea was related to what later would become the *Carnivora*, the carnivores, as well as to the group which became the *Ungulates*. The ancestors of the whales became adapted to life in water. Of the first stage we know very little but we imagine that they started like rats or otters and became more and more specialized. Fossil remains from the Eocene show that they still had their external nares, their nostrils, at the front of their heads, and that they still had hind limbs, though already under-developed.

Whether the primitive cetaceans evolved into three different suborders, of which one, the *Archaeoceti*, died out, or into two suborders, the *Mysticeti* and the *Odontoceti*, is at this meeting of little importance. Whatever it may be, we know from fossil remains that the separation between toothed whales and baleen whales took place during the Oligocene, that is between 37 and 20 million years ago. The separate development of the two suborders is reflected in their anatomy, biology and behaviour. The *Mysticeti* became more ruminant-like, the *Odontoceti* stayed more carnivore-like. Relying on the fossil evidence, we surmise that to the middle of the Miocene, cetaceans have been inhabitants of rather shallow tropical waters. Afterwards they moved into temperate and really cold waters of both hemispheres. It is noteworthy that the taxa which moved into colder waters (and into freshwater as well) are mostly little specialized.

After the *Proteutheria* moved from the land into the water (a habitat that at that time was empty for mammals), slowly and steadily an adaptation to the new surroundings took place. The animals lost their hair (except for a few ones on their upper lip when they are still young). Furthermore, their posterior members became smaller and smaller, and eventually disappeared completely. The only remains are the rudiments of the pelvis and in some baleen whales a trace of the humerus. Subcutaneous fat became more and more important: partly as insulation, partly as a source of energy during times without food or sufficient food, partly for lowering the weight and partly to get a streamlined shape, which ensures the least possible resistance to the water. As stated before, the nostrils moved from the front of the head to the top of the head so that the animals could breath lying horizontally in the water. In the Odontocetes, where smell is no longer important, they externally fused into one single blowhole. In the Mysticetes, where location of an odorous food source (e.g. krill) is still important, the nostrils remained well separated.

In most cetaceans the neck disappeared through an extensive development of the muscles between the head and the body, the shortening of the cervical vertebrae and the smoothing effect of the subcutaneous fat. The anterior limbs also became adapted to life in the water. The upper- and the underarm became much shorter, the number of the fingerbones increased and the fingers grew together into a flipper, an organ used to steer the body, and used only in a minor way for propulsion. The main source of propulsion is the posterior part of the body. During evolution, that part of the body became longer and larger and the muscles of that part became very developed. Furthermore, two lateral skin folds at the end of the tail grew into flukes. They enlarged considerably the horizontal surface of the tail and this is most important because cetaceans move in the water by sculling. From anatomical studies we know that the upstroke of the tail is the more important source of propulsion. Furthermore, in a large number of cetaceans, a dorsal skin fold developed into a dorsal fin, an organ that is rather important for stability during diving. For an audience with many non-biologists it may be important to emphasize that neither in the dorsal fin, nor in the flukes, are there bones.

Also internally, many, many changes took place before the forbears of the cetaceans became completely adapted to life in the water. The end of the larynx grew out into a snout-like structure that fitted into the nasal duct ensuring thereby a good separation of the breathing system and the food system. The lungs became more cartilaginous thereby resisting pressure during diving, and a large series of valves are found in the bronchioles. Furthermore, the air in the lungs can be changed in a minimum of time.

Everybody who has seen a baleen whale or a dolphin surfacing, 'blowing', inhaling air and diving again within one or two seconds will understand that this is only possible by great anatomical, morphological and physiological changes. This way of breathing makes it necessary to have both a rapid absorption and a rapid emission of oxygen, and a rapid transport of the red blood corpuscles. And if we think of the dangers humans run when they dive or surface too quickly to or from great depths (diving sickness or the 'bends'), and if we consider that cetaceans can dive to depths over a few hundred meters within a very short time, we realize that also in this respect cetaceans have adapted themselves marvelously.

The new surroundings in which the primitive cetaceans ventured also had an influence on their senses. In the toothed whales, the sense of smell was not necessary any more and became rudimentary. In baleen whales the sense of smell stayed important, though less so than in land mammals. Also the importance of vision became less and a certain kind of regression in the development of the eyes was evident. It must be said, however, that recent studies have shown that that regression is far less than was formerly believed and that sight still plays a considerable role in the life of these animals. As regards the sense of touch little changed. The sense of hearing, to the contrary, became very developed. As compared to human beings cetaceans have an enormous range of hearing. All the sounds we cannot hear are called supersonic, especially the high-pitched sounds, and whales are, more or less like bats, very sensitive to high-pitched sounds. The toothed whales even developed a new kind of sense, the sense of echolocation. Independently this sense developed also in other orders of mammals, like the bats. By producing high frequency vibrations, supersonic calls, they can pick up the reflected vibrations and deduce from the difference in time between the outgoing call and the incoming sound the distance between the animal and the object that worked like a reflector. As compared to what Odontocetes can do with their ultrasonic distance finding system, our human-invented sonar system is very childish and clumsy. It is understandable that the whole ultra-sonic signal system called for an enormous integration centre, a kind of supercomputer, next to the normal brainfunctions. It is therefore very understandable that toothed whales have relatively very large brains. In the popular press the brain size in dolphins has been used, if not misused, to indicate a high intelligence in these animals.

Relatively little changed in the reproduction system. Because of the streamlining of the body there are no external genitalia. In females one finds the genital orifice close to the anus, and on both sides of the genital orifice the teats hidden in skin folds. Only if a baby whale touches these folds does the nipple become erect and protrude; it can then be taken in the mouth. Suckling is hardly necessary as the thick and very nourishing milk is squirted into the mouth of the young. In males the genital orifice is situated more anteriorly than in females. In dead male whales the muscle, that keeps normally the penis retracted in the body, slackens and this muscle relaxation together with pressure from putrefaction gases in the abdominal cavity cause the penis to be squeezed out. Stranded or landed whales with visible penises intrigued seventeenth-century artists and are therefore often depicted.

As whales are mammals and need to breath air, it is self-evident that newly-born specimens must reach the surface of the water as quickly as possible. It is known that in socially-living species other animals, called 'aunties', help the mother to push the baby to the surface. As in other mamals or better, in all other animals, the young are born in the ecologically best suited period. A period either with plenty of food, or with a high temperature, or with both.

In the beginning of the Eocene the sea was one large, empty niche for mammals. But as soon as the first cetaceans adapted themselves to life in the sea, it is clear that competition for food was an important speciation force. More and more different taxa developed, each specialized in a unique source of food or unique combination of food species. As stated before, about 20 million years ago a group of cetaceans developed a system to exploit a new source of food. In this group of whales, the baleen whales, there was a reduction of the teeth and instead they developed dermal ridges laterally in the roof of their mouths which grew out to baleen plates. These series of baleen plates, hanging on both sides of the oral cavity, act as sieves when the water is pressed through them by the closing of the mouth and by bringing up the tongue. This system enables the animals to catch anything from small fishes to calanoid copepodes (rather small pelagic Crustacea), depending on the morphology of the snout and the development of the baleen plates. Animals with very long baleen plates, like the Greenland Whale or the Nordcaper, take normally only small crustaceans to a length of maximally one centimeter, species with shorter baleen plates take larger crustaceans, *Euphausia* species, with a length up to four centimeters, small squids and small fishes. Either they are more or less exclusively feeding on one type of food species or they can change their food-items in relation to the season or place. Preference or better a dependence on a certain food source in relation to time (season) and place determine the occurrence of cetaceans.

In the toothed whales, the Odontocetes, a food specialization can also be noted. There are species feeding exclusively on squids, on larger fishes, on small fishes, on bottom-living crustaceans, or on combinations of these food items. In the Killer Whale, *Orcinus orca,* mainly feeding on fishes, even pinnipeds, birds (e.g. penguins) and small cetaceans are taken.

It is remarkable that in species mainly feeding on squid, like the Sperm Whale, the Beaked Whales and Risso's Dolphin, a reduction of the dentition of the upper jaw is found. It does not seem necessary to grab the slippery and wriggling squid species with teethed jaws, but just taking them and sucking them in seems to be sufficient.

Into the typical biology of cetaceans hunted in arctic areas now and in the past; I shall not enter. For this, see the article by Dr. E.D. Mitchell in this volume. But it is necessary to talk briefly about the taxonomy of the baleen and toothed whales of the arctic an their Latin and common names as there still exists a great deal of confusion about these things among non-biologists. To understand the taxonomy and nomenclature it is necessary to go back in history. Prehistoric men, when roaming along beaches and rocky coasts found often dead cetaceans. Sometimes the cadaver was still fresh, so that the meat and the fat could be eaten and if putrefaction had already started, the fat, or blubber, still could be used for heating or lighting. If the animal was a large one, then the bones could be used as building material. The use of ribs of large cetaceans is known from excavations in many parts of the world and not only from the arctic. Later, smaller cetaceans like dolphins and porpoises were hunted by driving them into the creeks and gullies of tidal flats. And as time progressed, this hunting of smaller cetaceans became more specialized. Fishing nets and harpoons were used and in the early middle ages along the whole European coast small cetaceans were hunted and eaten, especially during Lent. Also North American Indians hunted dolphins in this way. This kind of whaling is still practised outside the arctic, south of the town of Dakar in Senegal and a few other places.

Contrasting with rather flat coasts and shallow waters, in several localities there is deep water inshore and migrating larger whales could be observed by the inhabitants of the coasts. Such places are, for instance: the Bay of Biscay, the Norwegian coast, the North-West coast of North America, the north-eastern passages to the Savu Sea in Indonesia, the East coast of Japan, and to some extent, also along the coast of Alaska, where open watr between the coast and the sea ice forces the whales to migrate inshore. At these places another kind of whaling developed. The whales that were hunted could be harpooned from small boats. It was then possible to hunt the 'right' whales, the species which were slow swimmers, which were so fat that they floated when dead, which had so dorsal fins and which had very long baleen plates, as opposed to the other kind of baleen whales, which had dorsal fins, therefore the common name fin whales, which outswam their pursuers, which sank when dead, and which had rather short baleen plates. The first species hunted by the Europeans and the Japanese was a species whih spent its winter in subtropical waters, feeding in summer in low arctic waters far from the ice. In West Europe it was either called the Nordcaper (it summered also North of the North Cape in Norway) or the Biscayan Whale (females with young migrated close to the Biscay coast), or the Black (Right) Whale, *la Baleine franche.* It was only much later, at the end of the sixteenth century, that the Europeans discovered another Right Whale, the Greenland Whale or Bowhead Whale. Although the sailors, the whalers, knew the differences between the two species, their descriptions were not very clear and not understood by the scientists of the seventeenth and eighteenth century. The two species were confused and a clear sign of that confusion is the Latin name of the Black Right Whale, namely *Balaena glacialis: glacialis* as a name of a species which never meets ice, a curious mistake. The other species, the Greenland Whale or Bowhead, was named *Balaena mysticetus,* probably in relation to its very long baleen plates which were seen as part of the beard. This species is always found near the pack-ice and can be called pagophilic or ice-loving. It was only around the middle of the last century that Scandinavian scientists published clear descriptions of the two species. The confusion between the two species, however, persists in non-biological literature.

To avoid difficulties, I would suggest talking only about the Greenland or Bowhead Whale, *Balaena mysticetus,* and the Nordcaper or Black Right Whale, *Balaena glacialis,* and to keep the term 'right whales' as the name of the family. The more so as in the Southern hemisphere there is another species of right whale, the Pygmy Right Whale, *Caperea marginata.* To the fin whales, the family Balaenopteridae, belong the Blue Whale, the Common Fin Whale, the Piked or Minke Whale, the Sei Whale, the Bryde's Whale, and the Humpback Whale. The third and last family of recent baleen whales consists of only one species, the Grey Whale, a taxon more or less intermediate between the right whales and the fin whales. See also the table given in this article. Among the many toothed whales, the two real arctic species are included, namely the Narwhal and the White Whale or Beluga.

It has already been mentioned that baleen whales mainly feed on planktonic crustaceans, the so-called krill. These crustaceans in turn live on microscopic organisms, namely very small algae and diatoms. The planktonic crustaceans and their food species only can develop in great masses where cold waters, rich in nutritious salts, mix with warmer oxygenous surface waters. This is always at localities deeper than 100 fathoms, thus outside the continental shelves. In the Northern Atlantic during summer such krill-rich areas can for example be found between Norway and the Spitsbergen Archipelago (a), at the Northwestern side of the mentioned archipelago (b), around the Island of Jan Mayen (b), Southeast of Iceland (a), in the Davis Strait (b) and West of Nova Scotia (b) and Newfoundland (a + b). All areas where in the past whaling occurred; at the localities marked with (a) Nordcapers, with (b) Greenland Whales.

WHALES = CETACEA

Toothed Whales = Odontoceti	Baleen Whales = Mysticeti		
	Right Whales = Balaenidae	Grey Whales = Eschrichtiidae	Fin Whales = Balaenopteridae
e.g. Sperm Whale = *Physeter macrocephalus.* Pilot Whale = *Globicephala melaena.* Narwhal = *Monodon monoceros.* *Beluga* = White Whale = *Delphinapterus leucas.* Common or Harbour Porpoise = *Phocoena phocoena.* Dall's Porpoise = *Phocoenoides dalli.* Beaked Whales, etc.	1) Black Right Whale = Noordcaper = *Balaena glacialis.* 2) Greenland Whale = Bowhead Whale = *Balaena mysticetus.* 3) Pygmy Right Whale = *Caperea marginata.*	Grey Whale = Mud Devil = *Eschrichtius robustus.*	Blue Whale = *Balaenoptera musculus.* Common Fin Whale= *B. physalus.* Minke Whale = Piked Whale = *B. acutorostrata.* Sei Whale = *B. borealis.* Bryde's Whale = *B. edeni.* Humpback Whale = *Megaptera novaeangliae.*

Table I. Simplified taxonomic review of the recent Cetacea.

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ECOLOGY OF NORTH ATLANTIC BOREAL AND ARCTIC MONODONTID AND MYSTICETE WHALES

by

Edward Mitchell

A number of the tens of species of *Cetacea,* the whales, dolphins, and porpoises, inhabit waters adjacent to the Arctic Ocean, and seasonally migrate north of the Arctic Circle. Of these, dolphins and porpoises, the Atlantic White-sided Dolphin, *Lagenorhynchus acutus,* the White Beaked Dolphin, *Lagenorhynchus albirostris,* and the Harbour Porpoise, *Phocoena phocoena,* perhaps migrate farthest north in the North Atlantic-Arctic area (cf. Mitchell, 1975a; ed. 1975). Other, larger species of odontocete cetaceans such as the Long-Finned Pilot Whale, *Globicephala melaena,* the Killer Whale, *Orcinus orca,* and the Northern Bottlenose Whale, *Hyperoodon ampullatus,* also migrate far north and the last relates to the ice edge during a substantial part of its life (Benjaminsen and Christensen, 1979). The largest socially mature bulls of the largest of the toothed whales, the Sperm Whale, *Physeter catodon,* undertake lengthy poleward migrations, but in the northern hemisphere they neither penetrate deeply into nor spend much time in Arctic waters.

A few mysticetes or baleen (filter-feeding) whales in the northern hemisphere likewise migrate to high latitudes. The Gray Whale, *Eschrichtius robustus,* now extinct in the North Atlantic, might have migrated north of the Arctic Circle as do Gray Whales today in the North Pacific and Bering Sea, but there is no evidence to prove or disprove this point. The diverse family Balaenopteridae includes species which, in the southern hemisphere, migrate to and feed along the ice edge. In the North Atlantic the most northerly of these are the Minke Whale, *Balaenoptera acutorostrata,* the Blue Whale, *Balaenoptera musculus,* and the Humpback whale, *Megaptera novaeangliae.*

The Humpback and Minke whales have not figured prominently in the history of whale exploitation in the Arctic by Europeans and aborigines. The Minke Whale is the smallest of the slim, large and fast-swimming Balaenopteridae, most of which are cosmopolitan in distribution. It is not easy to catch, and has an inshore distribution (where it feeds on schooling fish in the North Atlantic) and is presently taken off West Greenland by aborigines as well as throughout the North Atlantic by a pelagic fleet. The Humpback is a middle-sized balaenopterid, differing from all finner whales (*Balaenoptera* spp.) in body shape and structure, pigmentation, sound production and behaviour, and appears to be the feeding generalist (Hain et al., 1982) of the family. It mainly takes schooling fish and euphausiids. West Greenlanders have taken the Humpback since at least the eighteenth century but it did not figure in pre-nineteenth century whaling in Denmark Strait and the Arctic Ocean (Mitchell and Reeves, 1983). It is easy to approach but difficult to kill, hence its varied history of exploitation.

These seasonal migrants generally return to temperate and tropical waters during the northern winter. A few cetaceans relate on a year-round basis to the Arctic Ocean and to ice - these are the subject of this essay and comparison.

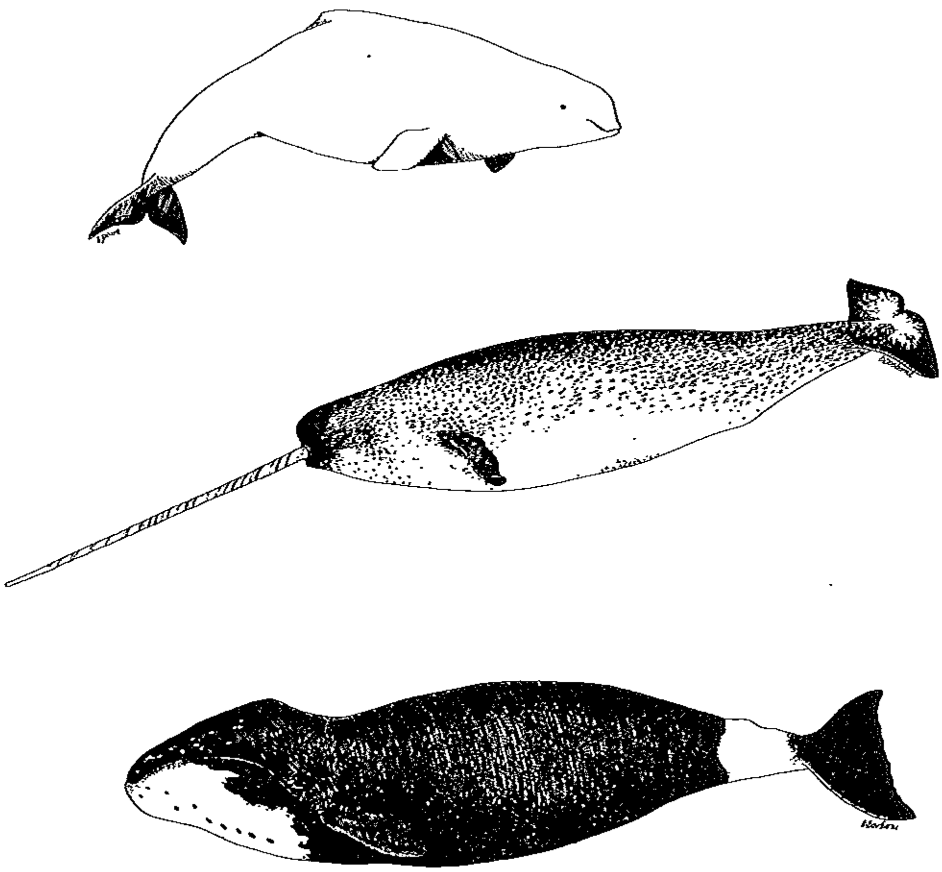

Fig. 1. Arctic whales, from top to bottom: Beluga, *Delphinapterus leucas*; Narwhal, *Monodon monoceros*; Bowhead or Greenland Right Whale, *Balaena mysticetus*. Drawings by B. Dalzell and B.B. Osborne (modified from Mitchell, 1973, *Nature Canada*), not to same scale.

True Arctic Cetaceans

Three species can be said to be adapted fully to the Arctic environment: the Polar, Greenland or Bowhead Whale, *Balaena mysticetus,* the White Whale or Bėluga, *Delphinapterus leucas* and the Narwhal, *Monodon monoceros* (Fig. 1). The Black or Biscayan Right Whale *Eubalaena glacialis* and the Bowhead Whale, and to a much lesser degree the White Whale and the Narwhal supported the pre-nineteenth century expansion of whaling by Europeans, spreading from the continent offshore to Iceland, Spitsbergen and Greenland. The Bowhead, Beluga and Narwhal have possibly relict distributions restricted to Arctic and ice-infested waters, and have no anti-tropical analogue in Antarctic waters.

The Bowhead (Scoresby, 1820) and Right Whales comprise, along with a poorly known and apparently rare pygmy species, the mysticete family Balaenidae. Abundant in historic times, populations of tens of thousands in different regions were depleted by whaling. All existing populations presently number in the low to middle hundreds, or in one case in the Bering Sea Bowhead stock, low thousands. In the North Atlantic and adjacent Arctic, the Bowhead and Right Whales appear to have mainly allopatric distributions (Reeves and Mitchell, 1983 Ms and references), enhanced by behaviour, and have been regarded by some taxonomists as congeneric. The two species are similar in body size, shape and aspects of colouration, they have similar feeding preferences, and early whalers and current scientific studies have found their behaviour similar. Since they are closely related taxonomically and are allopatric to a high degree, the simplest interpretation of their life history is that they are likely to be similar in many of their biological parameters.

Their feeding habits or preferences appear almost identical. The Bowhead feeds primarily on copepods and euphausiids, and on hyperiid amphipods and mysids in some regions; the Right Whale feeds primarily on copepods and euphausiids (Nemoto, 1959, 1970; Mitchell, 1975b). This similarity in feeding habits, morphology and behaviour indicates that they are potentially close competitors and may partly account for their allopatric distribution. It also helps explain why the two were not distinguished by many whalers and most zoologists until late in the nineteenth century. Together, the two species comprised a pool of "Right Whales" with a nearly continuous distribution from the shores of the Bay of Biscay where Basque whalers developed the technology to take large whales pelagically, to Spitsbergen where whaling became an important commercial enterprise of substantial political interest to Europeans. Right Whales were highly important to whalers because of their slow swimming speed, high oil and baleen yield, and the usual buoyancy of their carcasses.

Little is known of growth and age in Bowheads. Few gonads have been collected and examined by biologists from any bowhead population, and nothing is known of ovulation rates. The interval between calves is not known from direct evidence. In eschrichtiids, ear plugs (the waxy accumulation in the external auditory meatus) have been found to show growth layers and have been used for age determination studies (Rice and Wolman, 1971). The ear plug was first found to show growth layers in balaenopterids (Purves, 1955). Growth layer groups have long been used for age determination in some species of balaenopterids but have proven unreadable in adequate samples from some populations. Growth layers have also been sought in other tissues. Klevezal' and Mitchell (1971) found growth layers in the auditory bullae of Fin Whales, *Balaenoptera physalus* and Sei Whales, *Balaenoptera borealis,* and this pattern of growth layers has been found in other balaenopterids (Christensen, 1981). However, comparable results have not been found to date for many balaenids. Omura et al.(1969) found "12 dark laminae" in an ear plug from a North Pacific Right Whale. Braham et al. (1980) reported that the ear plugs of a few Bowhead Whales showed no growth layering. Apparent growth layers are present in the periosteal bone on the dorsal surface of the involucrum of the auditory bulla (Fig. 2) in bowheads (Fig. 3).

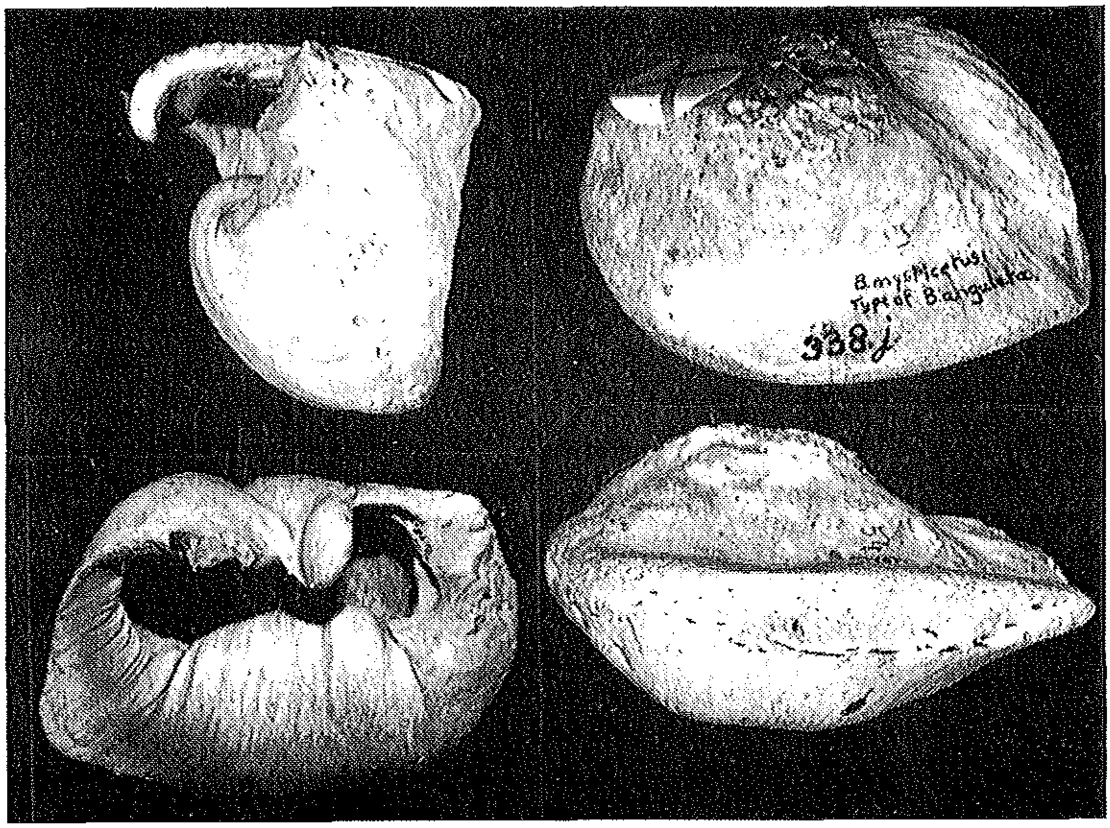

Fig.2. Auditory bulla of balaenid whale, BM (NH) 338j (type of *Balaena angulata*. Gray, 1871).

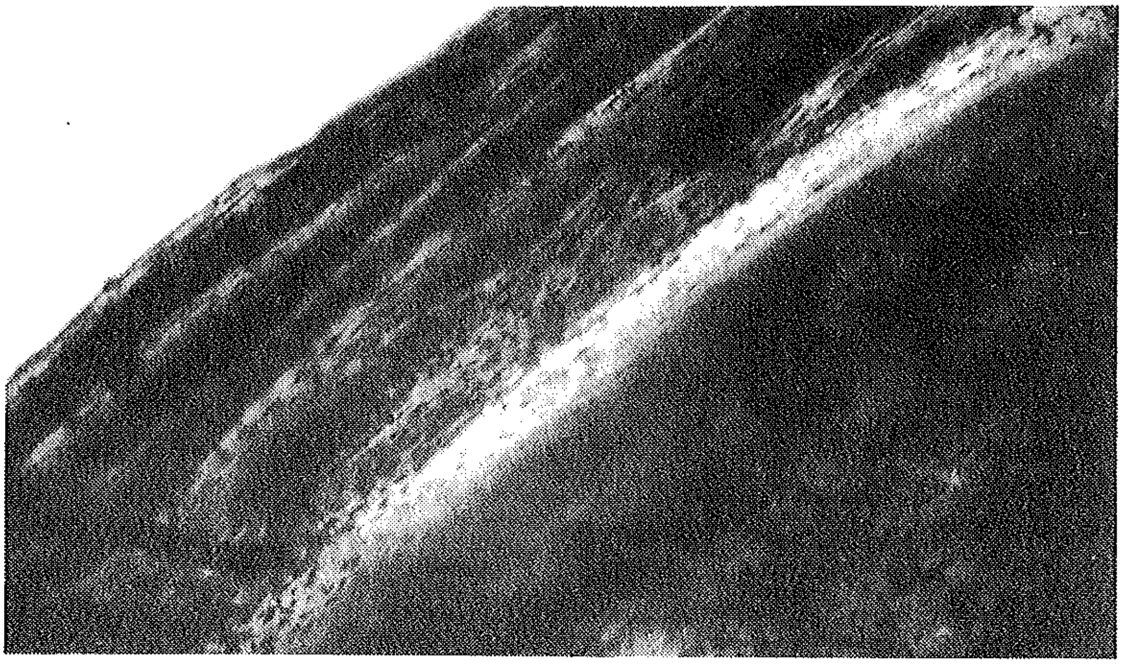

Fig. 3. Photomicrographs of transverse section through dorsal surface of involucrum of auditory bulla of *Balaena mysticetus* (LACM 54754).

The Beluga and Narwhal are four or more meter long white to dark gray odontocetes, with reduced and specialized dentition, distributed in a number of separate circumpolar populations (Kleinenberg et al., 1964, 1969; Vibe, 1950, 1967; Sergeant, 1968, 1973; Leatherwood and Reeves, 1982; Mansfield, et al., 1975; Reeves and Tracey, 1980; Finley and Gibb, 1982). Having the same body size and general shape, they differ markedly in dentinal specializations and in details of body colouration, schooling habits, and possibly social structure and feeding habits. A variety of evidence published to date indicates that the Narwhal dives longer and feeds more deeply than the Beluga. It has been perceived as frequenting ice fields and ice cracks in winter, while the Beluga prefers the floe-edge and open water. Similar prey are taken by both species especially squid, Arctic cod, halibut or other flatfishes, shrimp, and other crustaceans. The Narwhal also takes mysids (like the Bowhead), and the Beluga takes small schooling fish such as herring and capelin where available. The Narwhal and Beluga have long been thought to be closely related, and have comprised the entire family Monodontidae. They are geographically sympatric but adaptively divergent and have apparently partitioned the water column and feeding resources although they are often found together. Aboriginal and commercial hunting practices took advantage of the social nature of Belugas and their inshore, ice edge and estuarine habit (Mitchell and Reeves, 1981).

Problems in interpreting life history and ecology of Arctic cetaceans

One major problem is the obvious one of collecting biological data on species that dwell in or near ice fields in the winter. Little is known of reproduction, feeding, and social structure and behaviour during winter months for any of the Arctic species. Perforce some of the knowledge about them must come from inferences and comparisons.

Although, as has been mentioned above, the Narwhal and Beluga have generally been regarded as closely related species with different ice-related, diving, and feeding habits (Sergeant, 1978), examination of stomach contents and construction of food webs (e.g. Davis, et al., 1980; Bradstreet and Cross, 1982; Finley and Gibb, 1982), do not bear this out. Both species have nearly the same primary prey preferences in the same regions. (The apparent diversity of the prey taken by belugas may reflect their wider geographic distribution and subdivision into isolated stocks - and the availability to some of these stocks of different prey.) In the Canadian eastern Arctic, the narwhal and beluga show markedly similar feeding habits (e.g. Figs. 7-8, Davis et al., 1980).

I do not necessarily subscribe to the generally prevailing interpretation and consider it useful to frame an hypothesis alternative to this view.
The resulting two hypotheses are:

1. The Beluga and Narwhal are closely related monotypic genera in family Monodontidae, and they are geographically sympatric but avoid direct competition by character divergence.
2. The Beluga and Narwhal are not closely related species, possibly not even belonging to the same taxonomic family. They are geographically sympatric due to utilization of similar resources. Differences stem not from character divergence but from different ancestry.

In support of the first hypothesis there is a substantial body of data available in published form. But it must be pointed out that Kasuya (1973) concluded in an examination of ear bone morphology that the Beluga and Narwhal are related only distantly through common ancestry in kentriodontids, and he placed the Beluga with *Orcaella* in a family Delphinapteridae, separate from a monotypic family Monodontidae. Mitchell (1975a, p. 65) commented on the similarity between Belugas and the Irrawaddy River Dolphin, *Orcaella brevirostris.* The two might represent an old, antitropically distributed species-pair. Clearly, more research on this point is needed. If the Narwhal and Beluga are in fact not closely related but convergent from different mammalian groups, care must be taken in assuming similarities in, e.g., their biological parameters. For example, the growth and age features of Narwhals and Belugas have been taken to be similar. Yet, a closer examination indicates some apparent differences and substantial problems of evidence and interpretation.

Most odontocete cetaceans show by current interpretations one growth layer group (GLG) deposited in hard tissue per annum (cf. Perrin and Myrick, eds., 1980 and appended papers). However, the Beluga has been interpreted to deposit two GLG per annum in the teeth (Sergeant, 1959; Kleinenberg and Klevezal', 1962a, b) concurrent to the deposition of only one GLG per annum in the dentary (Brodie, 1969). The Narwhal on the other hand is interpreted to deposit only one GLG per annum in teeth and dentary tissue (Hay, 1980). Differing interpretations of the Beluga data (e.g. Ohsumi, 1979) have not led to a resolution of the problem, and Brodie (1971, 1982) concluded that the simplest explanation of the data is that the Beluga is different in this regard (Figs. 4-5).

Clearly, problems concerning the intrinsic and extrinsic factors affecting GLG deposition in hard tissues of monodontids require much more work and should be a research priority (e.g. Bada, et al., 1983). If this disparity is true, what might affect the Beluga differently such that twice as many growth layer groups are deposited in a year in the teeth of this species than in all others? Most comparisons do not emphasize the differences between Narwhal and Beluga migratory or reproductive cycles. Indeed, due to the nature of the stringent environment in which they coexist, they must undergo roughly similar migrations in terms of latitude and day length.

Various observations on sloughing of the skin of the Beluga (e.g. Kumlien, 1879; Bartman, 1974) have been suggested to me to represent the possibility of annual molt in this species (T.G. Smith, pers. comm. 12 VI 83). This might represent some additional physiological stress or change for Belugas not otherwise present in an annual cycle for other cetaceans. But even if true it would not appear to represent the suitable factor affecting dentine deposition on the evidence of timing alone.

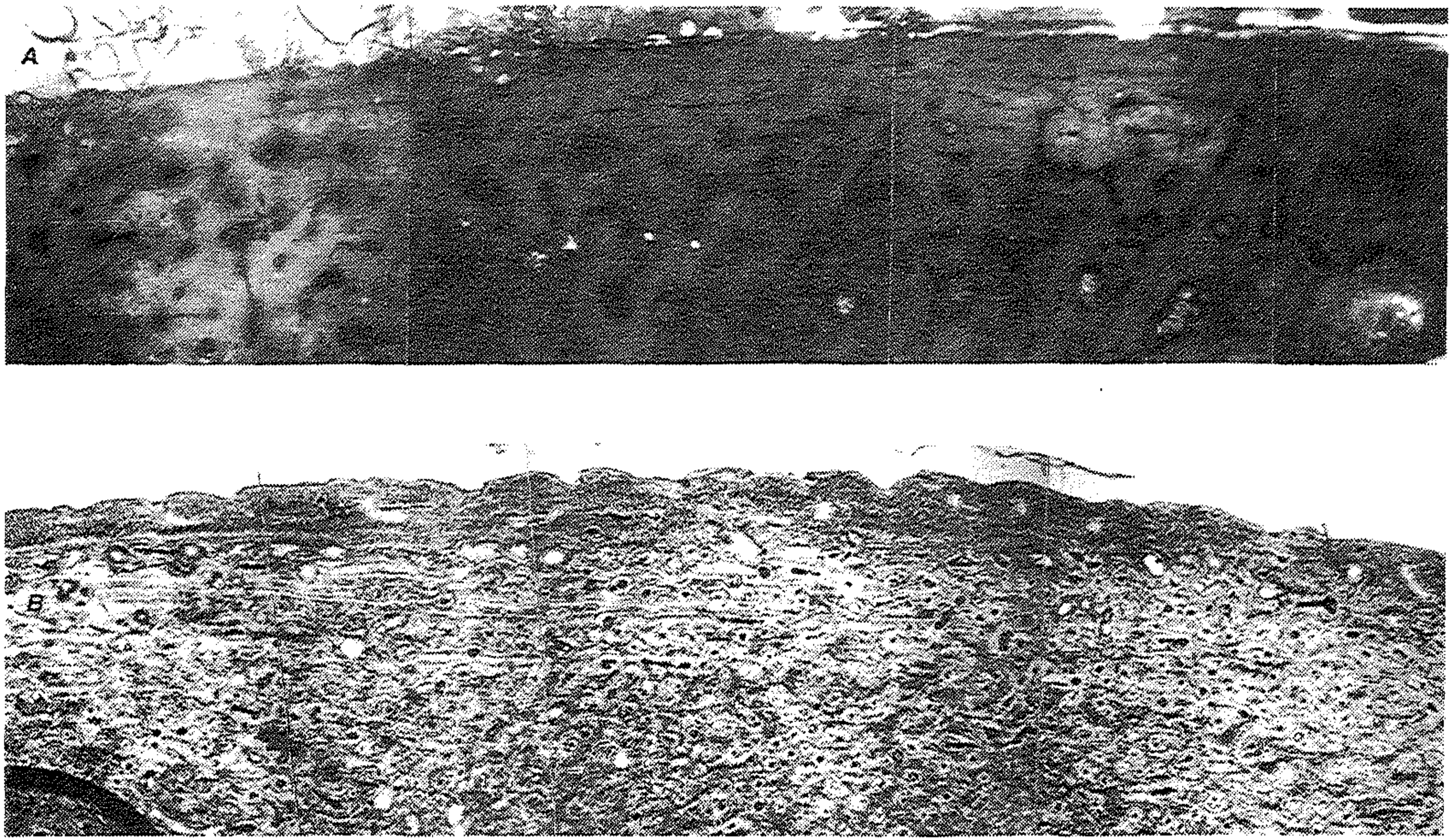

Fig. 4. Photomicrographs of transverse sections through premaxillary bone (A), and left dentary (B), of 404 cm. long, female *Monodon monoceros* (EDM 1423). Eight observers counted an average of 10 growth layer groups in etched, longitudinally-sectioned preparations of unerupted tusks from this individual narwhal (cf. Table 8, Perrin and Myrick, eds., 1980). Note growth layers being modified by haversian systems. Section is approximately 12 mm wide in A, and approximately 15 mm wide in B.

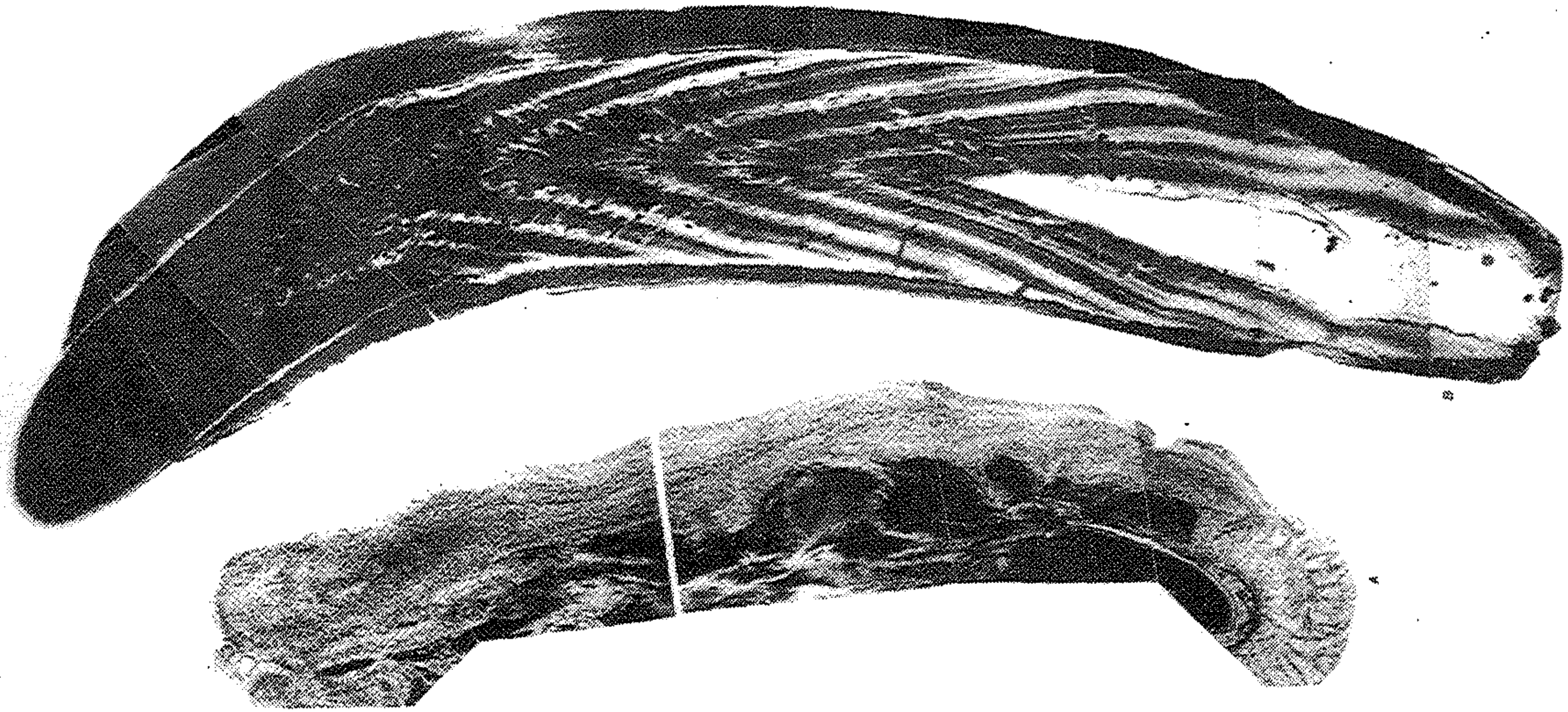

Fig. 5. A. Photimicrograph of longitudinal section of an upper right vestigial tooth (Eales, 1950) of 404 cm. long female narwhal, *Monodon monoceros* (EDM 1423; cf. Fig. 2). Tooth is approximately 17.5 mm long.
B. Photomicrograph of longitudinal section of an upper right tooth of 320 cm. long male *Delphinapterus leucas* (EDM 1420). Eight observers counted an average of 8 growth layer groups in sections of teeth from this individual beluga (cf. Table 9, Perrin and Myrick, eds., 1980). Tooth is approximately 23.5 mm long.

Conclusions

Substantial problems remain in documenting and interpreting the life history and ecology of Arctic cetaceans. Paramount among these is the determination of age on a reliable basis from obtainable samples from Bowheads, Narwhals and Belugas. Various techniques to interpret growth layer phenomena in hard tissues of these species appear promising.

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HISTORY OF NATIVE WHALING IN THE ARCTIC AND SUBARCTIC

by

Allen P. McCartney

Introduction

Commercial whaling's importance to European and eighteenth and nineteenth American economic development is clearly recognized in historical accounts of the major fisheries (Scoresby 1820; Scammon 1874; Jenkins 1921; Sanderson 1956; Matthews 1975; Ross 1975; Bockstoce 1977). From the Bay of Biscay to Newfoundland and from Spitsbergen to the Bering Sea, Euro-American whalers contributed to geographic discovery, colonization, and trade routes as they sought out train oil, whalebone (baleen), and other products. Whaling was no less important economically to coastal Native American societies but, in contrast to European documentation, non-literate Indians and Eskimos left no records of whaling beyond an occasional painted or incised sketch of harpooned whales. There exists no comprehensive "history" of Native whaling along New World and adjacent Northeast Asian shores, although Lantis (1938), Heizer (1941, 1943a), Huntsman (1963), and Bisset (1976) offer valuable regional comparisons of whaling techniques and associated social/religious observances. Heizer (1968) compiled an aboriginal whaling bibliography, and many other authors describe whaling within one society.

This short paper provides no more than a summary of 1) the antiquity of whaling in the New World Arctic and Subarctic, as well as on the Asian side of the North Pacific, 2) the comparative distribution of whaling in those regions, and 3) the common modes of human behavior necessary to successfully hunt and use large whales. Before discussing these themes, several caveats are in order. The pursuit of large whales such as bowheads and humpbacks is emphasized over smaller belugas, narwhals, and beaked whales because the former were the most dangerous to hunt in the past and are the most endangered today. Secondly, procurement technology and use rather than social and religious significance are stressed, since the latter is difficult to discern from the prehistoric record. However, it is acknowledged that whaling among coastal societies is a primary determinant of hunting and thus social rank, of a community's ritual organization, and of economic organization as a function of food and material surpluses provided. Key ceremonial activities derive from the cosmological importance of whales to

Native groups (e.g. Lantis 1938; Spencer 1959; Huntsman 1963). Finally, much of our knowledge of early Native whaling comes from the incomplete archaeological record and from occasional references contained in Euro-American documents. To review the antiquity, spread, and patterns of whaling, then, is very much a matter of interpreting fragmentary evidence.

If a tone of anthropological relevance is in order, let us remember that the "whale problem" facing us today, that of conservation of species, is the result of past *human* predation. Anthropological investigations into the Native, pre-commercial whaling period can provide baseline data about species ranges, densities, sizes of animals taken, and procurement techniques against which to evaluate the impact of later commercial whaling.

Evidence of Whaling

Our knowledge of Native whaling and whale use is based, in the main, on prehistoric, ethnohistoric, ethnographic, and biological information (McCartney 1980). For the prehistoric period, we note the occurrence, depending upon time and place, of whale bones used in old dwellings and related structures, and baleen and bones transformed into implements that made northern adaptation possible. Large harpoon heads found at Siberian to Greenlandic archaeological sites are almost identical to those used by nineteenth century Alaskan Native whalers, and demonstrate an unbroken technologic sequence which lasted for almost two millennia. In addition, the infrequent engraved or painted depiction of contemporary whaling scenes from the prehistoric past serves as strong evidence for past whaling. Indirect evidence for whaling includes the prehistoric presence of hunting and boating gear that could be applied to large whales, but also to smaller sea mammals, and requisite community size to field multiple boat crews (Bockstoce 1976). Circumstantial evidence includes cultural continuity between prehistoric peoples and recent whaling societies, the overwhelming inclination for hunting bands to take advantage of large meat "packages" within their technologic grasp, and the association of winter meat caches or storage pits with coastal settlements of permanent houses that were occupied for a number of years. To be sure, the presence of whale bones and baleen in prehistoric sites does not necessarily imply that whale *hunting* took place, in contrast to scavenging of beached dead whales, but this conclusion is a reasonable one in most cases.

Ethnohistoric whaling accounts - those descriptions or references left by early explorers, seamen, and traders - and ethnographic data collected by more recent trained field observers comprise a second major category of whaling evidence. Northern peoples wrote nothing of their own life-styles in early contact times, but European explorers often documented, usually in a pejorative vein, the ways that Eskimos and other indigenous people lived, including the occasional reference to whale hunting and use. Earliest Europeans in any particular region could only learn about Native patterns such as whaling by direct observation, as they did not understand the Native language and therefore could not record accounts of prior whaling experiences. In addition, European descriptions of voyages and discoveries usually dwelled on such objectives as finding a Northwest Passage and the hardships of arctic journeys rather than the lives of Natives who were so briefly encountered. Although Natives are better described and portrayed in drawings (depending upon the locale) by the early nineteenth century, this is also the period when European whaling was beginning to have a significant impact on New World whale stocks and Native subsistence-settlement patterns. Eskimos and adjacent groups possibly found themselves competing with foreign ships over decreasing numbers of whales, and at the same time they were lured to whaling outposts and wintering harbors to improve their trade connections. Foote (1964) and Ross (1975), for instance, describe whaler-Native acculturation for the western and eastern New World Arctic respectively. Thus, as the mechanisms for describing Native whaling practices were enhanced, there was less Native whaling to describe (Taylor 1979).

A final category of whaling evidence, independent of the above human contexts, is modern (or ancient) cetacean distributional, ecological, and anatomical data that suggest past ranges and behavior (Taylor 1974:25; McCartney 1975:313). To cite a ready uniformitarian example, the fact that bowheads are ice-edge whales today with slow swimming habits allows us to infer that bowheads a millennium ago expressed the same behavior as they were pursued by Natives. Obviously modern stocks are greatly reduced from what they once were in the pre-commercial whaling period, but individual whales were constrained then, as now, by food availability, ice, water depth, and related factors. Heizer (1968:345) notes that:

> The practical duplication of the hunt carried out with this (harpoon and float) technique by recent Europeans and primitive peoples is a remarkable fact, and may be explained in terms of being a functional parallel which has developed as the only method which would work successfully under the same basic conditions of a simple technology, the sea, and the habits of whales.

Areal Survey

Northwest Coast

This areal survey begins on the subarctic Northwest Coast. Sea mammal-hunting here originated with the Early Developmental stage (3500-1500 B.C.; Fladmark 1982: 110ff), exemplified by the Charles phase (c. 3500-1500 B.C.) and the Locarno Beach phase (c. 1500-500 B.C.) in the Gulf of Georgia area. One- and two-piece toggle harpoons, some slotted for end blades made of mussel shell and ground stone, are found in addition to fixed barbed heads. In the following Marpole phase of the first millennium A.D., the Northwest Coast pattern of more recent times arose. While direct evidence for whaling in these archaeological cultures is absent, the development of a sea mammal hunting pattern potentially made possible the hunting, rather than just scavenging, of large whales that frequent this coast today. The Northwest Coast, as an area stretching between northern California and the Gulf of Alaska, is characterized by prehistoric shell midden sites which contain whale bones and whale bone artifacts.

During the nineteenth century, most coastal tribes used dead drift whales, but the Nootkan speakers of Vancouver Island and the related Quilliute and Quinalt of the Olympic Peninsula were outstanding whalers (Scammon 1874; Curtis 1913, 1916; Drucker 1951, 1965). Whaling of the Makah tribe of Cape Flattery, the southerly Nootkan group, was especially well described between the 1870s and 1920 (Swan 1870; Waterman 1920). Using the dugout Chinook canoe, eight or more men paddled offshore to the whaling grounds where California gray, sperm, humpback, finback, blue, and killer whales passed. Of these, grays and humpbacks were commonly hunted but other species were used when animals washed ashore from natural causes. A whale was struck with a massive 18-20 ft. harpoon with mussel shell-bladed head attached to 60-100 ftm. of cedar and spruce line. Sealskin floats were secured to the line for drag and buoyancy. The harpoon was too large to be thrown and was thrust into the animal. Nearby boat crews were alerted to a struck whale and the animal was eventually lanced to death and towed to shore using additional seal floats for buoyancy. There, the whale was butchered according to strict rules of division, and feasting and ceremonials took place. Blubber and oil were especially important to the Indian diet of fish and other foods.

Although such northern and central Northwest Coast Indians as the Tlingit, Haida, Tsimshian, and Kwakiutl did not engage in late nineteenth century whaling (e.g. Drucker 1955:16; Krause 1956:124-125; de Laguna

1972:41, 373), the conventional anthropological wisdom is that whaling must have been practiced along the entire Northwest Coast in earlier periods. Similarity of Nootkan harpoon and float whaling with that of Alaskan Eskimos suggests a spread of this whaling pattern in ancient times (Lantis 1938; Birket-Smith 1953:196; Drucker 1955:199-200; Huntsman 1963:122). Archaeologists have suggested prehistoric cultural connections along the Northwest Coast-Southwest Alaskan continuum based on other evidence (Borden 1962; Dumond 1978:89). Prehistoric contact between Northwest Coast and Alaskan Eskimos may also be seen through the similar mythical treatment of a giant who feeds on whales. Among the Makah, this giant Indian also takes on the guise of a thunderbird, whose flapping wings produce peals of thunder. This thunderbird, in consort with the lightning fish (Fig. 1), seizes a whale at sea and carries it to the mountains where he feeds upon it (Swan 1870). The Northwest Coast version can be compared to an Alaskan thunderbird-whale design engraved in a nineteenth century ivory whaling harpoon rest collected by Edward Nelson at Cape Prince of Wales (Fitzhugh and Kaplan 1982:184, Fig. 226). In this example, thunderbirds (eagles) lift bowhead whales from the sea. Another example of this theme is shown on two North Alaskan spruce wood breast plates worn with masks in ceremonies (Murdoch 1892:370-372, Fig. 372). These show giant men atop whales, perhaps portraying the thunderbird's alternate human aspect. Asiatic Eskimos and Chukchi also share in the mythological interaction between giants, eagles, and whales (Chlenov 1983). Finally, killer whales are a

Fig. 1. Thunderbird with lightning fishes seizing a whale

dominant element of the highly developed Northwest Coast art forms of carving and painting but these animals were not hunted.

Southwestern Alaska

Moving into the Gulf of Alaska region northwest of the Northwest Coast, we note that the Eyak Indians used washed up whales for meat, fat, and baleen (Birket-Smith and de Laguna 1938). The Chugach Eskimos evidently knew two whaling patterns, one in which large boat crews harpooned whales and towed them ashore in the northern Eskimo manner, and one in which hunters in two-holed kayaks used poisoned lances on whales (Birket-Smith 1953). In the latter case, the whales would wash ashore, if at all, within several days. This poisoning technique is an extension of that used by Aleuts and Koniags described next. Several archaeologists report whale bones in coastal Gulf of Alaska region sites, including de Laguna and others (1964) for Yakutat Bay, de Laguna (1956) for Prince William Sound, de Laguna (1934) for Cook Inlet, and Lobdell (1980) for Kachemak Bay. These date at least as early as the first millennium A.D..

Kodiak and the Aleutian Islands are treated together because many whaling techniques are shared between the two areas. Clark (1975:212-213) suggests that Ocean Bay II slate lance points, dating to the second millennium B.C., may have been used for whaling, as were similar points in late prehistoric times. A number of midden sites among these islands, dating as early as 2500 B.C., have whale bones as structural pieces as well as bones made into implements (Jochelson 1925; Hrdlicka 1944, 1945; Heizer 1956; Clark 1974). Dall's (1877) description of prehistoric Aleutian sites, the first archaeological treatise for Alaska, lists bones of killer whale, humpback, Pacific right, bowhead, gray, blue, finback, and sperm whales found in such shell middens. If correctly identified, most of these bones represent drift whales as the humpback was the only commonly hunted species (Turner 1886:200; Elliott 1886:151; Bisset 1976:107). Lucian Turner's 1886 *Natural History of Alaska* lists several species of large whales sighted in and around the Aleutian chain, and these animals were hunted and processed locally during the twentieth century at the Akutan whaling station (Birkeland 1926).

Typical of nineteenth century Russian period accounts is that given by Von Wrangell in 1839 who described eastern Aleutian whaling as follows:

> A single Aleut in his single-oared baidar, and armed only with a short spear the point

> of which consists of sharp, ground slate, attacks this giant of the sea; he approaches him cautiously from behind until he gets in the vicinity of the head, thrusts his weapon into his body under the front fluke, and goes away with the greatest rapidity. If the spear has penetrated through the blubber into the flesh, the wound is mortal; within 2 or 3 days the whale dies; the current or the waves throw the body on the nearest shore. Each spear carries a certain mark, by which one recognizes the catcher and owner of the same if the weapon still sticks in the body of the slain animal (Heizer 1943a:429).

This and similar nineteenth century depictions indicate that whaling was done from one-or two-hole kayaks (baidarkas) rather than from umiaks (baidars), that no heavy Eskimo-style harpoon with floats was used, and that whales were ultimately obtained by drifting ashore in contrast to being towed ashore. The projectiles used in whaling were darts propelled by throwing boards, and tipped with large non-toggling bone heads and stone end blades (McCartney 1971:112, Figs. 3, 4). Scammon (1874:47) and Liapunova (1975:81) illustrate similar bone heads collected during the nineteenth century, and Von Kittlitz, in 1858, describes this type of whaling dart or lance head (Heizer 1943a:431). These are commonly found in the upper, or late prehistoric, midden layers at sites throughout the chain. Aconite poison may have been used with these darts or lances in the eastern islands (see below). No large toggle heads, associated with whaling as in North Alaska, are known from Kodiak or the Aleutians. Therefore, Aleutian-Koniag whaling of whatever age appears to have utilized barbed, non-toggling lance heads (Heizer 1943a:429, fn. 25).

Emphasis placed on hunting sea otters and seals for the fur trade possibly contributed to the decline of eighteenth century Native whaling (Heizer 1943a, b). Von Wrangell states that whaling was only carried out in the eastern Aleutians in the 1830's, and Black (1982:23) notes that Koniag whalers were sent to Atka in 1828 to teach Atkans whaling. The nineteenth century lance-and-wait technique described above may have replaced a quite different eighteenth century technique. Black (1982:20-22) quotes a 1760's whaling account by Prokopii Lisenkov as follows:

> When they hunt communally the whales, a multitude in their small baidarkas collecting together, they aim to wound the whale with a blade inserted into a foreshaft; to the foreshaft they tie inflated bladders (drag floats) made of seal (skin) and they pursue the whales. When by the means of these drag floats the whale is tired out, they spear the whale with ivory spears and tow it to shore by means of a cable (line).

Heizer (1943b) and Ivanof (1930) describe similar nineteenth century Aleut hunting methods of multiple boats attacking whales with spears and floats. Although there are no ethnohistoric portrayals that mention umiak crews or toggling whale harpoon heads, the Lisenkov reference to killing and towing whales suggests that a major shift in whaling technique occurred at the end of the eighteenth century. Heizer (1943a:447-449) suggests that aconite poison whaling overlay earlier harpoon and float whaling which, in turn, was related in technique and accompanying ceremonial aspects to Eskimo and Northwest Coast whaling. Perhaps the shift away from lancing and towing whales coincided with the introduction of aconite whaling from Asia (Heizer 1943a; Bisset 1976).

Present evidence shows that use of aconite poison originated with the Ainu, from whom Kurile Island Ainu, Kamchadals, Koryaks, Yukaghir, and Chukchi eventually learned of its use and put it to practice in varying degrees. The likely mode of transmission from Asia to the New World was through the Kamchadals (Heizer 1938) and other Asian Natives who made up part of the early Russian boat crews to Alaskan waters. Once there, these colonists could have taught Aleuts and Koniags how to use such poison on their lance heads so that by the beginning of the nineteenth century, the technique was well entrenched in the eastern Aleutian-Kodiak area. Bisset (1976) stresses the fact that not enough aconite poison could be applied to a lance head to directly kill a whale whith its toxicity. Therefore, there exists side by side with aconite poison the notion of "magical poison" with no real toxic properties (Lantis 1938). Such magical poisons include grease and bits of clothing from a dead whaler's mummified remains (I. Veniaminov, quoted in Petroff 1884:154).

Northeast Asia

Turning westward from the Aleutians to Japan, we find whale remains in Middle Jomon times (3000 B.C.) and they continue to be found in Late Jomon times (2000 B.C.) when a wide variety of toggle heads and bladder floats also occur (Chard 1974; Yamaura 1976, 1980). Small to large sea mammals were now being hunted. Onto this long whaling history, the Dutch and/or Portuguese are thought to have introduced net whaling and windlasses for beaching during the seventeenth century (Heizer 1943b; Matthews 1975).

North of Japan, on the margins of the Okhotsk Sea, arose two maritime cultures about the beginning of the Christian era: the Okhotsk Sea culture on Sakhalin, Hokkaido and the Kurile Islands, and the Ancient Koryak culture on the mainland coast. Whale bones, along with other sea and terrestrial mammal bones, are found in Okhotsk culture middens, and harpoons and fishing gear are common as well (Ohyi 1975). In addition, archaeologists have discovered small pictorial representations of whale harpooning from boats (Befu and Chard 1964). Sea mammal bones, but not whale bones specifically, are mentioned by Vasil'evsky (1969) for Ancient Koryak sites. Toggle and barbed harpoon heads are also found. Whereas the importance of whales is difficult to assess from English accounts of these Asian archaeological cultures, the presence of sea mammal bones, harpoons, and some large wooden boat remains (Vasil'evsky 1969) make whaling a distinct possibility.

The Ainu replaced the Okhotsk culture on Sakhalin and in the Kurile Islands about A.D. 1400-1700, and the Ainu, as pointed out previously, are thought to have developed and spread the knowledge of aconite poisoning (Bisset 1976). Aconite poison whaling spread northward, probably after Eskimo float whaling had spread southward of Bering Strait through its adoption by neighboring Chukchi, Koryak, and Kamchadals. Thus, the two major North Pacific-Bering Sea whaling patterns of aconite poisoning and toggle harpooning with floats meet on the Northeast Asian shore, perhaps with the same people using one or the other at different periods.

The eighteenth century Kamchadals of the northern Kurile Islands and Kamchatka Peninsula used large whales extensively, but the method of their capture is not well documented beyond statements that poisoned arrows were used on them (Krasheninnikov 1775; Heizer 1943a; Bisset 1976). Their northern neighbors, the Koryak, harpooned bowhead whales using northern Eskimo-style toggle heads with stone blades (Jochelson 1908:551-552, 726). Whales were lanced, when tired, and towed to shore. The Koryak's northern neighbors, the Chukchi, were very accomplished whalers and also hunted bowheads and possibly gray whales using the harpoon-float technique (Bogoras 1904; Heizer 1943a:426-427). The nineteenth century composite sketch of Chukchi life collected by Nordenskiöld (Fig.2) documents the Asian spread of Eskimo whaling technique. The late nineteenth century Maritime Chukchi built boat rests and subterranean ice cellars with whale mandibles and other bones (Bogoras 1904); Asiatic Eskimos also constructed many features of bowhead bones along the Chukchi Peninsula coast (Arutiunov et al. 1982).

Western and Northern Alaska

Northwest Alaska has special significance since Native whaling has continued as a primary subsistence activity there from at least 2000 years ago to the present. The Arctic Whale Hunting culture (Larsen and Rainey 1948), the Northern Maritime tradition (Collins 1964), and the Thule tradition (Dumond 1977) are different terms given to the sequence of archaeological phases that begin around the turn of the Christian era and are characterized by toggle harpoons, bladder floats, and related sea mammal hunting gear. These phases, from west to east, are Okvik, Old Bering Sea, Punuk, Birnirk, Thule, and Inugsuk. Weapons made of whale bones and burials that include

Fig. 2. The nineteenth century composite sketch of Chukchi life

large whale bones are known from Chukchi Peninsula, St. Lawrence Island, and Seward Peninsula sites (Arutinuov and Sergeev 1975). These Eskimos incorporated whale bones into houses as well (Giddings and Bandi 1962; Giddings 1967). Whaling toggle heads of the Punuk stage are found near East Cape and on St. Lawrence Island, and these can be directly compared to nineteenth century Alaskan whaling heads (e.g. Murdoch 1892; Geist and Rainey 1936; Collins 1937).

If this sequence is securely tied to whale hunting, what earlier cultures can be assigned to whaling? Norton culture of approximately 500 B.C.-A.D. 500 is represented by very few organic artifacts. Small toggle harpoon heads found in Norton collections may have been used on walrus, beluga, and seals whose bones are associated with Norton sites (Giddings 1964:186). However, at Point Hope, two large whaling toggle heads of the Norton period, one with a whale engraved on it, is direct evidence for whaling (Larsen and Rainey 1948:163, Pl. 79; Larsen 1982:54-55; Dumond 1975:169). Still earlier, at 1800

B.C., is the so-called Old Whaling culture, named by Giddings (1967:223-245) for artifacts, house ruins, and related whale vertebrae, ribs, skull bases, and mandibles found on a beach ridge at Cape Krusenstern. Large chipped stone blades similar to nineteenth century slate blades used in whaling harpoon heads are found as well. In summary, it appears that northwestern Alaskan whaling was an experimental pattern by the second millennium B.C. and was well established throughout the region by early in the Christian era, at least where large whales occurred with frequency.

Recent whaling in the Bering Strait area and northward is well known through the writings of Murdoch (1892), Curtis (1930), Rainey (1947), Spencer (1959), Hughes (1960), VanStone (1962), Foote (1965), and others. Hunters wait for bowheads at ice edge camps during April, May and June when these whales migrate from southwest of St. Lawrence Island northeast along the Alaskan shore to Banks Island (Braham et al. 1980). The settlements closest to this annual migration route are those with the strongest whaling traditions. The northern Eskimo whaling pattern spreads throughout northwestern Alaska: umiak hunting crews, whale harpooning with floats, lancing to kill whales, towing whales ashore, butchering patterns for meat and blubber distribution, and ritual behavior surrounding all aspects of whaling activities. A selection of nineteenth century Alaskan Native drawings and engravings, taken from Hoffman (1897), illustrates recent whaling (Fig.3). Some examples include sailing ships of the American whaling fleet among Native umiaks.

The western bowheads that migrate along the Alaskan shore each spring are the same animals that become available to western Canadian Arctic Eskimos in the Beaufort Sea during the summer months. As the polar pack pushes south in the fall, these whales move westward towards Wrangel Island and then south along the Siberian coast and through Bering Strait where East Cape Eskimos and Chukchi hunt them (Bogoslovskaya et al. 1982). Bones of these animals appear in great frequency at Asian coastal sites (Nelson 1899:257, 265-266; Arutiunov et al. 1982). Gray whales are commonly found in the northern Bering Sea, and St. Lawrence Islanders and Asiatic Eskimos hunted them in prehistoric and recent times (Marquette and Braham 1982; Krupnik et al. n.d.).

Canadian Arctic

From a North Alaskan foundation, whale hunting Thule Eskimos spread throughout the Canadian Arctic at approximately A.D. 1000-1300. The earlier Dorset and Pre-Dorset peoples knew the use of toggle harpoon heads, but they subsisted on walrus, seals, and caribou. Very few whale bones are

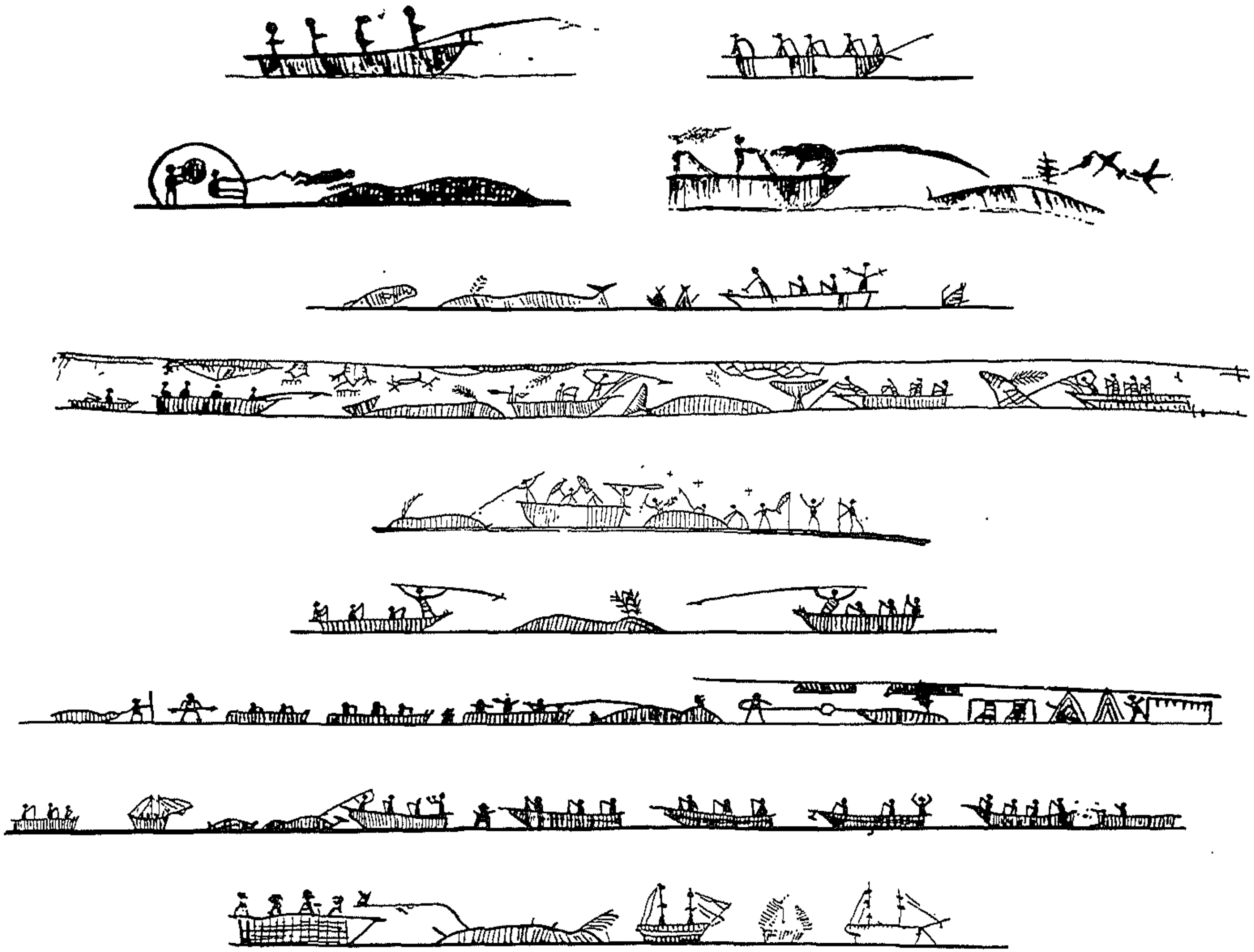

Fig. 3. Nineteenth century Alaskan Native drawings and engravings

found in their small stone house ruins and with the exception of some small sled runners or shoes made of bowhead bones (Collins 1956; Harp 1978), Dorset people did not commonly work whale bones into implements. A sharp contrast is, therefore, noted between Dorset and Thule peoples in that the latter (and their more recent Inuit descendants) depended heavily upon whale bones for house rafters, sled shoes, and other artifacts (including whaling harpoon heads similar to those of Alaskan Natives), and upon baleen for many flexible manufacturers (Mathiassen 1927). Thule Eskimos occasionally engraved whaling scenes that showed umiak hunters harpooning bowheads (Collins 1951:63; Mary-Rousseliere 1960; Schledermann 1975:122).

Historic period information on Canadian Inuit whaling is relatively scarce, although European depictions of Natives begin with Frobisher's voyages in the late sixteenth century. Nineteenth century graphics are more accurate, but they rarely give us insights about Native whaling. Parry (1824:509-510) describes early nineteenth century whaling of the eastern Canadian Arctic in which several umiaks searched out a whale and one approached it to secure a harpoon with sealskin floats. Other harpoons were then thrown at the whale as opportunity arose, and eventually it was killed with spears or lances. The dead animal was towed to shore for butchering (see also Hall 1865:216-217; Boas 1901:255-256).

Whale bones found at Canadian Thule sites (Fig.4) correspond closely in their distribution to modern summer ice-free areas, to historic and modern bowhead sightings, and to locations of seventeenth-nineteenth century commercial whaling kills. Additional information from ethnohistoric accounts also supports this correspondence. As with the western bowhead population, the eastern population moves out of the Canadian Archipelago as winter sea ice forms. Bowheads winter along the moving pack ice in southern Davis Strait, and they do not appear to winter over in open polynyas or leads (Reeves et al. 1983:54-55). Bowheads moving northward in the spring and summer are limited to open water, and ice normally remains fast against the continental shore (between coronation Gulf and Foxe Basin) and among the northwestern islands of the Archipelago. There is, therefore, an ice barrier year-round separating the Beaufort Sea stock from the Baffin Bay-Hudson Bay stock. Reeves et al. (1983:59) review existing evidence (marked harpoons found in dead whales) for interchange of animals between the eastern and western populations. They consider that among proposed instances "none are incontrovertible and few are even plausible". The western half of the Canadian Archipelago, along with the Gulf of Boothia and Foxe Basin are areas where Thule Eskimo (A.D. 1000-1300) whale bone houses are not found, indicating that summer ice distribution a millennium ago was much like that of today. Finally, commercial whale kills mapped from ships' logs

Fig. 4. Whale bones found at Canadian Thule sites

and journals by Ross (1975, 1979a, b) show that Euro-American whalers took most bowheads where Reeves et al. (1983) indicate they were concentrated, based on non-whaling sightings. Ross' (1979b:93, Fig.1) map of the three northern New World fisheries (i.e. Davis Strait, Hudson Bay, and Beaufort Sea), clearly corresponds to the regions where Thule Eskimo archaeological bones are distributed; the "blank" areas where bowheads were not taken commercially are also the areas lacking Thule whale bone houses. Where bowheads did not occur, Thule Eskimos subsisted primarily on caribou and seals and winter houses were constructed without whale bone rafters or supports. This correspondence between ice distribution, whale sightings, whale kills, and archaeological sites is relevant to Native whale use in other arctic and subarctic regions.

Labrador

Sixteenth century maps of the western Atlantic show great spouting whales off both the southern and northern shores of North America. The whales that embellish the maps of what is now Labrador suggest the abundance of contact period whales there. Basque whalers had fished the Newfoundland-Labrador coast since at least the fourteenth century, but supposedly abandoned it due to Eskimo raids on their shore stations (Gosling 1910; Jenkins 1921; Tuck and Grenier 1981; Tuck 1981). The French hunted Labrador whales during the eighteenth century. As with the northwest coast of North America this northeast coast provided a great variety of whales including (depending upon latitude) humpback, blue, Atlantic right, sei, finback, sperm, bowhead, beluga, narwhal, and killer. Historic Eskimos of northern Labrador, between Ungava Bay and Hopedale, primarily hunted humpbacks and the slower bowheads during the fall migration along the coast. Other whales were used when washed ashore. Whaling utilized umiaks and drag gear for harpooning and kayaks for lancing them to death (Hawkes 1916:82, 145; Taylor 1974, 1979). This use of both small and large boats for whaling parallels that of Baffin Island Thule Eskimos (McCartney 1980). The Labrador Eskimos are the eastern termination of the Thule migration around the Canadian Arctic, and their old house ruins with whale bone rafters are a continuation of the more northerly Thule winter house pattern (Hawkes 1916; Bird 1945; Fitzhugh 1972; Schledermann 1976; Jordan 1978). Eskimo distribution fluctuated up and down the Labrador coast with time and climate, but their Thule founders were generally established between A.D. 1350-1500. Pre-Dorset and Dorset people preceded Thule Eskimos on the coast. Maritime Archaic Indians of approximately 2000 B.C. on the Newfoundland coast had a toggle harpoon complex that included whale bone foreshafts. Killer whale amulets and unworked whale bones are also found at their sites (Tuck 1975; Harp 1978).

Greenland

A prehistoric sequence around Greenland's margins mirrors that of the adjacent eastern Canadian Arctic. A Thule culture period is preceded by Dorset and Pre-Dorset or Independence periods (Gad 1971; Meldgaard 1976). The latter peoples sustained themselves principally on walrus, seals, musk-ox, and caribou, at the exclusion of bowhead whales. Greenlandic Thule implements made of whale bones are essentially the same as those of Canada and an occasional whaling harpoon head is found (e.g. Holtved 1944). Whale bones and baleen are commonly encountered in Thule and more recent houses (Wissler 1918; Holtved 1944).

Norse colonists of the eleventh to the fifteenth centuries intracted with Thule Eskimos in northern Greenland, yet little is known of the specific Native whaling techniques of the Norse period. The Norse brought whaling knowledge with them (Nansen 1911) and pursued whales near their southern Greenland settlements while the Eskimos whaled in the north. With the re-establishment of Scandinavian contacts in the sixteenth century, more complete information about Greenlandic whaling became known; much of the European contact of the eigteenth century was of whalers who had moved west as the Spitsbergen fishery played out. Mid-seventeenth century paintings of Greenlandic Eskimos suggest that Europeans had an increasingly accurate understanding of Natives over those of the so-called *skraelings* whom the Norse had earlier described. Egede's (1745) description and graphic portrayal of Native whaling in West Greenland (Fig.5) depicts umiak crews hunting whales, as kayak hunters pursue seals in the Thule fashion:

> The men go in search of the whale and when they have found it they strike it with their harpoons, to which are fastened lines or straps 2 or 3 fathoms long, at the end of which they tie a bag of a whole seal filled with air; so that when a whale finds itself wounded and runs away with the harpoon it may the sooner become tired, the air bag hindering it from being long under water. When it thus loses strength they attach it again with their spears and lanced until it is killed (see also Holtved 1962:129-131).

Many details about Native whaling, such as those of whale butchery, emerge during the eighteenth and nineteenth centuries. Bowheads and humpbacks were the most commonly hunted of the large whales.

Stages of Whaling

From this sampling of diverse Native culture history, we may tie these

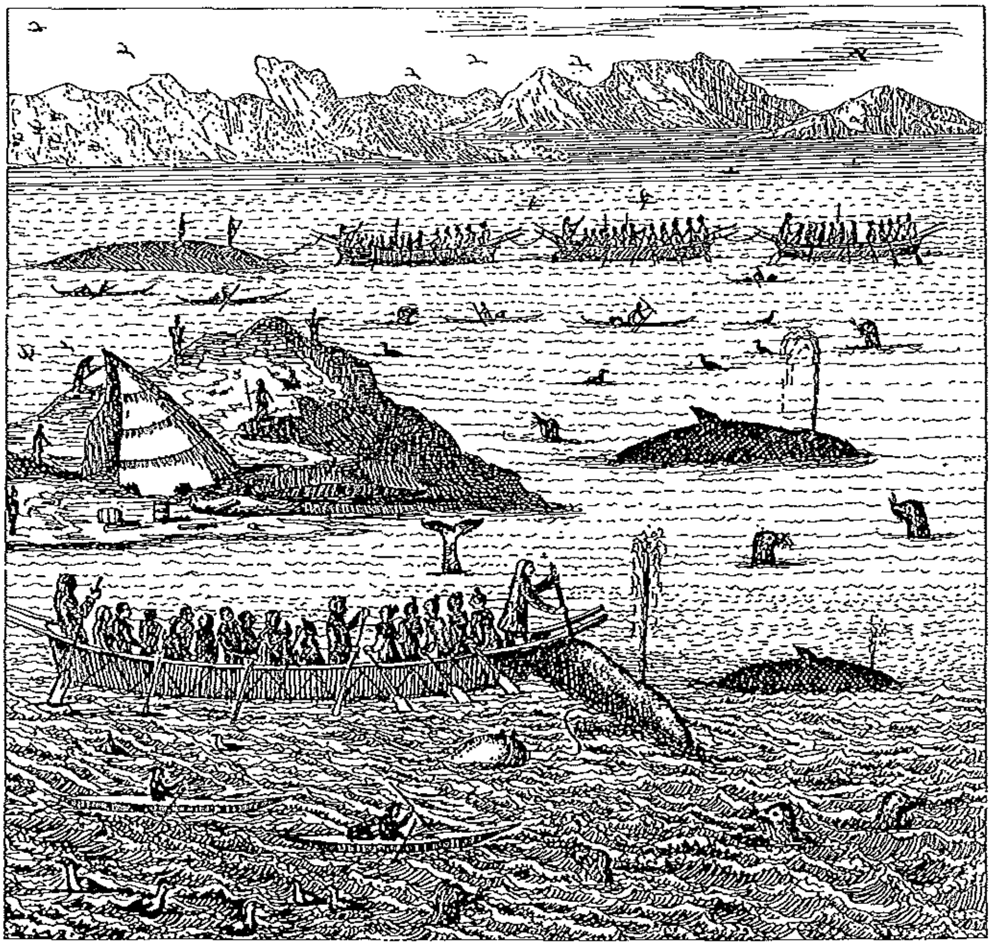

Fig. 5. Egede's description and graphic portrayal of Native whaling in West Greenland

societies together by reviewing behavioral modes dictated by large whale hunting. Whether the species be bowhead, humpback, or gray, coastal Natives of any region were faced with developing similar immobilization and utilization strategies. Hunters made adjustments for each species' peculiar behavioral traits, but overall, Natives seasonally killed these largest of mammals in a common fashion. Whaling resemblance is based on diffusion of hunting patterns from group to group and on the fact that there existed little latitude in the manner that aboriginal hunters could successfully capture large whales, given their use of paddled boats and thrown harpoons (Heizer 1968). The following stages apply to harpoon-and-float whaling, the oldest and most widespread of New World Native whaling techniques.

Sequential harpoon-and-float whaling behavior is organized here in nine stages, (following Laughlin's 1968 sequence of hunting behavior), ranging from finding the animal to eating it, making tools from it, and building houses with its bones. Examples from the literature are cited for each stage, but no attempt is made to represent each major arctic or subarctic region. As noted earlier, not included here are the complex ritual preparations and observances that virtually every Native group held prior to, during, and after whaling.

Sighting

From the Native perspective, once or twice a year large whales swam by the coasts they occupied. Lookouts on high bluffs or ice ridges sometimes spotted offshore whales (Elliott 1886:152). In the case of subarctic open seas, such as along the Northwest Coast, whalers paddled many miles to offshore whaling grounds in hopes of encountering migrating animals. The whale's large size and its blowing enabled hunting parties to locate them. Farther north, bowheads typically swam along ice fronts or shore leads that often channeled them by waiting hunters. Usually, several Native crews hunted cooperatively which gave them greater coverage over an ocean tract than was possible with a single boat (Jochelson 1908:551; Curtis 1913:146; Drucker 1951:51; Spencer 1959:340). Once a sighting was made, silent signals were used to direct other boats to the whale (Drucker 1951:51; Hughes 1960:113).

While range maps show extent of whale sightings for a species, hunters knew from experience that some coastal waters were better than others for finding whales. In fact, there is evidence that the same animals return to the same localities year after year (Reeves et al. 1983:59). In the case of offshore waters, such characteristics as water depth and food density can shape migration routes whereas ice edge whales are limited by any particular year's ice patterns.

Pursuit

Once sighted, whales were run down not because of superior boat speed or long endurance chases, but rather by prejudging where a sounding whale would surface and paddling to that spot before the whale rose. A quiet approach is usually stressed by most accounts in order not to scare the whale, but once struck, the whale may be chased by shouting boat crews beating on the sides of their boats to tire the animal. Whales were approached from the (left) rear, the boat being brought up beside the shoulder area for striking (Nelson 1969:217).

When faced with choices, hunters had to choose among different sized animals to pursue. Historic accounts of Northwest Coast, Aleutian, North Alaskan, and Labrador whaling, for example, suggest that small whales were preferred over large ones because young animals were less dangerous to harpoon, they tasted better, they were easier to tow ashore, or they may have been more available closer to land than larger animals (Ross 1835:xxiv; Petroff 1884:142; Elliott 1886:152; Rainey 1947:261; Laughlin 1963:76; McVay 1973:28; Bisset 1976:106). Nansen (1911:156) reports that the European Norse in Ireland also hunted young whales. This suggests that the pursuit of subadults may characterize pre-commercial European shore whaling as much as New World Native shore whaling. Bowheads migrate in three or four waves or "runs" alrese 1980). The later whales, passing when leads widened with advancing spring, were not as likely to be channeled within range of hunting camps. Reeves et al. (1983:56-57) cite nineteenth century sources about eastern Arctic bowheads being segregated by age, with young animals either preceding older ones into an area or swimming closer to shore. Among both eastern and western populations, young bowheads appear to be more susceptible to Native capture.

Striking

Striking the whale by throwing a heavy harpoon a short distance at the surfaced animal or jabbing the harpoon into it began the killing process. As observed above, the predominant pattern is one of drag floats being used to tire the wounded animal and to mark its soundings. Floats were thrown overboard by crew members as the harpooner struck the whale. It was often necessary to strike the whale several times in order to immobilize it as well as to attach sufficient floats to prevent its sinking (Taylor 1974:31). Bowheads are exceptionally good floaters but other whales taken on the northwest and northeast coasts are not. As with "struck" bowheads in North Alaska today, striking a whale gave no assurance that the hunting crew would get the whale (Taylor 1974:31). Often a neighboring group would benefit from the dead animal washing ashore many miles from where it was struck, with harpoons and floats attached.

The Aleutian-Kodiak technique of striking the whale with a non-toggling barbed harpoon on the assumption that it would die, become bloated, and float ashore three or four days later is a radically different, and less sure, technique than float whaling (Heizer 1943a; Bisset 1976). Much discussion has centered on whether it was aconite poison that killed the whale, or whether the chipped or ground stone-bladed harpoon head worked its way deeper into the moving whale, causing hemorrhaging and eventual death. Many accounts do mention that harpoons must penetrate the blubber and pass into the animal's flesh before a strike will prove mortal (Taylor 1974:31).

This is the reason why striking is done at close range, with great force, and heavy harpoons.

Killing

In the bladder float harpoon procedure, the struck whale, once tired, usually had to be approached for a final lancing. A long lance or spear with fixed stone-bladed head was often used for stabbing the creature about the head and neck until the animal died (Murdoch 1892:240-241). Bisset (1976) points out that the common practice of striking the whale near the flippers, with or without poison, is aimed at impairing the flipper's function, which is to provide stability as the fluke drives the animal through the water. If flipper coordination is weakened, the whale may lose its balance and drown by having its blowhole submerged. References are made to striking the flipper area in humpbacks and grays (Davydov 1810-1812:224, Heizer 1943a:429; Drucker 1951:52-53; Holtved 1962:130), but bowheads are commonly speared in the brain, the heart, or the lungs (Spencer 1959:26), probably because the flippers are submerged at too great a distance. Lancing or spearing the whale can be as dangerous, or more so, than initially striking it because of the unpredictable and enraged nature of the wounded animal.

Towing

The dead whale may not float ashore at a suitable spot and therefore it was common procedure in drag float whaling to attach floats, if necessary, and to pull the carcass to shore by several crews working in tandem (Rainey 1947; Spencer 1959). This could take hours, if not all day, depending upon the killing site, wind, and the currents. Teamwork was important in this task and the larger the participation, the greater the probability of landing the whale. Bowheads float well when dead, but other whales may sink or only float when bloated, many days after death. The flippers and jaw were sometimes lashed against the body to reduce drag while towing the animal ashore (Mason 1902; Waterman 1920).

Beaching

Once at shore or ice edge, the huge carcass had to be secured for butchering. Several possibilities exist at this stage. Ice edge whalers of North Alaska would use ice picks to chip out a ramp at the floe edge on which to haul up the whale. A primitive windlass was used for this purpose prior to incorporating block and tackle taken from sailing ships in the late nineteenth century (Hadley 1915; Brower n.d.).

If landed on an ice-free beach, the whale could be butchered at land's edge in shallow water. If beached on a coast with tidal fluctuation, the floating carcass might be grounded at high tide for ease of butchering. This could have occurred in the eastern Canadian Arctic, is known from the Siberian shore, and took place on the Northwest Coast (Waterman 1920; Drucker 1951).

Finally, West Greenland Eskimos butchered whales at the ice edge or shore by wearing waterproof suits of sealskin (Egede, quoted by Mason 1902:239; Fabricius, in Holtved 1962:84, 87). Flensing in these suits gave excellent protection to Natives who could even float in them. Taylor (1979) reports these suits from Labrador, and Alaskan Eskimos of the early twentieth century are shown at the ice edge cutting up a whale in what appear to be similar waterproof exposure suits (Bernardi 1981:142). There is no direct evidence of how Thule Eskimos flensed whales, but perhaps combination or dry suits, as noted by Taylor (1979), had wide use in prehistoric Thule times.

Butchering

The carcass, in recent times, is butchered according to strict distribution patterns (Curtis 1913; Drucker 1951; Spencer 1959). For instance, VanStone (1962) and Worl (1980) illustrate the way that Point Hope Eskimos divide bowheads today. Presumably some division rules applied to the prehistoric period as well. Typical of hunting societies, northern groups that whaled shared the meat and blubber throughout the community. As a cooperative venture, whaling necessitated that boat crew members received parts of the animal, and usually multiple boat crews were involved in killing and towing the animal, thus earning shares for them all. More than any other animal, a large whale's sheer size required that it be distributed among many hunters, since one family could not use it, or cope with it, alone.

Storing

Once cut into pieces, most of the whale is ordinarily hauled to safe spots for storage in ice cellars or cache pits, or for processing near settlements (Rainey 1947; Spencer 1959). Part is eaten at the time of butchering or shortly thereafter in communal feasts. Thule period and recent Canadian Eskimos used holes dug into beach gravels as storage pits that, when full, were covered with gravel or heavy rocks (McCartney 1980). Aleuts and some Asian coastal groups cut whale meat into strips for drying prior to storage. Whether preserved by permafrost or drying, the goal of storage was to provide a food surplus for many months ahead.

Using

Whale meat and blubber were important sources of protein and oil to Native people. Blubber could be burned as fuel in stone lamps for heat and light, bones were often fashioned into implements because of their density and large size, mandibles and skulls could be used for house walls and rafters in areas of little wood, mandibles were formed into sled shoes, and baleen was unique as a pliable material and was used for containers and lashing.

Whaling in Perspective

The above discussion emphasizes the great size of whales and the food and material abundance they provided to New World and Asian coastal Natives. Yet, we must remember that 1) few whales were taken annually by any particular society, 2) some years whales were not taken at all, due to shifts in ice and other migration determinants, and 3) no whaling society depended totally upon whales for year-round subsistence. When whales were taken in low frequency or not at all, greater dependence than usual shifted to smaller sea and land mammals and fish. Flexibility, after all, is the mainstay of hunters and gatherers.

On the other hand, the archaeological record is less clear than the ethnographic record in defining Native diets. Several faunal analyses used to reconstruct prehistoric diets, such as those of Denniston (1972) for the Aleutian Islands, Lobdell (1980) for Kachemak Bay, and Staab (1979), Schledermann (1975), and Rick (1980) for Canadian Thule sites, demonstrate that whales do not receive proper dietary assessment because their bones do not become part of refuse heaps as do smaller animal bones. Mountains of meat and blubber, once stripped from the carcass at water's edge, will leave no direct archaeological trace for its dietary presence.

Summary

Five aspects of northern Native whaling are mentioned here in summary. First, seasonal large whale hunting took place on most coastal zones of North America and adjacent Asia that were ice free in summer. Even along the northern Northwest Coast, where nineteenth century whaling was not conducted, one finds references to the possibility of whaling in earlier times. Of course, local ice, water depth, and food availability may limit whale access to some coastal areas. Points of land closer to deep sea migration routes were richer whaling spots than shallow embayments. In the mid- to high-Arctic, seasonal ice controlled access of bowheads there, and short-term or long-term fluctuations in climate and ice cover dictated shifts in whale ranges. Of the large whales, bowheads, humpbacks, and grays were the animals most often hunted by Natives. These whales swim slowly and close to shore, are of a manageable size, and otherwise display behavior conducive to Native capture such as sleeping or resting at the surface (Scammon 1874; Jurasz and Jurasz 1978). Carcasses of all large whales were used by Native peoples if washed ashore, and sometimes rules of "salvage rights" existed among Native societies (Drucker 1951:255; Lantis 1970:246-252).

Second, two major whaling patterns emerge from this literature review: 1) harpooning with a large toggle head, long line, and floats or drag gear from a crewed boat, and 2) poison harpooning or lancing without line or floats from kayaks or, possibly, larger boats. The first is thought to be of Bering Sea origin, which spread eventually across northern North America to Greenland and Labrador and south along the Northeast Asian coast and along the Northwest Coast of the New World. Northwest Coast Nootka-style harpooning is a technologic variant of this pattern, but it differs in specifics such as style of harpoon head, large thrusting versus smaller thrown harpoon, and boat type. The aconite poison pattern of Northeast Asian origin spread only along the Aleutian-Kodiak-Kenai Peninsula axis in the New World, and was a recent introduction to the American side. Asian coast whale netting was of possible late European introduction.

Third, whaling arose from generalized sea mammal hunting adaptations of the second and first millennia B.C. and was fully developed by the first millennium A.D.. Whaling necessitates boats for offshore pursuit, and if boats were available, then one can imagine a hunting gradient from small, less dangerous sea mammals to larger ones, or from seals and sea otters to sea lions and walruses to small whales and immature large whales. The technologic shifts required to successfully hunt these animals were largely those of size rather than form. The reader is referred to Fitzhugh (1975) and McGhee (1978) for thorough reviews of northern maritime technology and adaptations. Whatever whaling preceded A.D. 1000-1300, Thule Eskimos of that period were responsible, directly and indirectly, for the greatest New World spread of whaling, from Chukchi and Kamchatka Peninsulas to Greenland and Labrador.

Fourth, evidence for whaling prior to the ethnographic period is often weak to marginal. Whales were likely to be butchered away from settlements with only soft parts retrieved. Bones and baleen returned to a settlement for structures and implements cannot aid in distinguishing between whale hunting and use of stranded animals. Many lines of evidence may have to be considered to demonstrate that whaling, indeed, occurred in the past.

Finally, the social impacts of whaling are far-reaching (Fitzhugh 1975; Ellanna 1980, Spencer 1959, Huntsman 1963, and others). The development of umiak crews and offshore travel open up social and trade connections and bring a much larger area into hunting use. Permanent coastal settlements with relatively large populations can be supported on the larger and usually abundant food resources of whaling. Communal and inter-communal feasts, with the social alliances they imply, are made possible by excess foodstuffs. Larger food supplies permit the development of dog traction which simultaneously extends hunting range for smaller animals and terrestrial winter travel. Minor social differentiation emerges from food and material surpluses being unequally distributed on the basis of crew participation. Reliance and reciprocity are stressed by the group nature of whaling and butchering. And, with focus placed on dangerous whale hunting, spiritual observances naturally follow as a means of offsetting risks to whalers.

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THE ARCHAEOLOGY OF A CONTEMPORARY WHALING SOCIETY: THE LATER PREHISTORY, ETHNO-ARCHAEOLOGY AND RECENT ETHNO-HISTORY OF WHALING IN THE BARROW, ALASKA AREA

by

Albert A. Dekin, Jr.

Any study of the aboriginal and historic Inupiat culture in Northwest Alaska must take as its point of departure the recent studies by Ernest S. "Tiger" Burch, Jr. His seminal article in the 1980 Senri Ethnological Series publication, *Alaska Native Culture and History,* contributes much to our understanding of Inupiat ethnography but makes an important methodological point as well. That is, to gain a proper understanding of the ethnohistoric period as reconstructed through older informants and the accounts of explorers and travelers, one must take "proper account of change over time..." (Burch 1980:264). Since these accounts span a century of significant change in the area, his reconciliation of what have been perceived as conflicting data provides what we must regard as an essential set of understandings from which to conduct archaeological research on this important period of Inupiat whaling culture.

Since some of these ideas may not be widely known or appreciated, I will summarize several of those which are relevant to our interests today.

> "Life seems always to have been in a state of flux in Northwest Alaska, particularly at the individual society level. What European interference did initially was heighten the amplitude of the oscillations, and bring the oscillations of the separate units into approximate synchrony. Only later did it result in the termination of the units themselves" (Burch 1980:261).

The units of which he speaks are individual local-based "societies", comprised of one or several bilaterally extended families which might, during periods of seasonal aggregation, comprise a single village (Burch 1980:262-263).

> "A few localities in Northwest Alaska were so productive, year in and year out, that more than one large family unit could maintain a permanent base there. Practically all such localities were situated on the coast at points where major sea mammal migration routes were easily intercepted. At such locations there were more local family units, the individual units typically were larger, and there tended to be greater continuity of membership in those units than in other places.

In less productive regions ... a resource crisis would force the unit to fission within a year (or season) or two. This happened so often that large local families rarely could be maintained for any length of time in the interior ..." (Burch 1980:265-266).

The successful adaptation of these "societies" had to cope effectively with the ecological conditions which constrained their subsistence and travel. Burch points out that" ... the Northwest Alaskan Eskimos seem to have exploited virtually every animal and vegetable resource that was available to them" and that "... *all* of the major faunal resource species that occur in Northwest Alaska - mammals, fish, birds - are seasonally nomadic", forcing human groups either to move with them or to harvest more than immediately required during periods of availability, storing the harvest for later use. "The universal pattern in early nineteenth century Northwest Alaska was to do both" (Burch 1980:275).

Burch points out that "... no two societal territories in early nineteenth century Northwest Alaska had precisely the same resource base ..." and "... that in only one case ... did all of the members of a society typically remain in there own territory all year round" (Burch 1980:275). However, even with all of this movement, major settlements within each territory would be inhabited throughout the year and larger aggregations would occur from Fall whaling through Spring whaling at these "winter" villages. Here, whaling provided the social and economic focus, through patterns of hunting, ceremonies, feasting and re-distribution of subsistence products.

Organization of these efforts was based primarily on bilaterally extended kinship relations, which also formed the basis for residence at both the village and household levels. Ranking within each society was based on both kinship and ability. Residence within a territory and ties to major villages within each territory contributed to a sense of social identity, so necessary in maintaining territorial and social relations. The prehistoric Kakligmiut society was centered on the major villages at Barrow, Alaska. Here, they reached their greatest population and permanence of occupation during the late prehistoric period, derived in large part by the success of their social and ecological whaling adaptation. Utqiagvik was a village of three kariyit and, by inference from Burch (1980:271), three large, integrated families. Maintenance of the social order, patterns of exchange and economic re-distribution, feuding and warfare, and the extension of territorial boundaries were all dependent to one degree or another on whaling and the processes of organization, celebration and social interaction which accompanied it.

By viewing whaling as an important, if not vital, integrating mechanism on which Kakligmiut society depended, it is important for us to understand that we are talking about this society as an organized structure for people. Some of the generalizations made in this discussion of Kakligmiut society would not apply were we to discuss the maintenance of Kakligmiut population or Kakligmiut territory. Were Kakligmiut society to be dissolved, as we might expect were whaling to have become less successful during this prehistoric period, while some would go to neighboring societies, there was sufficient adaptive diversity to allow subsistence patterns to broaden, to allow families to disperse across the landscape and even to allow maintenance of a smaller population in the Barrow area. However, Kakligmiut Society, as we know it, would no longer exist. Here, we are clearly talking about a particular social order whose particular way of life was organized around successful whaling.

It is also important to recognize that we are not talking here about maintenance of the regional social and language groupings of Northwest Alaska. Of the twenty-five societies discussed by Burch, only eight had any direct involvement in whaling (Burch 1980:Appendix). In these, whaling activities were concentrated in a single, or perhaps two villages, which provided a focus for social interaction within that society to the extent that most of the population might be aggregated at these whaling settlements during the winter, or at least during the whaling seasons. Whaling was a primary integrative force at the village level during this period, with a concomitant effect on settlement patterns for the "society", since all extended families might comprise a single village during this period.

With the depopulation and breakdown of this system of social relations across Northwest Alaska in the second half of the nineteenth century (Burch 1980:256, 282), the pattern of societal territories broke down and people aggregated at the sites of major whaling villages. This aggregation brought people in from all of Northwest Alaska and even portions of Canada, concentrating them in a few settlements, of which Barrow was one. Even at this time, whaling provided a focus of activities and a structure for the organization of social relations based on patterns of kinship, which has continued until the present day.

For Kakligmiut Society, whaling affected: the location of their settlement; the pattern of their subsistence, both spatially and temporally; the focus of their social and ceremonial behavior; the nature of their re-distributive economy; the rigor of their adaptation; the success of their settlement, based on both size and permanence; and their very social identity. Whaling provided a symbol of society: what it meant to be Kakligmiut. Through the major period of change in Northwest Alaska in general and in Barrow in particular, whaling as a symbol and as a social and subsistence fact has persisted to the present day. While today's whaling is vital to the maintenance of society and subsistence, the term "Barrow Whalers" is also applied to high school athletic teams, the whaling motif is common in posters, advertisements, T-shirts and elsewhere. Over the past several years, a popular Barrow T-shirt was emblazoned with the message "Keep On Whaling". As background to the present, let us turn to a discussion of the archaeological evidence and of the evidence of continuity from the late prehistoric period to the present.

The Archaeological Evidence

The origins of whaling in Alaska are somewhat murky, because the evidence is sparse. The Old Whaling culture from Beach 53 at Cape Krusenstern was dated by Giddings to ca. 1800 B.C. (Giddings 1961:164). Many whale bones and flint blades of a size judged appropriate for whaling harpoons were found. However, the subsistence was also broadly based on small seals. Unfortunately, very little can be said of the origins and endings of this culture, which is seen as an interloper into the Bering Sea cultural sequence.

Whaling apparently became a significant element in Bering Sea subsistence during the Punuk Period (Collins 1937; Stanford 1976:113), expanding into Northwest Alaska during the subsequent Birnirk Period of 500-900 A.D. Following Stanford (1976), sealing dominated the Birnirk subsistence and it was not until the later Thule period that whaling came to its position of prominence (Stanford 1976:110-113). Most investigators have seen continuous cultural development and occupation of the Barrow area since ca. 500 A.D., with late prehistoric Kakligmiut, as found at the Utqiagvik site, emerging as the latest development from the Late Thule period.

Several explanations for the development and expansion of Thule culture have been offered, including partial destruction of the indigeneous seal population (Stanford 1976:113), ecological changes due to changing climate (McGhee 1970), and a synthesis of these two (Stanford 1976:113). Whatever the causes and origins of the Kakligmiut whaling adaptation, there is no argument over the interpretation that it existed in a "fully-developed" state little different from that observed by explorers and ethnographers in the early and late nineteenth century.

At the regional scale, evidence for the success of these developments lies in the establishment of large, seemingly permanent, villages at locations appropriate for whaling at that time and in the extension of the Thule culture across broad areas of the Arctic. At the village scale, winter sites appear to be divided into specialized areas, for different uses, and even to be divisible into relatively tighter house clusters, although this analysis is not yet complete, being directed by Dr. Raymond Newell. Boundaries are reported between areas of the village and village growth leads to fission in several cases, ethnographically described. At the scale of individual structures, houses are substantial in construction, often housing large families, either in mounds containing a single house or in mounds containing more than one house, occasionally linked together at the tunnel. However, at Utkiagvik it is presently not possible to differentiate among houses in terms of contents or size. At the scale of artifacts, there is little archaeological evidence for whaling subsistence. This is because many of the activities related to whaling were conducted in the karigi, rather than in the houses, and much of the whaling equipment was destroyed at the end of whaling and replaced prior to the next season. Whaling motifs occur on artwork as decoration of utilitarian objects and as sculpture in the round for toggles and similar artifacts. Identifying marks of owners of hunting weapons, principally whaling harpoons and arrowpoints, were ubiquitous, pointing to the heightened importance of individual and crew possession at this time.

Our excavations at Utqiagvik, a year-round Kakligmiut settlement, have been hampered by several factors of deposition and preservation which constrain our ability to address several of these issues with clarity. While house structures in mounds are easily found (evidence for winter occupation), summer occupations, recorded for the late nineteenth century, are ephemeral and occur apparently in surface horizons. Except in the rare circumstance where catastrophe prevented it, the houses were systematically abandoned each Spring, with lamps and other artifacts and furnishings from within the house removed for storage and use. Hence, if they were never re-occupied or re-used, the mounds may contain only a shell of the house and little *in situ* material. In addition, once a house was no longer systematically occupied, anything within it that might be usable could be removed, including wall boards that protruded above the surface, floor and roofing materials and even oil indurated gravel from the kitchen area. These abandonment and post-abandonment processes have produced an uneven record of occupation, compounded by the fact that Ford excavated several mounds in the 1930's and relic collectors have been active since the turn of the century. However, from the excavations conducted in more than eight house mounds in 1981 and 1982, we have amassed a considerable quantity of information from a wide range of deposit types. The archaeological evidence of setting, site and structure confirms the essential accuracy of the ethnographic and ethnohistoric record, partial though it may be, and provides a base from which to discuss cultural continuity through the prehistoric-historic-recent periods of Inupiat culture and Kakligmiut society.

Trends, Continuities and Discontinuities

Based on our reconstruction from ethnographic and archaeological evidence, the following trends are seen in the changing prehistoric Kakligmiut society:

1. increasing village size and permanence, at whaling location;
2. social differentiation, based on rank; and
3. with social stability and population growth there was increased potential for increased social complexity.

The second half of the nineteenth century saw a general regional breakdown of the territorial and social structure at this level of organization. Disease, starvation and wage-labor affected the viability of former structural relations and the decline of whales both weakened the ability to reform whaling practices and removed the economic base that had developed with commercial whaling. These changes effectively halted the trends described before. Continuity of group identity was achieved through the survival of members of the Kakligmiut and in-migration from adjacent societies whose own social entity had been destroyed and was no longer viable. With these additions, Kakligmiut society continued as a sort of amalgum of generalized Inupiat origins, but with a renewed sense of territory and integrity, based once again on kinship. Whaling was renewed, forming a focus once again for social integration and leadership, especially as expressed in ceremony, politics and subsistence.

Significant continuity can be demonstrated in areas of whaling practices and organization, ceremonies and rituals, dances, arts and crafts, oral tradition and re-distributive subsistence. The twentieth century Inupiat of Barrow have emerged from their Kakligmiut heritage as a modern expression of ancient values and life ways. In this fashion, they maintain a social identity and persist as an independent and integrated society, assisted both by pressures from outside to change and adopt western ways and by internal strength and a resolve to "Keep on whaling".

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HISTORICAL SURVEY OF THE EUROPEAN WHALING INDUSTRY

by

Richard Vaughan

Defining the Arctic is not just a question of latitude. Southampton Island in the north of Hudson Bay, surrounded by ice in winter and the centre of a historic Arctic whale fishery, is in the same latitude, namely just south of the Arctic Circle, as Iceland. Yet the offshore whale-fishery of Iceland is rightly held to be North Atlantic in character rather than Arctic. The same applies to the hunting of the pilot whale *Globicephala melaena* in the Faroes (not to mention Newfoundland and Cape Cod) and even to the destruction of the blue whale *Balaena musculus* in the Varanger Fjord in 1867-1900 (Risting 1922: 110-163; Johnsen 1959) at 70° North, the same latitude as Disko. These are not Arctic animals, nor are these fisheries Arctic. In what follows discussion will be limited geographically to that half of the Arctic between 90° West and 90° East longitude, namely approximately between Hudson Bay and the Taymyr Peninsula.

It makes sense to consider the history of Arctic whaling in the first place in terms of the whale. Of the seventy-six species of cetaceans in the world we are concerned with three only, the most important of which is the Greenland right or bowhead whale *Balaena mysticetus.* This is the only large species limited to strictly Arctic waters which was numerous, slow-moving and accessible enough to be effectivily hunted there by man.

Apart from the bowhead, two smaller truly Arctic cetaceans have been hunted and ought to be mentioned here. They are the two members of the Monodontidae family, the narwhal *Monodon monoceros* and the white whale or beluga *Delphinapterus leucas.* The narwhal was already being hunted by European settlers in Greenland in the eleventh century and its ivory exported (Vaughan 1981:17). Crowds of these animals coming up to breathe at a single weak place or hole in the ice occasionally allow the Greenlanders to kill large numbers at once. One of the most spectacular of these hunts, called *savssat,* occured in Disko Bugt in the winter of 1914-1915, when some 2.000 were killed. Nowadays the Greenlanders' total annual catch is around 500 animals, and the Canadian (not exclusively Inuit) catch, which at one time approached 3.000 in a single year, is now limited by quota to 335 animals (Muus and others 1982: 439-440).

The annual Greenlandic kill of white whales has been stable at between 500 and 1.000 per annum for more than a hundred years (Rink 1877: 122-130 and

Muus and others 1982:437). In the USSR, this species has been netted or harpooned by the Samoyeds and other native peoples and attempts to develop this fishery in the Ob-Yenisei area were made by the Taymyr and Northern Urals Trusts in the 1930s (Taracouzio 1938: 220-222). In 1878 Nordenskiöld was told at Khabarovo on the south shore of the Proliv Yugorskiy Shar that the local whaling company *(artel)*, the thirty shares of which were held by nine Russians and St. Nicholas (two shares), was producing 1.500-2.000 poods of train oil annually from white whales. At that time they were being hunted successfully by Norwegians using nets both off Spitsbergen and Novaya Zemlya (Nordenskiöld 1881a: 75-90 and 180-200). Tromsø vessels took 2.167 white whales in 1871 alone.

In the case of the bowhead whale, the native contribution to the annual catch has been small when compared to that of the European whalers. Indeed, in the area under consideration, native whalehunting took place only in Hudson Strait, along the western coast of Baffin Island, off the west Greenland coast, and at Angmagssalik. In west Greenland Hans Egede described and illustrated Inuit whaling with umiaks in his account of Greenland published in 1741, but it was already in decline by that time. The annual catch was probably under ten. Besides the bowhead, the humpback whale *Megaptera novaeangliae* has been hunted by Inuit from Frederikshåb and Godthåb (now Nuuk); the annual catch was put at 2-3 in the nineteenth century (Rink 1877:127-128 and Vanhöffen 1897:36-37).

In west Greenland a curious mixed native-European bowhead fishery was developed by the Danes between about 1776 and the late nineteenth century. This was based on shore stations between Sukkertoppen in the south and Upernavik in the north; the most important ones being Holsteinsborg and Godhavn. These processing stations and their look-out posts were manned through the winter, for the whales were only present close inshore between November and February. The Greenlanders caught them themselves, using European whale-boats and tackle. The catch was at first 20-30 per annum at the end of the eighteenth century, but it declined to half that amount in 1800-1850 and by 1870 only one animal a year was averaged from the only station still working - Holsteinsborg (Eschricht and Reinhardt 1866: 4-14, Rink 1877: 121-122, Vanhöffen 1897: 34-35 and Gad 1973: 387-391, 405-407).

Research in the annual reports of the different factories could certainly establish accurate production figures for this Danish-Greenlandic fishery. Similarly, only further research will make it possible to estimate the annual bowhead cull by European whalers in the seas on either side of Greenland within, say, a ten per cent margin of error. When figures are presented, their sources must be given in detail so that figures at variance with one another can be compared and verified. Take, for example, Ross's pioneering paper (1979) on the annual catch of bowheads in waters north of Canada from 1719 to 1915. When discrepancies are found between Ross's (100) annual figures for Dutch whalers and whales caught, in Davis Strait in the first decades of the eighteenth century, and de Jong's (1979:162), or between Ross's German figures and those that can be found in Oesau (1937 and 1955) and Brinner (1913), Ross's documentation turns out to be insufficient for these discrepancies to be resolved. In fact, we are in no position to present definitive figures of the whale cull of any European fishery at this stage. According to Ross, the David Strait fishery yielded 28.394 whales in the years he covers, or an average of about 145 whales per annum. This figure includes an estimated 413 whales taken by American whalers and excludes an unknown number taken by French, Danish and other whalers and by British whalers before 1814. Ross himself admits its provisional character. We shall return later to the Davis Strait fishery.

Apart from the careful investigation and detailed documentation of production figures, attention needs to be given to the way these figures and therefore the history of European whaling as a whole, can best be presented. So far, nationalism in Europe has dictated a division of whaling history by nations or states, even though in fact whaling was for the most part not undertaken by states. Thus, we have the histories of the Danish-Norwegian whaling industry by Dalgård (1967), of the Dutch whaling industry by de Jong (1972-1979), of the German Arctic whaling industry by Brinner (1913), and *The British whaling trade* by Gordon Jackson (1978). Each national state must necessarily create an independent and exclusive past for itself; but what was the state of affairs in reality?

When the French and Spanish were doing their best to wage war on one another in the middle years of the sixteenth century, their Basque subjects, fishing off Terranova, now Newfoundland, made local non-aggression pacts between themselves so that they could continue their whaling operations in peace and quiet (Ciriquiain-Gaiztarro 1961:220—225). These whalers were Basques from a group of Biscay ports on either side of the Pyrenees, rather than French or Spanish. Similarly, one can appreciate the problems with which Dalgård found himself wrestling when he came to write the history of what he called the Danish-Norwegian whale fishery. After all, Johan Braem, for nearly thirty years in the first half of the seventeenth century the uncrowned king of Danish whaling, had only moved to Copenhagen from his probably native Hamburg around 1620, after residing for a time in Lisbon and Hamburg. In 1622-1623 he went into partnership, for his Spitsbergen whaling operations, with two Basque merchants, one from Ciboure and one from Saint-Jean-de-Luz, who provided one ship, while Braem chartered a second ship in Amsterdam. At this very time he was also a royal official in charge of King Christian IV's own private whaling enterprise.

Exactly the same kind of problem arises in the early days at Spitsbergen. There were just as many disputes between Muscovy Company ships and other English so-called interlopers, and between the Noordsche Compagnie and other Dutchmen, as between the English and Dutch, and these last disputes were between the two companies, not nations. I suggest, therefore, that we start writing non-national whaling history. That is, let us take whaling history fishery by fishery, or area by area, or even town by town, rather than nation by nation.

It is a curious fact that the origins of European Arctic whaling are shrouded in mystery. What we know of its early history seems to move in unaccountable steps with inexplicable gaps between them. In the sixteenth century European whaling was still North Atlantic rather than Arctic in character. From about 1530 Basque whalers were catching nordkapers or great right whales *Balaena glacialis* along the shores of the Strait of Belle Isle between Labrador and the island of Newfoundland and, from around 1570, ships were going annually from Hull in Yorkshire to Vardø in Finnmark (which the English then called Wardhouse) and bringing back fish and whale oil. The whales, which were nordkapers, were apparently killed by Norwegians (Gillet and MacMahon 1980: 143-145). The try-works and nordkaper bones that were found at Vardø in 1882-1883 and were thought to have been the remains of Dutch activities (Sørensen 1912:1916), may well have belonged to this English trade. In 1577 the Muscovy Company (Willan 1956) acquired a royal monopoly to kill whales wherever they chose and to hire Basques to help them, but no Arctic whaling was embarked on. In 1594, the year when the Bristol ship *Grace* brought back a load of whalebone taken from a wrecked Basque whaler in St. George's Bay, Newfoundland, the Dutch actually caught their first whale. Its capture close inshore off the mainland Russian coast south-east of Ostrov Kolguyev was described by Jan Huyghen van Linschoten, who mentions that it yielded twenty tuns of blubber (Van der Moer 1979:197). That was an incident on the first of Willem Barentsz's three expeditions; during the third, in June 1596, Spitsbergen was discovered. Still, there was no Arctic whaling. Even when Henry Hudson, returning from his 1607 voyage to Spitsbergen, reported whales in plenty in Whales Bay (now Kongsfjord) (Pows 1928: 31-38), no effort was made to hunt them. The object of the Muscovy Company, in sending Jonas Poole north in 1610, was evidently to discover the elusive North-East Passage rather than search for whales. No whaling gear was taken. It was only finally in 1611, on the strength of Poole's detailed report, that the company fitted out two ships, hired six harpooners from Saint-Jean-de-Luz, and sent Jonas Poole and Thomas Edge to Spitsbergen specifically to catch whales.

There seems to be no direct connection between the different earlier sub-Arctic whale fisheries, nor between them and the Arctic Spitsbergen fishery inaugurated in 1611. Pilot whaling, in which the animals are driven ashore to be killed, is or was found in places colonised by the Vikings and may thus historically be connected with the Norwegian coastal whale fishery, for which there is evidence as early as the ninth century. Both were pursued quite independently of one another and probably of the North Sea (?) whale fishery described by Albertus Magnus in the thirteenth century (Vaughan 1981:16). They were independent, too, of the Basque whale fishery which progressed from the Biscay shores via Iceland, apparently around 1400, to Newfoundland after 1530, always hunting the nordkaper.

When the English Muscovy Company hired some Basques for their 1611 Spitsbergen voyage these people had to switch from one prey species to another and operate much further north than hitherto. In the following year, we are told because the whales were becoming scarcer in Terranova, a San Sebastian ship set course for Spitsbergen instead, piloted there by the Englishman Nicholas Woodcocke, and found numerous whales. In 1613, ten whalers went north from San Sebastian and other Spanish ports and three from the French Biscay ports of Saint-Jean-de-Luz, La Rochelle and Bordeaux. The French ships found whales "likes carps in a fishpond" but had to pay the English a tribute of eight whales. The Spanish ships, which reported that, eighty leagues from the shore "you couldn't see the sea for whales", were attacked, damaged and driven off from Spitsbergen by four armed English ships (Ciriquiain-Geiztarro 1961, Conway 1904, 1906, Lubbock 1937).

The bowhead fishery of the Spitsbergen bays and coasts flourished exceedingly from its initiation by the Muscovy Company until almost the end of the seventeenth century. In 1648, after over thirty years of intensive whaling, we have a graphic description of this bay fishery written by Christian Müller who was on board *Der Schwartze Adler* (Oesau 1955:19-23). Typically, she sailed out of Hamburg with a skipper from Bremen under the Danish flag and her owners were Johan Been, a Dutchman, and his associates. Arriving at Hamburgbukta, they found that their sister ship had already arrived in the bay, tried out over 300 cardels of train oil and loaded half of it. Lying in the bay were five large whale carcases which still had not been flensed through lack of manpower. There was a "great and ghastly stench" and, after a few fine days, the sun had melted the blubber from the decomposing whales, so that oil lay a finger thick all over the surface of the bay. The men were pestered by bears. If someone walked a little away from the try-works, five or six of these animals would advance towards him. The following year, the Hamburgers filled their casks with the chopped up blubber and tried out the oil at home. As late as 1671 Friedrich Martens described succesful whaling in the bays of north-west Spitsbergen.

Long before this, the practice of catching and flensing whales at sea and taking the blubber home for processing had been initiated, possibly by Basque or Dutch whalers. Only the Basques seem to have tried out the blubber on board ship. It has been said that the disappearance of the Noordsche Compagnie in 1642 was followed by an increase in the number of Dutch whalers operating in Spitsbergen seas, but quantitative data to establish this seem so far to have been lacking. Gradually, after about 1650, the practice of trying-out the oil ashore in Spitsbergen was abandoned and more whales began to be caught in or near the pack-ice. Specially strengthened waling ships were built; the Danes and the English (Jackson 1981), failing, it is said, to adapt their methods to the ice fishery, though this again has yet to be proved, dropped out, leaving the Spitsbergen whaling for a time to the Dutch.

Between the middle seventeenth and the middle nineteenth century, that is, more or less between the times of those two great whaling historians and writers, the Hamburger Friedrich Martens (1675, White 1855) and the Englishman William Scoresby Junior (1820), the general nature of the Spitsbergen bowhead whale fishery did not fundamentally change. The whales were caught increasingly in the ice which drifts down the east coast of Greenland, but still, invariably, between 70° North latitude and 80° North, and between the longitudes of Greenland and Spitsbergen. Spitsbergen remained the rendezvous and sheltering place of the whalers right up until the end of the fishery. Jan Mayen, once the scene of a rewarding bay fishery, especially in 1616-1619 and the scene, too, of the tragic overwintering of 1633-1634 (Brander 1955), was only a landmark on the way to the fishery.

Pending the exact figures wich detailed research in the relevant, mostly town, archives, will one day provide, we can obtain some idea of the annual catch of the Spitsbergen fishery by looking at the approximate size of the whaling fleet and the average number of whales taken per voyage (no allowance is made here for escaped whales which subsequently perished), using the tables in de Jong (1979) and other information. In the second half of the seventeenth century something over fifty ships per annum were sailing from Hamburg, Bremen and other 'German' ports, and 126 from Dutch ports (annual average for 1661-1700 from de Jong's Table 1). The catch per-ship voyage averaged four or five, so the annual catch cannot have been much less than 176 x 4.5 = 792 whales. The contribution of French, English, Danish and other ships may have brought this figure to near 1.000, but probably only in some years. For the second half of the seventeenth century, then, the general picture is an annual kill of something less than a thousand whales made by rather under two hundred ships. In some years practically no whales were killed by the Dutch because of wars, for example in 1665-1667 and 1672-1674. In other years, namely in the fifteen years 1675-1689 of peak pressure, whales were being caught at the rate of very nearly 2.000 per annum. The high peak of Dutch whaling was in 1684, when a fleet of 246 ships set sail for the Arctic; from Hamburg, the largest fleet ever, numbering 83 sail, set out in 1675.

What was it actually like to take a trip to Spitsbergen on a Dutch whaler in the golden age of the fishery? One of the most graphic surviving accounts is by Johann Dietz of Halle, who later became an army surgeon and a court barber (Miall 1923: 117-160). It must have been when he was in his early twenties, in 1685-1690, that he met three Dutchmen from Rotterdam when he was staying in Hamburg. They had come with their ship *De Hope* in order to recruit crewmen and buy provisions for Willem Bastaensz's three whaling ships. Dietz signed on, bought himself a medicine launched, each manned by six men. The whale is towed to the ship and six or eight men leap onto it to flense it. The chopped up blubber is sent down to the hold in a canvas chute to be stowed in the casks below. The flesh and bones are left in the sea and attract Polar bears and large white gulls. Many bears are shot; the skins are carefully cleaned and packed in sacks with sawdust. They capture one bear alive, a hundred miles from the shore, and haul it aboard, but it escapes and the alarmed crew take to the rigging until the skipper floors it with his flintlock. The resultant roast bear meat is much appreciated. The crew are up to all kinds of tricks, the captain being an easy-going man. But he will not allow the crew to ease themselves except by going to the gunwale; where they have to hold their breeches with one hand and grip the rigging with the other. However, Dietz is allowed to use the privy in the captain's cabin. This had the disadvantage that, in rough weather, salt water would shoot up through the hole and soak him. There are prayers every evening. Dietz wards off scurvy, which everyone else suffers from, by drinking a total of four gallons of French wine with grated horseradish in it. In the end they are all cured by eating green leaves gathered on Spitsbergen. Things could not have been too bad for our surgeon; he went again in the following year!

During the course of the eighteenth century the size of the combined Dutch-German whaling fleet declined from over 200 in 1700-1740 to around 160 ships per annum in the 1770s; the catch per ship-voyage also declined, to something between two and three whales; and an unknown but perhaps increasing proportion of ships sailed south and west of Greenland: the so-called 'Davis Strait' fishery was born. According to de Jong's Table 23, the annual Dutch-German whale catch in the first eighty years of the eighteenth century was 645 whales, a proportion of which were killed in Davis Strait. The significant drop in the Spitsbergen catch was followed by the dramatic decline of Dutch whaling in the last twenty years of the century, and then its complete collapse during the Revolutionary and Napoleonic Wars, 1795-1804.

De Jong analyses the causes of the collapse of Dutch whaling after 1780 and shows that the 1777 disaster was not a principal one. In that year (de Jong 1978:412-420) 12 ships, 4 of them Dutch and 7 from Hamburg (Oesau 1955: 171-173) were beset in the so-called West Ice along the north-east coast of Greenland, drifted south for weeks, and were crushed one after another. One of the last surviving ships went down on 11 October. It had had 286 eaters on board, some 250 of them being survivors from sunk ships. A hundred and fifty men eventually made their way to the Danish west coast colonies; double that number died. A narrative of the harrowing adventures of one group of survivors from the *Jacobus* out of Hamburg, written by Jürgen Seeth, was printed soon after the event (Oesau 1937: 231-243). Their ship was first beset on 3 June. By the end of that month there were 27 ships in sight of them, all beset in the ice: 9 from Hamburg, 7 from Dutch ports, 8 English, 2 Swedish and one from Bremen. Their ship went down on 20 August and its crew was divided between four ships. By early October the author and his companions had to divide their time between small boats and ice-floes as they drifted down the Greenland coast. They remained on one floe for 32 nights. On 22 October they saw icebergs as big as Helgoland. From 24 November until 20 March, when some Inuit arrived and rescued them, they camped on a rock off the south-east coast of Greenland which was drenched with water at high tide and during storms, which were frequent.

From the mid-eighteenth century, after a long period of inactivity, some mainly east coast ports in England and Scotland, stimulated by the offer of government subsidies, called bounties, increasingly took up whaling. London, for instance, which sent four ships annually in the 1730s and 1740s, averaged 30 ships per annum in the 1750s, and reached 78 in 1785 (Jackson 1978: 262). In 1816 over 100 English whalers sailed to Spitsbergen but, after 102 in 1820, in which year an English ship reported "36 foreigners" as well (Lubbock 1937: 215), there was a rapid decline to 12 per annum in the 1830s.

After about 1850 it is doubtful if whales were any longer being killed annually in Spitsbergen waters. In 1880 the Peterhead whaler *Hope* enrolled a twenty-one year-old Edinburgh University medical student as surgeon. The *Hope*, captain John Gray, was one of the last Scottish Arctic whalers. The surgeon wrote an entertaining account of his trip, describing the killing of seals and the search for whales further north, for the *Strand magazine*. The captain, who had many Arctic voyages to his credit, claimed to be able to recognize individual whales; he thought that there were only 300 left in Spitsbergen waters. The name of that surgeon was Arthur Conan Doyle, later to become famous as the creator of Sherlock Holmes. Captain Gray may have over-estimated the size of the surviving stock of whales. When the Norwegians began mopping up the population of blue and fin whales *(Balaenoptera physalus)* in Spitsbergen waters from 1890 onwards they did not even see a bowhead until 1911, and that one was killed (Risting 1922:261). In spite of everything, the bowhead still exists in this area. On 23 April 1979 two were seen in a lead in the ice between north-east Greenland and Spitsbergen in 80°45'North latitude and 5°45'longitude (Muus and others 1982: 459).

In the seventeenth and eighteenth centuries the continental Spitsbergen bowhead fishery was conducted in the main by shipowners in a variety of ports between Rotterdam and Lübeck, in particular Amsterdam and Hamburg, whose ships were skippered and crewed very largely by men from the offshore islands, namely the Waddenzee, East Frisian and North Frisian Islands, from Den Helder (then almost an island) and Texel to Föhr and Sylt. Every year in the early spring a fleet of fishing smacks left the island of Föhr for Amsterdam loaded with whalemen eager to sign on for the annual Greenland voyage. The legendary Matthias Peterson, "Lucky Matthias", who died in 1706 having caught 373 whales, was from Föhr. In summer 1760 it was reckoned that, of the island's 4.500 inhabitants, 1.450 males were away whaling in the Arctic (Dekker 1971: 35, 33).

In the late eighteenth and first half of the nineteenth century it was a group of English and Scottish ports which provided the capital and the skippers for the Spitsbergen whalers. At first, from the mid-eighteenth century, London was supreme; then she was overtaken in the early nineteenth century by Hull which, after the mid-nineteenth century, surrendered her supremacy to the Scottish ports first, Peterhead, then after 1870, Dundee. From the tiny Yorkshire harbour of Whitby, 20 ships sailed annually in 1786-1788, and it was Whitby which was the home port, not only of James Cook but also of William Scoresby Senior, who was credited with catching more whales "than any other individual in Europe", namely 533 (Scoresby 1851: 186). Whether or not this is true, his thirty Arctic voyages did not constitute a record; the commander of an Altona whaler named de Bryhyt went on 54 whaling voyages between 1722 and 1777 (Oesau 1937: 37-46). As for their crews, both English and Scottish whalers left their home ports with more or less of a skeleton crew and picked up the rest, amounting to anything from a quarter to a half of their crew, in the northern isles, Orkney and Shetland.

Besides the areas so far mentioned, the contribution of others to the Spitsbergen fishery was limited. Between 1615 and 1660 one to three or occasionally five ships went to Spitsbergen in most years sailing under Danish royal privilege and fitted out in Copenhagen or, occasionally, Bergen (Dalgård 1962). From 1749 to 1758, the Danish Royal Chartered General Trading Company sent up to four ships annually both to Spitsbergen and Davis Strait (Gad 1973: 282). Because of heavy losses, a prize was offered in 1773 for the best explanation of this failure. It was won by a Danish naval officer called Andreas Henrich Stibolt, who earned a large silver medal from the Royal Danish Society for Rural Economy for his first answer to the question in 1773, and a gold medal for his second answer the following year, which was backed with figures from Holland. It was used as the basis for a government-supported attempt to set up a Danish whaling industry to be carried out by a fleet of 50 ships under the leadership of an experienced Dutch commander from Den Helder, Jacob Potter. Two hundred ship-voyages to Davis Strait and Spitsbergen were made in 1775-1788 but substantial losses occurred in spite of government subsidies (de Jong 1978: 385-387).

From Bergen and other south Norwegian ports one to four whalers sailed annually through most of the eighteenth century, and from 1755, again with help of bounties, ships sailed from Gothenburg in Sweden, apparently both to Spitsbergen and to Davis Strait. Operating from Bruges from 1665 and again from 1772, and in Ostend from 1727, there were short-lived whale fisheries. The early seventeenth-century whaler Jean Vrolicq may have been Flemish. He apparently lived for a time in Saint-Jean-de-Luz, and had connections with San Sebastian and also Copenhagen. He also served as harpooner with the Noordsche Compagnie before obtaining a charter valid for four years from Richelieu, that is, the French government, to catch whales north of 60° North latitude. He organised French Arctic whaling from Le Havre. In Spitsbergen he annoyed the Dutch by renaming places with French names; he claimed to have discovered Jan Mayen and called it the Isle de Richelieu (Dalgård 1962: 156-160, 183-184). But his efforts bore fruit, and the role of protector and encourager of French whaling was later taken over by Mazarin in 1644. In some years more than ten French ships sailed to Spitsbergen, but the enterprise collapsed in the 1670s (La Roncière 1923: 675-680 and 1934: 433) and French whalers only appeared fitfully in the eighteenth and nineteenth centuries. In 1830, there were three in Spitsbergen waters, and the three-masted ship *Ville de Dieppe* was one of those crushed by the ice in Davis Strait (Lacroix 1938: 34, 36).

The name 'Davis Strait' fishery covers at least three more or less distinct areas or fishing grounds. Firstly, the coastal waters of south-west Baffin Island, especially the two great inlets of Cumberland Sound and Frobisher Bay, and Hudson Strait. This area was penetrated at an early date and fished until the end of Arctic bowhead whaling by Europeans around 1915. Secondly, the coastal waters around Disko and, thirdly, the northern and western coasts and inlets of Baffin Bay, including Lancaster Sound, first penetrated in 1819 and 1820 (Parry 1821: 235-237, 258-259). How many distinct populations of whales were involved it is impossible to say. Indeed it should be emphasised that we do not know that the whale population in Davis Strait and Baffin Bay was distinct from that in Spitsbergen waters. There is some evidence to the contrary: in 1805 a whale was harpooned in Davis Strait but got away; later in that same year it was killed near Spitsbergen (Eschricht and Reinhardt 1866: 20). And William Scoresby Junior mentions three well-authenticated cases of a stone or bone Inuit harpoon being found in a whale killed near Spitbergen (1820a: 10-11).

The present state of research in whaling history permits us to say little definitive about the Davis Strait fishery. The Dutch and the Germans began it in the 1690s, but, in the 1760s, only about a fifth of the Dutch whaling fleet was going there. Between 1690 and 1730 the Dutch explored and mapped West Greenland and Dutch whalers developed a trade with the Greenlanders as a side-line to whaling which flourished at Disko through the middle of the eighteenth century. Jackson's figures (1978: 270) show that the number of English and Scottish ships sailing to Davis Strait caught up with the number going to Spitsbergen in 1821: in that year 80 ships went to Spitsbergen and 79 to Davis Strait. Numbers were equal again in 1822 (61 and 60 respectively). After that, Davis Strait whalers outnumbered those going to Spitsbergen. Indeed in 1830, 91 British whalers went to Davis Strait and none to Spitsbergen. From 1837, however, against a background of rapid decline of the industry and frequent losses of ships in the ice, the pendulum swung the other way, and for a time more ships went to Spitsbergen. Figures for the second half of the nineteenth century, which were in any case insignificant, have yet to be worked out. The Davis Strait fishery survided longer than the Spitsbergen fishery, namely until the outbreak of the First World War. From 1851 onwards ships or parts of crews overwintered from time to time in Cumberland Sound and an effort was made to diminish financial losses by diversification. The last European port to send out whalers to the Arctic, and the only one after 1900, was Dundee (Lythe 1964).

The Hudson Bay bowhead fishery in the area of Southampton Island remains to be mentioned, though it was primarily American, not European. The Hudson's Bay Company tried to hunt bowheads there in 1719 and 1765-1772 but without success. Then, between 1860 and 1915 American whalers developed a flourishing fishery based on overwintering, and trade and cooperation with the local Inuit. European participation amounted to a total of 29 English and Scottish voyages, as against 117 American. Thanks to the work of Stackpole (1969) and, above all, W. Gillies Ross (1975), we have fuller and more accurate information about this fishery than any of the others so far discussed. We know exactly where the whalemen came from, the times, seasons and years of their activity, the area in which they operated and the number of whales they killed. We know a great deal about the life of the whalemen and their impact on and relationship with the local Inuit inhabitants. The economics of the fishery, so well worked out for Britain as a whole by Gordon Jackson, we know less about. Let us hope that, in the foreseeable future, historical research will begin to make available comparable information about the other, older, much more significant, and wholly European bowhead fisheries whose history I have tried to sketch out.

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THE HISTORY OF EARLY DUTCH WHALING: A STUDY FROM THE ECOLOGICAL ANGLE

by

Louwrens Hacquebord

"...Just as in our lands the cold is not always equally severe, so is it also in Spitsbergen..." Friedrich Martens 1710.

In 1978 the Arctic Centre started research on the first phase of seventeenth-century Dutch whaling activities in the waters close to Spitsbergen and Jan Mayen Island. This research is mainly concerned with the ecological effects of the whalers' stay in the Arctic. In this multidisciplinary project, attention also was paid to the living and working conditions in the seasonal settlements sited on the west coast of Spitsbergen against the background of the changing climatological and oceanographical circumstances.

Apart from the field study undertaken on the islands in the north west corner of Spitsbergen, a search was made in the Dutch archives for written sources which could provide information concerning events in the North Atlantic Ocean in the seventeenth century. Ship's logbooks, notarial documents concerning fishing disputes and ice damage, freight contracts and receipts were studied from an ecological perspective. The information derived from work in the field has been systematically compared with the information from the archives in order to acquire as comprehensive as possible a picture of the Dutch presence on the Arctic coasts.

Location of the hunting areas

Dutch whaling in the beginning of the seventeenth century took place mainly in the bays and coastal waters of Spitsbergen, which currently on an increasing number of maps is given the modern Norwegian name Svalbard. The most important hunting area lay in the north-west corner of this Arctic archipelago. There is a large bay here which is bounded on the eastern and southern side by steep mountains with glaciers between them. On the seaward side it is separated from the Ocean by two Islands, Amsterdam Island and Danish Island. In the seventeenth century this bay was called *Hollandsche of te Mauritiusbay* and is now named the Smeerenburgfjord.

Apart from this area, in the early years the Dutch also hunted whales in a

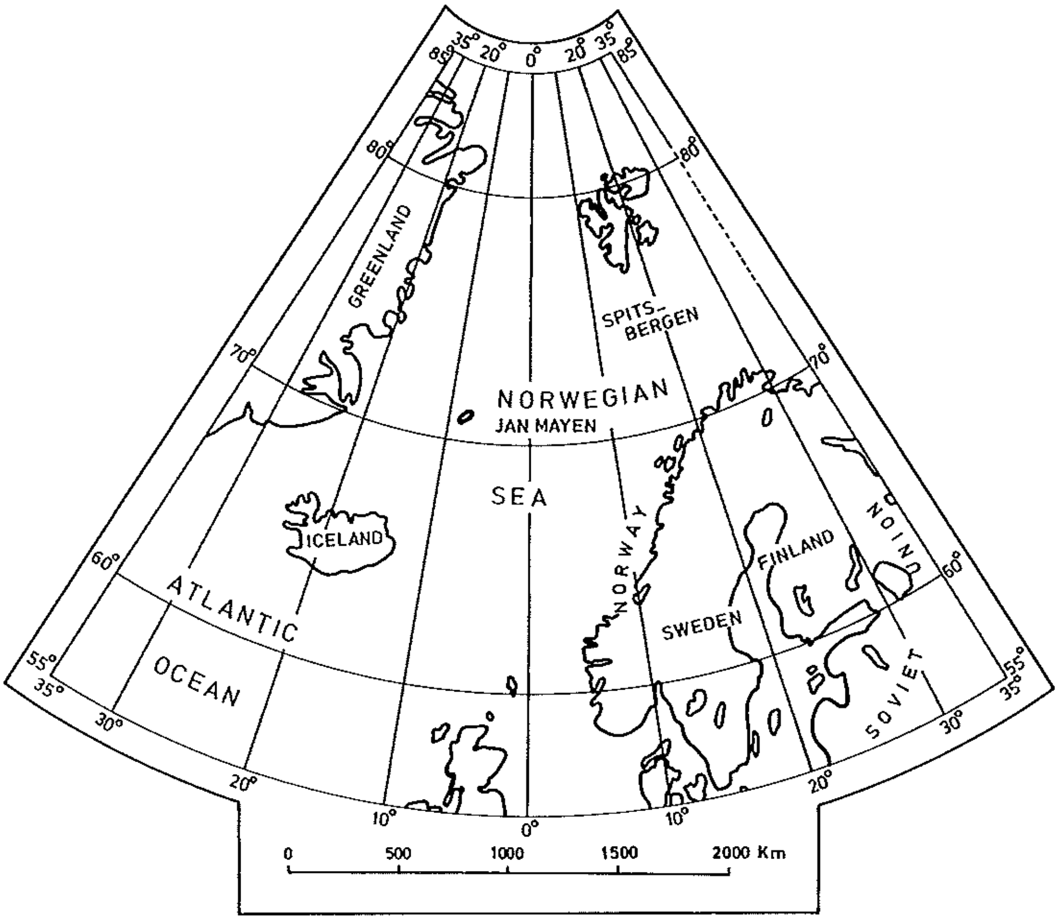


Fig. 1. Location of places mentioned

more southerly area, namely in the waters around Jan Mayen Island at lat. 71° N., and at first this area was more important for the Dutch whalers than Spitsbergen (Fig. 1). The most important species of whale hunted was the Greenland whale or Bowhead (*Balaena Mysticetus* Linné).

The habitat of the bowhead whale

The bowhead whale is an endemic Arctic whale which lives the whole year round near the pack ice. In spring, it used to migrate from the waters south of Greenland along the edge of the pack ice in a northerly direction to the waters around Spitsbergen, and probably even further to the coastal waters of Novaya Zemlya (Zorgdrager 1727 p. 120 ff.). The animal followed the habitat of the plankton until it came to the most northerly corner of its biotope. In the convergence zone, where the relatively warm water of the Gulf Stream and the cold water of the East Greenland Current meet, (Fig. 2) the waters mix and produce an ideal environment for phytoplankton, which undergoes a short lasting explosive growth when the pack ice disappears and therefore produces an ideal feeding area for the zooplankton which forms the food supply of the bowhead whale. As the seventeenth-century whalers said, "It is a good sign of a large catch of whales when many of the creatures [zooplankton, LH] are seen, for the whales gladly come there and the sea is sometimes so full of them that it swarms"[1]) (Honoré Naber 1930 p. 2). The whale stands at the summit of a very short feeding chain, which is especially efficient since, by virtue of the small number of links involved, little energy is wasted. The zooplankton is composed of a few species but consists of a great number of individuals (Zenkewitch 1963 p. 47). According to Vibe (1967) the most important

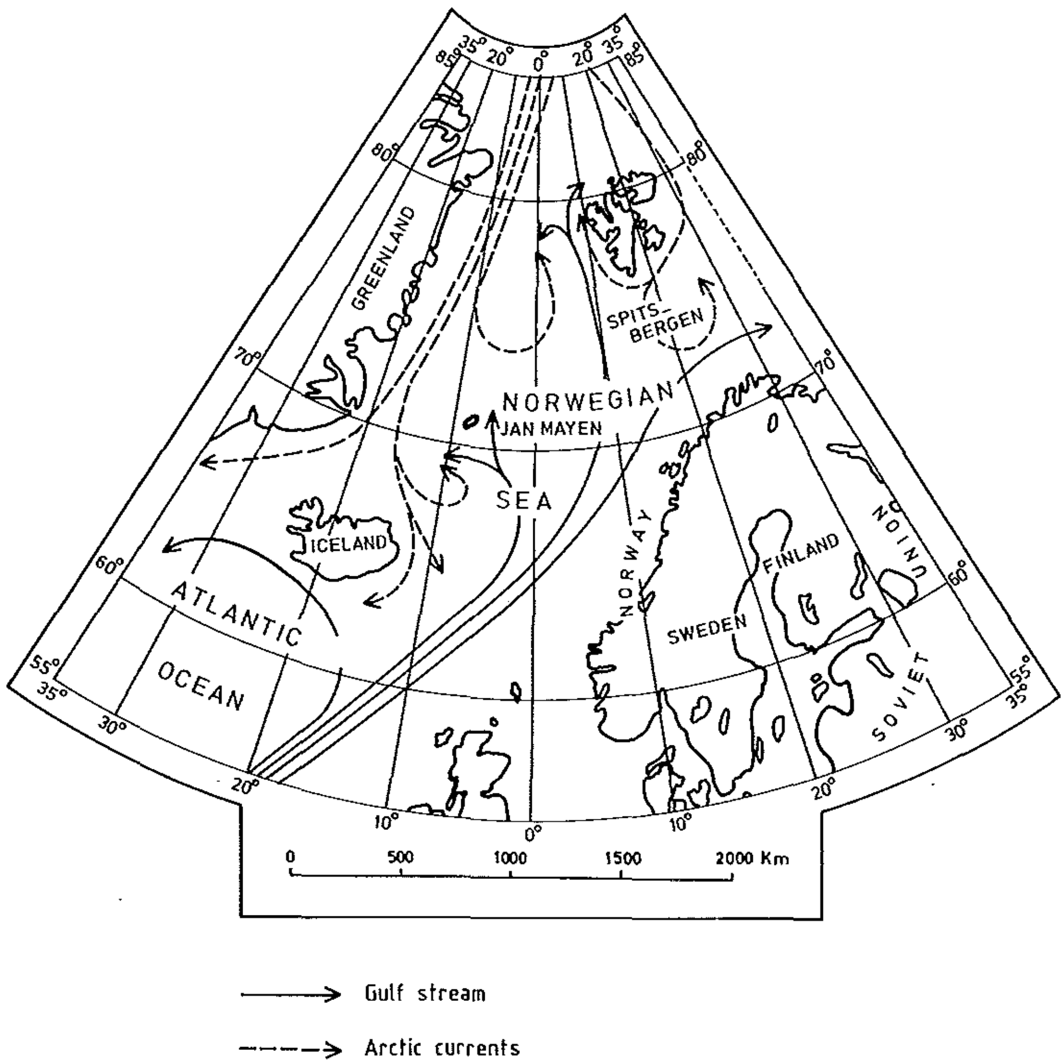


Fig. 2. The general water circulation in the North Atlantic Ocean

feeding places for the bowhead whale lie at the edge of the continental shelf between 200 and 1000 metres deep. When this part of the Atlantic Ocean remained covered with pack ice for the whole summer, the phytoplankton and therefore also the zooplankton failed to develop and the bowhead whale stayed away.

Climatic change and the bowhead whale

From isotope studies of the Greenland and Canadian ice cores it appears that during the 'little ice age' there was a cold phase which lasted from 1570 to 1625. This cold phase was marked by a noticeable advance of the glaciers of northern Scandinavia (Karlèn 1979). During this period the entire Atlantic Oceanic current system expanded and the Gulf Stream moved closer to the Norwegian coast. Within this enlarged Atlantic Ocean current pattern a good mixing took place of the cold Arctic water with the relatively warm water of the Gulf Stream so that, along the edge of the continental shelf, large concentrations of plankton could come into being. As a result of changes in the path of the Gulf Stream and a reduction in velocity of this ocean current, less pack ice melted (Dunbar and Thomson, 1979). Thus it very often happened that during the summer months July and August the edge of the ice-pack lay close to the north east coast of Spitsbergen (Fig. 3). Thus, an ideal habitat for the bowhead whale developed in the bays and coastal waters of Spitsbergen and concentrations of this species occurred there.

The widening of the Atlantic Oceanic current system also brought a larger part of the North Atlantic Ocean into the sphere of influence of the cold Arctic waters. According to Lamb (1979), the Arctic water extended to the waters around the Faroe Islands, to the detriment of the codfishing in this area.

The first cold phase of 1570 - 1625 was, according to the pollen studies, followed by a relatively warm phase which on Spitsbergen had its peak around 1635 (van der Knaap, 1983). The glaciers in northern Scandinavia melted at this time and entered into a phase of recession (Karlèn 1976, 1979). The zonal component dominated the atmospheric circulation in middle latitudes and the sub polar low pressure area moved towards the north, while milder air appeared more frequently in the sub-Arctic and Arctic. In reaction to these changes the Atlantic Oceanic current system shrank, so that a less efficient mixing of the warm and cold water occurred. In the surface water of the Atlantic Ocean the warm water of the Gulf Stream predominated, and the Gulf Stream moved away from the Norwegian coast. This greatly influenced the ice situation around Spitsbergen. The velocity of the whole current system

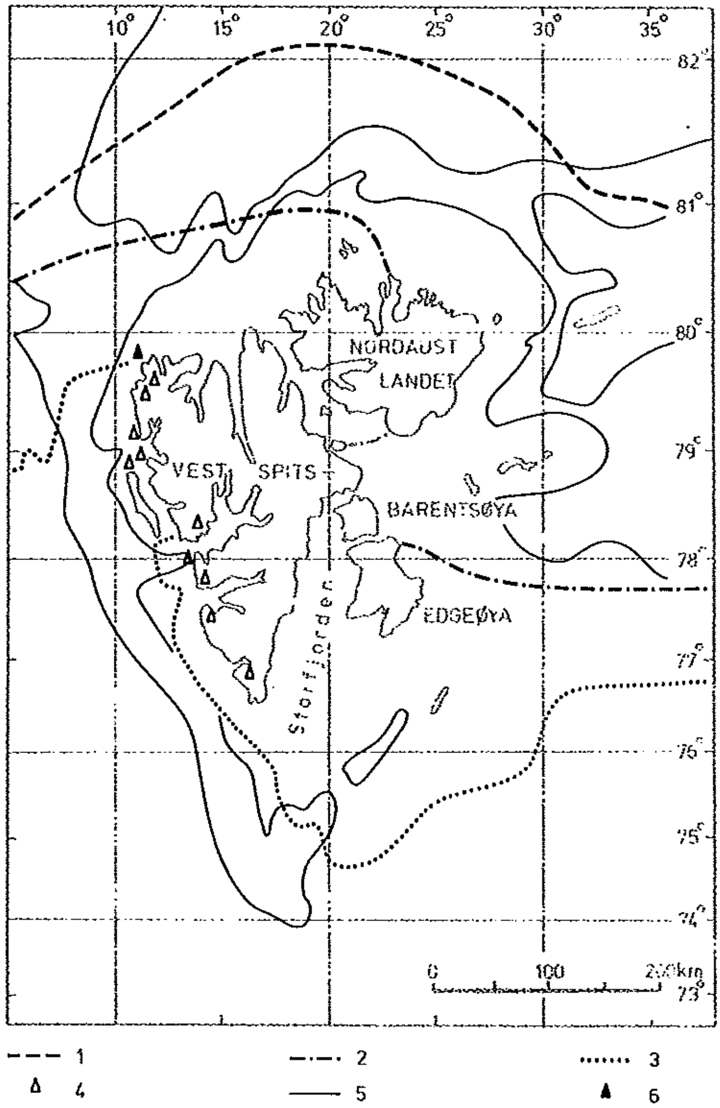
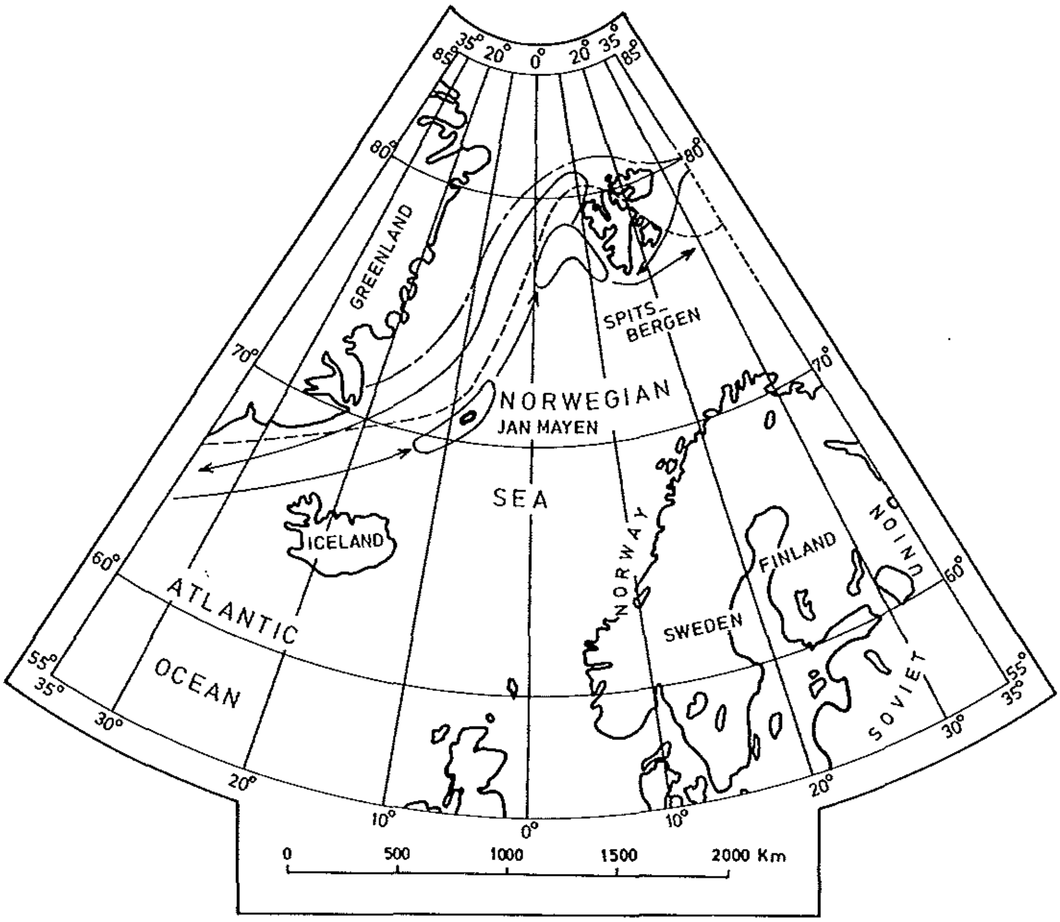


Fig. 3 Average position of the edge of the pack ice in August during the period 1946-1963
1. Minimum extension of the pack ice
2. Average extension of the pack ice
3. Maximum extension of the pack ice
4. English whalingstation
5. The 200-1000 meter depth zône near Spitsbergen
6. Dutch whalingstation

increased and more ice drifted out of the Arctic basin. This ice was transported southwards by the likewise stronger East Greenland Current and the edge of the ice-pack thereby came to lie further from the north coast of Spitsbergen. As a result of these changes the feeding areas of the bowhead whale moved further from Spitsbergen and it was concentrated in its bays less frequently. Reports from Iceland show that at this time the number of weeks with Arctic ice on the north coast increased substantially (Koch 1945). Complaints from Dutch whalers about ice damage and obstruction by ice around Jan Mayen also increased in the sixteen-thirties, while in this period there were no complaints from Spitsbergen waters. In a number of notarial acts it was explicitly stated that there was no excess ice in the bays of Spitsbergen in the years the whaling around Jan Mayen was troubled by ice (various notarial acts and log books of Michiel A. de Ruyter 1633 and 1635, Honoré Naber 1930). Codfishing around the Faroes flourished once again at this time, in keeping with the above events (Lamb 1979).

In the beginning of the 1640s the climatic situation changed again: in middle latitudes the zonal air circulation decreased and the subpolar minimum moved south. Thus the influence of the polar maximum dominated in the Arctic and the average temperature fell. The Atlantic oceanic gyre widened once more and a better mixing of the superficial and deep water occurred. Along the continental shelf around Spitsbergen a favourable habitat for phytoplankton now came into existence. As a result of a diversion in the path of the Gulf Stream towards Norwegian coastal waters, its influence on Spitsbergen decreased. The ice-pack could therefore increase and its summer boundary came once more to lie in the vicinity of the north coast of Spitsbergen. So the bays of Spitsbergen became once more attractive for the bowhead whale, which returned to them more often in large numbers, but only for a short time, because the cooling caused the bays to remain frozen until later in the summer. In the consequent short open season the phytoplankton and zooplankton had insufficient time to proliferate and the whales soon stayed away (Vibe 1967). During this cool period the glaciers in northern Scandinavia advanced, and from historical sources it is known that the glaciers in Spitsbergen also advanced at this time. Friedrich Martens, when he sailed in Spitsbergen waters in 1671, remarked: "Yet, for all this, some greater ice mountains are seen there that stand firm on the shore, and never melt at bottom, but increase every year higher and higher, by reason of the snow that falls on them and then rain freezes, and then snow again alternately; and after this manner the ice-hills increase yearly, and are never melted by the heat of the sun at the top"[2]). In this same period there was little ice in the neighbourhood of Jan Mayen, the bowhead whale was less common there and around 1650 whaling stopped.

The number of notarial acts referring to ice and damage by ice increased rapidly in the 1660s, and the number of ice years reconstructed from this information rapidly increased. From historical research it appears that between 1660 and 1665 Spitsbergen was bothered with excess ice in four out of five years. The ice situation around Spitsbergen was undoubtedly deteriorating; indeed the ice-pack came so close to the coast that the open water 'lead' very often froze over completely: "it also happeneth sometimes that the land is begirt with ice in summer, as they have often seen that go thither every year"[3]). Concentrations of bowhead whales now only occurred at feeding grounds in the open sea near the edge of the ice-pack (Fig. 4).



------ The edge of the ice-pack in july

---·--- The edge of the ice-pack in september

———→ Migrationroute of the Greenland whale or Bowhead

Fig. 4 Relation between the migration route of the Bowhead whale and the edge of the ice-pack in the North Atlantic Ocean

Climatic changes and whaling

When climatic change affects the bowhead whale so dramatically, whaling activities are naturally affected as well. The influence of climate goes much further than the determination of the hunting areas, for the change in hunting areas is accompanied by changes in hunting and processing methods, so that the entire whaling industry has to be reorganised. A combination of historical research and archeological field work permits us to sketch the following developments.

The first Dutch whaling voyages took place in 1612 and 1613, and in these years the whale catch had a very incidental character. The new investment possibilities had been tried without much succes, and their incidental character was shown by the temporary nature of the settlements on the Spitsbergen coast. In 1614, a number of merchants set up the *Noordsche Compagnie* and requested a charter from the States General. Each important port in the Dutch Republic took its place as an independant enterprise or branch (called in Dutch *kamer,* chamber) in this whaling company. In this way, a cartel of whaling enterprises was formed, and agreements were made concerning catches and prices, so that the whaling trade made some impression of order. However, on arrival in the hunting areas, these agreements were often forgotten. Whereever possible, temporary arrangements were made for trying out the whale oil, and at the end of the catching season everything was dismantled, the components which were still usable were taken on board ship, and the rest were left behind. During this first period of Dutch whaling history most of the whaling ships went to Jan Mayen Island. Less important was the whaling on Spitsbergen where, because of English competition, the Dutch whalers were forced to concentrate in the northern bays. In one of these bays some ovens were established on a completely unsheltered beach on Amsterdam Island, which layed approximately one meter above sea level. This location in many ways resembled the situation in the Netherlands, and must have appeared familiar to the whalers. Thus recognition in the light of previous experience may have played an important role in the choice of site for the principal Dutch whaling settlement on Spitsbergen. Among the Dutch, at first only the Amsterdam Chamber of the *Noordsche Compagnie* had a train oil works on Amsterdam Island; the Danish Whaling Company also established themselves there. But after the Danish whalers ceased to visit the place for some years in 1624, the other *Noordsche Compagnie* Chambers established cookeries on this site. The ovens were built for use over a period of several years, and the earlier huts were soon replaced by wooden houses with stoves. In subsequent years a process of adaptation continued, whereby the houses were made more comfortable under Arctic conditions. The settlement at Smeerenburg consisted of six try-works and approximately fifteen houses with provision for about 150 inhabitants (Hacquebord 1981^{A}, 1981^{B}).

From the excavations, it appears that Smeerenburg had three habitation phases. During the first phase, temporary shelters were made from oars and sail canvas. A culture layer found approximately 50 cm. below ground level containing hardly any building materials formed the remains of this first habitation phase. At the end of the sixteen-twenties Smeerenburg was visited less frequently. Interest in whaling temporarily decreased in the Republic, because a variety of new investment possibilities appeared. The ships fitted out in those years sailed mostly to Jan Mayen Island where whaling was more succesful. In the thirties, because of high oil prices, Smeerenburg once more became busy; more ships arrived and the settlement was improved. The buildings were raised above ground with the help of ballast sand, so decreasing the problem of excess water. This raised layer could be easily recognised on all the profiles and its origin could be determined by identifying the shell remnants in the sand (Den Hartog Jager 1982). A single brick-built house rose between the wooden houses during this second habitation phase at Smeerenburg. The bricks were laid on a clay foundation and the outside of the brick wall was protected from the effects of frost by a wooden wall. The edge of the ice-pack, as mentioned above, moved away from the north coast of Spitsbergen during this phase of the Smeerenburg settlement because of the climatic change around 1625. Fewer bowhead whales came into the bays, and whaling moved into the open sea. In contracts with harpooners the clause "in sea by the edge of the ice-pack"[4]) was used from 1634 (NA no. 963/fol. 77^{v}; Rijksarchief, Haarlem).

Initially, the blubber was mostly cooked in Smeerenburg, but when the distance between Smeerenburg and the hunting grounds increased, the blubber was placed in barrels and, despite the reduction in quality, was cooked in Holland at the end of the catching season. A surviving contemporary notarial act shows that the difference in quality was taken into account in fixing the price. Thus in 1633 there was a price difference of fifteen guilders between a barrel of oil cooked at Smeerenburg or on Jan Mayen Island, compared with a similar quantity cooked in Holland. Blubber was cooked in Holland in spite of this price difference. In the same document it is stated that the Enkhuizen Chamber was already cooking oil in Holland in 1633 (NA 930/133 (1); Rijksarchief, Haarlem). As whaling was now carried out in the open sea, where it was almost impossible to control, the number of ships not belonging to the *Noordsche Compagnie* increased. These so-called interlopers had to barrel the blubber and to cook it in Holland because they were not allowed to cook in Smeerenburg or elsewhere on the coast of

Spitsbergen. At the end of the thirties, however, Smeerenburg was visited less frequently, and a second decline occurred.

When in 1642 the charter of the *Noordsche Compagnie* expired, the members decided not to ask for a prolongation. Since the most important hunting grounds now lay in the open sea, it was thought that the States General would in any case not agree to this. A prolongation of the charter would have involved an extension of the area covered by it, and the States General would, by issuing a monopoly right for the open sea, have been in conflict with the accepted views in Holland concerning the status of the sea. In the forties climate changed once more. After a delay of some years the edge of the ice-pack again bordered the northern coast of Spitsbergen and the bowhead whales once more congregated in the bays there, while they very rarely visited Jan Mayen. Whaling moved back to Spitsbergen, from which the chambers of the *Noordsche Compagnie* attempted to exclude their rivals. A turbulent period followed and, mainly because of the increased number of ships, there was a great deal of activity in the Spitsbergen bays. While many independent Dutch merchants tried their luck with whaling, the leading members of the chambers of the former *Noordsche Compagnie* attempted to revive the expired charter in 1649 en 1651 in order to restore their former monopoly. This failed because the group of interlopers had become too large and powerful. Thus whaling took on the character of a gold rush, mainly concentrated on the Spitsbergen hunting grounds. Everywhere on the coast try-works appeared, and Smeerenburg lost its character as an annual settlement. Evidence from the excavation and the dating of artefacts found during it, shows that after the second habitation phase, Smeerenburg had almost no real inhabitants any more. The ovens were still used during this third phase but the so-called land-men lived mostly on board the anchored ships. Occasionally the skippers even had to be forced by their freight contracts to cook the blubber in Spitsbergen (various notarial acts). Because of the climatic changes, whaling had been transformed from a more or less organised stable industry into a more speculative activity. There was no longer a comprehensive form of organisation. In such a situation, permanent try-works were no longer feasible.

The situation remained as it was for a time, but at the end of the fifties and the beginning of the sixties, both the bay and the sea fishing stopped, and the try-works were dismantled one by one. This transformation was a result of the severe cold period in the second half of the seventeenth century, which caused the bowhead whale to become less frequent in the bays of Spitsbergen. In these decades whaling took place in the drift ice along the edge of the ice-pack.

Whaling activity as a whole adapted to this change. In future, the dead whales were stripped of their blubber alongside the ship, and the blubber was mostly cooked in Holland[5]). The ships had now a double hull and other technical modifications. The skipper disappeared from the whaling ships and the commander, who before 1640 was only in charge during the whale catch, took his place. The heyday of free enterprise in the whaling trade now began. Up to 1640 an average 16 ships were fitted out each year, and an average annual catch of 90 till 180 whales was achieved. Around 1650, the various whaling companies fitted out about 50 ships, which caught 250 - 500 whales annually. From about 1660 until 1700 the Dutch fitted out 150 - 250 ships, catching 750 - 1250 whales annually. It was this period of free enterprise that was responsible for the extinction of the bowhead whale in the North Atlantic Ocean.

Because of the geographical position of their hunting ground, the Dutch became accustomed from early on to sailing in ice. Even during the period when the Spitsbergen bay fisheries were still active, the Dutch whalers were at times confronted with drift ice. The process of adaptation was therefore very gradual and when natural circumstances rapidly deteriorated the Dutch were not taken by surprise. The English whalers, whose hunting grounds lay in the more southerly bays, had less opportunity to accumulate the experience necessary for ice fishing. This lack of the necessary knowledge, combined with internal problems and strong competition from the Dutch in the whale-oil market, explains why the English did not make the step from bay to ice fishing. As a result, English whaling ceased to exist around 1670 and it was not until the second half of the eighteenth century that English merchants once more sent ships to the north (Jackson 1978).

Conclusion

It is evident that the relationship between whaling and natural circumstances was so close that it is almost impossible to fathom out the history of early Dutch whaling without an understanding of the climatological and oceanographical circumstances during the seventeenth century. Insight into contemporary technical, economic and social developments in Holland is also of importance. Even in whaling not all developments can be explained from the ecological angle. It is noteworthy that, in the first half of the seventeenth century, the waters round Jan Mayen Island were more important for Dutch whaling than the bays of Spitsbergen. Finally, it seems to have been the whaling in the period of free enterprise (especially 1660 - 1700) that was responsible for the extermination of the bowhead whale in the North Atlantic Ocean.

NOTES

1) Het is een goet teken van veel walvischvangst, daer veel van dit ongedierte [zooplankton of "spinnekoppen"] gesien wort, want de walvisschen daer geerne omtrent haer verhouden en de see is somtijts soo vol van dit vuyle tuygh dat het weemelt (Honoré Naber 1930 p. 2).
2) White, 1855:36, English translation of 1694. A later Dutch version has: Echter worden hier de grootste ijsbergen gezien als die tusschen de Bergen staen, welcke noyt van onder en smelten maer alle Jaer grooter werden door de opvallende Sneeuw, Regen, Gladijs ende weer Sneeuw. Op deze wijze nemen d'IJsbergen steeds in aengroey toe zonder oyt door Sonnewarmte van boven te smelten ... (Friedrich Martens 1710).
3) White, 1855:17, English translation of 1694. The 1710 Dutch version has: 't Gebeurt ook wel dat het Lant in de Somer van 't IJs bezet werd, gelijk die geene betuygen die alle Jaren dese Gewesten bevaren (Friedrich Martens 1710).
4) in zee aent ijs
5) During research in the municipal archives at Rotterdam after I gave this lecture I found two notarial acts in which it is stated that the whalers had to cook the blubber on land or on the ship. These are the first references I have come across to cooking on board a Dutch ship (GAR 509/207, 3 April 1658 and GAR 509/249, 30 April 1658; both notary Mustelius from Rotterdam).

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HISTORICAL SURVEY OF FOREIGN WHALING: NORTH AMERICA

by

Richard C. Kugler

A historical survey of Arctic whaling in North America by foreign whalers embraces so large a subject that the boundaries of discussion should be established at the outset. The term "foreign whaling," to begin with, is understood to mean whaling activity by non-indigenous peoples who came to the northern waters of the North American continent. The Eskimos of Alaska, Canada and Greenland and the Indians of the Northwest Coast of North America, each with long histories of whaling for subsistence purposes, are thus excluded from consideration.

The foreign whalers were commercial whalers. They came predominantly from the United States, although the British were present in large numbers in the eastern Arctic. Also in the east were once the Dutch, but their numbers had dwindled and, by the beginning of the nineteenth century, they had largely withdrawn from the waters west of Greenland. In the western Arctic, besides the Americans, were vessels owned and manned by Frenchmen, Germans, Danes, Australians and Hawaiian Islanders. Occasional vessels from Norway, Russia and Chile also appeared from time to time. For all who came, they had one purpose: to take the oil and baleen of the bowhead whale, *Balaena mysticetus.* In terms of chronology, foreign whaling in the North American Arctic took place almost entirely during the years from 1820 to 1910. In two major areas of activity, Hudson Bay and the western Arctic, the span of time was even more compressed, being confined to the last half of the nineteenth century and the first decade of the twentieth. By 1910, market conditions and the stocks of whales had sunk so low that no further incentive for commercial whaling remained.

The geographical boundaries of whaling in the North American Arctic extended from Davis Strait in the east to the Chukchi Sea in the west. To comprehend the history of whaling over this large expanse of space, one further area, outside the boundaries of the American continent, must be included. In the Okhotsk Sea, whaling occurred as an extension of North American whaling and should be viewed as part of the great expansion of the bowhead fishery in the middle decades of the nineteenth century. Within this expanded area, there were four areas of concentrated whaling activity, each having a distinct and largely separate history. Two of the four define the northern extremities of the North American land mass: Davis Strait in the east and Bering Strait in the west. Each of these straits leads into more northern waters, only briefly free of ice: the Chukchi and Beaufort Seas in the west; Baffin Bay, Lancaster Sound and other inlets in the east. Besides these two areas are two inland seas: Hudson Bay in the east and the Okhotsk Sea on the Asian continent.

In each of these areas, the primary, if not the only, reason for foreign whaling was the presence in large numbers of bowhead whales. Even today, biological knowledge about this whale is rudimentary, probably more so than for any other species of large cetacea. Given the meager amount of information available, it should be noted here that the four areas of major whaling activity do not assume four distinct or discrete stocks of bowheads. The spatial delineations that may or may not separate the world's population of bowhead whales are questions for which the evidence of history does not supply clear answers. Some aspects of past experience may be suggestive, but the data of history is neither specific nor comprehensive enough to determine whether geographical boundaries exist between the bowheads of one area and another.

The temptation to use the behavior of bowheads to substantiate geographical theory is nowhere more evident than in the nineteenth-century arguments supporting the concept of an Open Polar Sea. Advanced with nervous eloquence by Lieutenant Matthew Fontaine Maury of the United States Naval Hydrographic Office in the 1850's, a few years after the first such whales were taken in western North America, the theory relied in part on the bowheads, which have "taught us to suspect the existence of open water in the arctic basin, and in their mute way told of a passage there, at least sometimes." The assumption, of course, was that "the same kind of whale that is found off the shores of Greenland [and] in Baffin's Bay, etc., is found off the North Pacific and about Bering's Strait." To prove the point, Maury canvassed his whaling friends: "Will you find out ... what is the difference, if any, between the whale of Davis Strait and Bering's Strait? Can you provide me with a skull and bones of each? Does the polar whale swim long distances under ice?"[1]) To Maury's enthusiasm, one whaling master countered with a note of caution: "No one man has been in both straits or seen each fish. The opinion obtains by many that the two fish are the same, but so far it is only opinion, not evidence based upon fact."[2]) Notwithstanding the limited evidence, Maury found the theory appealing and called on the bowheads to prove it. When drafting the official instructions for an American expedition sent to the eastern Arctic in search of Sir John Franklin, he advised its commander to "observe closely the habits of the whales, and should these fish take a westerly course, use them as pilots to the open sea beyond."[3]) Maury should not be condemned too quickly, however, for although the theory of the Open Polar Sea has long since been cast aside by increased geographical knowledge, the question of whether bowheads once traversed the Northwest Passage is still open. Historically, only five hundred miles separate the westernmost kill of bowheads in the east from the easternmost bowheads taken in the west.

Three of the four areas of bowhead whaling, the western Arctic, Hudson Bay and the Okhotsk Sea, were the last of the whaling grounds opened by American whalemen. Together, they represented the culmination of a century of expansion that had uncovered all the world's whaling grounds except those of Antarctica. The story is a familiar one, beginning with the entry into the South Atlantic by American whalemen in the 1760's, followed by the passage into the Pacific by British and Americans in the 1790's. The lure that drew them further into the Pacific was the sperm whale, which represented the greatest value in marketable commodities. Within half a century, the whalemen of the United States, Great Britain, France and Germany could be found throughout the Pacific from 50⁰ South to 40⁰ North latitude.

During the decade of the 1840's the course and direction of this vast maritime deployment began to alter. One reason for the change was the apparent decline in Pacific sperm whale stocks. Once considered an inexhaustible resource, these whales had been so reduced by intensive hunting that even as early as 1843, the American industry's trade journal, *The Whalemen's Shipping List,* believed that "reflecting and judicious men would no longer join with the host of those who have seemed disposed for some years past to cover [that] ocean with whale ships."[4]) Confirming that judgment, the amount of sperm whale oil brought to the American market reached its highest level in 1843 and began to decline thereafter. Yet for reflecting and judicious whalemen, there was ample reason to continue in the business, if not for sperm whales, then for others. A second development in the 1840's did not escape their notice: between 1841 and 1844, the price of baleen doubled. Full skirts had come to fashion, and baleen was needed to flare them out. Right whales first, then bowheads, were to supply this growing market, and to find them the whalemen headed north. Between 1843 and 1845, the right whale grounds of the North Pacific rim were occupied, stretching from the Kurile Islands and the coast of Kamchatka in the west to the Gulf of Alaska in the east.

Beyond the North Pacific rim, there was an even greater prize. Although the documentation is sparse, Captain Thomas Sodring of the Danish whaleship *Neptun* appears to have been the first of the "foreign" whalers to take a bowhead in the Pacific. The year was 1845; the place was off Kamchatka, and the news spread fast among the whaling fleets. Eleven whaleships, 8 American, 2 French, and Sodring's *Neptun,* called that summer at Petropavlovsk. There, word circulated of a new kind of whale, heavy in blubber and rich in baleen. Two of those who heard it were the American captains, Mercator Cooper and Thomas W. Roys. Earlier that summer, Cooper had taken a whaleship, the *Manhattan,* into the Okhotsk Sea for the first time. Two French whaleships followed, and although none ventured more than a hundred miles into the Sea, they took 8 right whales and proved the possibilities of whaling in the Okhotsk. Within two years, 30 whaleships, 26 American and 4 French, were whaling there, and between them, they took 341 right whales and 85 bowheads, the first large catch of the species to be made in the Pacific. The other captain, Thomas W. Roys, made a daring but reasonable gamble in 1848. Sailing for Bering Strait in the Bark *Superior*, his crew apprehensive and near mutiny, Roys sailed a thousand miles north of the nearest whaleship, passed Bering Strait and discovered the bowhead grounds of the western Arctic.

In the eastern Arctic, one of the bowhead grounds was new, like those of the Okhotsk and western Arctic. Hudson Bay was first entered for whaling in 1860, being the last of the whaling grounds to be opened by American whalemen and thus bringing to a close a century of worldwide exploration. Only Antarctica remained, awaiting the Norwegians, with their new technology, in the twentieth century. By way of contrast, the last of the bowhead whaling areas of North America was an ancient one. Known generally as "Davis Strait," it came to include Baffin Bay, Lancaster Sound and other inlets and passageways of the Canadian archipelago. Whaling in Davis Strait itself had a long history, stretching back to the 1690's, when Dutch and German vessels began to frequent it. In a recent study, W. Gillies Ross suggests that in about 1820, this older fishery, conducted largely by Dutch and British whalemen along the west coast of Greenland, was replaced by a new effort that focused on the largely unexploited stocks of whales on the western side of the Strait, along the shores of Baffin Island, north to Pond Inlet and into Lancaster Sound.[5])

Over a period of 90 years, 1820-1910, Ross identifies 2,406 voyages to Davis Strait, mostly by British whalers. Half of the voyages took place in the first twenty years of the fishery, 1820-1840. Thereafter, a slow decline began, not as sharp or abrupt as on other bowhead grounds but continuing even after the crash of the baleen market in 1907. In terms of duration, the Davis Strait bowhead fishery outlasted all the others. In terms of effort, the number of voyages identified by Ross come as a surprise; even more so does his suggestion about the scale of productivity. If his initial estimate of 18,000 bowheads killed can be confirmed by a larger sampling of the documentary record, all earlier impressions of the magnitude of the Davis Strait fishery will have to be revised. By inviting consideration of Davis Strait as a fishery of major proportions, Dr. Ross has performed a signal service to whaling historians everywhere.

If the results of Ross' research stimulate a new look at the Davis Strait fishery, activity in the Okhotsk Sea.[6]) Begun, as we have seen, in 1845, that fishery began in earnest in 1847. Within the Okhotsk were found both right and bowhead whales, with the latter far outnumbering the former. A line of demarcation, running across the Sea from the northern end of Sakhalin Island (54^0 North) to the southern tip of Kamchatka peninsula (52^0 North), separated the two species, with right whales occupying the lower Sea and bowheads the upper. The absence of ice throughout the Sea from the end of July until mid-October deprived the bowheads of their natural protection and made the Okhotsk a hunter's paradise. The intensity with which whaling could be pursued resulted in the extermination of the bowhead population within two decades of the opening of the fishery.

During the 20 years from 1847-1867, 1,391 voyages were made to the Okhotsk Sea, 90 percent being by American whaleships and the remainder by vessels from France, Bremen, Hawaii and Russia, with occasional representation from Britain, Norway and Chile. During these 20 years, Henderson estimates a virtually complete kill of the bowhead population, with 86 percent of that mortality occurring within the first decade. In terms of numbers, Henderson's figures at this stage of his research suggest that 15,200 bowheads were taken and an additional 3,040 killed but not recovered, resulting in a total kill of 18,240. The mortality figures are arrived at by extrapolation from the returns of oil from all Okhotsk voyages, using an average yield of 75 barrels per bowhead. The seemingly low yield figure reflects the relatively large number of small bowheads, known as "pogies," that were taken in the Okhotsk. Comparable figures for right whales, as given by Henderson, are 2,400 taken and 1,200 mortally wounded but not recovered, for a total Okhotsk kill of 3,600. The high ratio of unrecovered right whales, compared to that of bowheads (1 lost for each 2 taken vs. 1:5) was due, Henderson suggests, to differences in hunting tactics: bowheads were usually taken in bays and gulfs, where "stinkers" could be recovered; right whales were taken in open, often rough, water.

Henderson's figures, like Ross' for Davis Strait, are preliminary estimates; they suggest, nonetheless, the need for reconsideration of the effect of the Okhotsk fishery on the overall reduction of worldwide bowhead stocks. Curiously, the precipitous decline of these whales in the Okhotsk did not bring an abrupt end to Okhotsk whaling. Whalemen continued to visit the Sea with some regularity, not as a primary whaling ground but in the course of "loop" voyages that took them to Baja California in the winter, to Hawaii and the Japan Sea in the spring, and to the Okhotsk in summer for right whales in the lower Sea but occasionally going north to look for the few surviving bowheads. During the 30 years from 1867 to 1896, 92 bowheads are known to have been taken in the Okhotsk; perhaps 10 to 12 more were killed but lost. Today, no bowheads are known to inhabit the Sea.

The largest of the remnant stock of bowheads to survive today is found north of Bering Strait in the Chukchi and the Beaufort Seas. Whether enough are present to perpetuate the species remains an open question; what is certain is that their once large numbers sustained the American whaling industry during the last three decades of the nineteenth century. Between Roys' pioneering passage of Bering Strait in 1848 until 1910, 2,712 voyages were made to the western Arctic bowhead grounds.[7]) As was the case with the 2,400 voyages to Davis Strait, over half occurred within the first two decades of the fishery. Specifically, 57 percent of all western Arctic voyages took place within the first 20 years; in the eastern Arctic 56.6 percent did so. The "oil rush" suggested by these figures recalls the experience elsewhere, before and after, whenever any new whaling ground was opened. The intensity of whaling effort in the early years of the western Arctic fully conforms to the familiar pattern of maximum initial exploitation. By 1855, a mere seven years after Roys' voyage, the drastic decline in bowhead catches led to the virtual, if temporary, abandonment of whaling effort north of Bering Strait. From 220 voyages in 1852, the number dropped to 5 in 1855, 13 in 1856 and 8 in 1857. To the whalemen, the western Arctic appeared to be "fished out."

The experience of the following half century, 1858-1908, would prove appearance wrong, unless the whalemen had indeed "fished out" a discrete stock of bowheads that inhabited the waters from about 53^0 North off Kamchatka to the lower Chukchi Sea, but not beyond Point Barrow. The possible existence of this separate population has been suggested by John R. Bockstoce, relying on evidence accumulated during the most exhaustive analysis ever undertaken of any pre-twentieth century whale fishery. As a hypothesis for explaining the abandonment of whaling effort in the western Arctic in the mid-1850's, it invites further investigation. Seemingly, the only alternative explanation for the subsequent absence of bowheads in the lower Chukchi Sea would have to rely on a theory of adaptive behavior in which the bowheads "learned" to avoid the whalers by moving north beyond Point Barrow to summer in the Beaufort Sea and rarely to descend below 60^0 North, the area in which the remnant stock is found today.

Whatever the explanation for the failure of the fishery in the mid-1850's, the whaling fleet returned in force in 1858, partly because of declining catches in the Okhotsk Sea. New tactics were developed, and the bowheads' autumn feeding grounds near Herald Island were discovered. In these waters, usually ice free until mid-September, the season of pursuit could be extended, although not without substantial risk. As the ice formed, it did so in two arms that reached out to surround the Herald Island ground. Failure to leave in time could mean disaster, as in 1871, when 32 ships were abandonned to the ice and in 1876 when 12 more were trapped and crushed. During the decade of the 1870's, 58 ships in all were lost; during the entire span of the fishery, the number amounted to 150.

Even at this cost, conditions in the marketplace still lured the whalemen north. By 1880, when petroleum products had severely depressed demand for whale oil, the price of baleen continued upwards. Fashion decreed another 20 years of corsets, bustles and wide skirts, and as long as this was so, baleen alone could make a paying voyage. With this incentive, the whalemen moved into the last resort of the bowhead whales, deep in the Beaufort Sea. To do so, auxiliary steam power was introduced into whaleships, enabling them to operate east of Point Barrow with greater assurance of safety. A base for wintering-over was established at Herschel Island in the 1890's, and here the last chapter in the history of American whaling was played out. In 1907 the end occurred, when a cheaper substitute for baleen was brought to market in the form of spring steel. When the whaling fleet withdrew, the bowheads of the western Arctic were thoroughly depleted.

The methods used to record and analyze the western Arctic fishery by Bockstoce and his associate, Daniel B. Botkin, deserve a brief description, although their application to other fisheries may depend on the existence of comparable amounts of surviving documentary evidence. To assess the impact on the bowheads of non-indigenous whaling in the western Arctic, Bockstoce first assembled a list of all whaleships known to have hunted there. By following the careers of these vessels in trade journals, customs and insurance records and the newspapers of New Bedford and San Francisco, he then compiled a complete list of voyages, numbering 2,712. Of these, useful logbooks or journals were located for 550, or about 20 percent of the total, evenly spaced throughout the years of the fishery. A team of six readers then extracted and encoded on computer data sheets more than 66,000 daily observations of whaling activity, other fauna, weather, sea and ice conditions and any unusual occurences that might effect the hunting effort. The resulting data base, containing close to 20 percent of the total voyage experience during the 67 years of the western Arctic fishery, represents not only one of the longest and most detailed mammalian population records in existence but one of the most complete records of any hunting and catch activity.

Information from the data base was then key-punched onto computer cards and converted to nine-track standard computer tape and processed under several different models selected by Botkin to determine the initial size of the bowhead population and the effects upon it of commercial whaling in the western Arctic. Allowing for a range of figures, depending on the model used, it appears that from an original population of approximately 30,000 bowheads, 16,600 bowheads were taken, with an additional 2,000 killed but not recovered. Of this total, one third was killed during the first six years of the fishery. By the end of the first twenty years, two thirds were killed, reflecting once again the "oil rush" phenonemen in which undepleted stocks attract intensive hunting activity, with a resulting reduction of the population to a small proportion of its original size.

The final area of bowhead whaling in North America occurred in Hudson Bay. Compared to the effort expended in the western Arctic, the Okhotsk Sea and Davis Strait, it was a minor fishery. W. Gillies Ross again provides us with the most thorough study to date in his monograph, *Whaling and Eskimos: Hudson Bay 1860-1915.*[8]) The fishery began in 1860 and was largely an American enterprise. Ross identifies 146 voyages to Hudson Bay during the 55 years of the fishery, 117 being by American vessels and 29 by those of Britain. The whaling season was short, lasting little more than 30 days, and vessels employed in the fishery found it advantageous to winter-over in order to increase the prospects of a profitable voyage. As in the western Arctic, two thirds of the voyages took place during the first 20 years. The reduction of the bowhead population was probably comparable as well, although catch statistics have yet to be compiled. As in the Okhotsk, the bowheads did not survive within this inland sea.

The commercial extinction of the bowheads of North America and the Okhotsk Sea was accomplished with tactics and technology developed for the most part in the eighteenth century. The introduction of auxiliary steam power on sailing whaleships represented a significant advance and enabled vessels so equipped to penetrate deeper and deeper into the Arctic. The practice of wintering-over, both in the west and east, extended the whaling season and offered the advantage of placing the vessels nearer to the arriving whales in the second summer. Certain improvements were made in the weapons of capture, notably the darting gun which simultaneously harpooned and fired an explosive bomb into the whale. These new techniques and gear came, however, after the initial onslaught, and even without them, the bowheads of North America were probably doomed by the foreign whalers who came to hunt them.

NOTES

1. Letters, Maury to Grinnell, Minturn & Co., Sept. 11, 1849; to William R. Jones, Sept. 15, 1849; to Capt. Thomas W. Roys, Oct. 3, 1849, in: National Archives (Record Group 78). See also Matthew Fontaine Maury, *The Physical Geography of the Sea, and Its Meteorology* 8th edition, 1861, edited by John Leighly. (Cambridge, Harvard University Press, 1963) p. 422-423.
2. "Letters to Maury from Captain Thomas W. Roys, Jan. 19, 1851, and Captain Daniel McKenzie, May 22, 1851", in: *Explanations and Sailing Directions to Accompany the Wind and Current Charts,* 5th ed. (Washington, C. Alexander, 1853) p. 310-315.
3. Maury to Lieut. Edwin J. DeHaven, "Instructions: Rough Draft for Navy Department," May 14, 1850, in: National Archives (Record Group 78).
4. *Whalemen's Shipping List and Merchants' Transcript* (New Bedford, Mass.), March 28, 1843.
5. W. Gillies Ross and Anne MacIver, *Distribution of the Kills of Bowhead Whales and Other Sea Mammals by Davis Strait Whalers, 1820-1910* (Arctic Pilot Project, 1982).
6. For information on the Okhotsk Sea fishery, I am indebted to Dr. David A. Henderson, research fellow at the New Bedford Whaling Museum. Dr. Henderson's study of "Whaling in the Okhotsk Sea" is scheduled for publication in 1984.
7. John R. Bockstoce and Daniel B. Botkin, *The Historical Status and Reduction of the Western Arctic Bowhead Whale (Balaena Mysticetus) Population by the Pelagic Whaling Industry, 1848-1914. Final Report to the National Marine Fisheries Service by the Old Dartmouth Historical Society.* New Bedford Whaling Museum, March 31, 1980. I am also indebted to Dr. Bockstoce for the opportunity to read the manuscript of his work in progress, "Whales, Ice and Men," to be published in 1984. For a critical comment on the Bockstoce-Botkin study, see Michael F. Tillman, Jeffrey M. Breiwick and Douglas G. Chapman, "Reanalysis of Historical Whaling Data for the Western Arctic Bowhead Whale Population," in: Michael F. Tillman and Gregory P. Donovan, eds., *Historical Whaling Records* (Cambridge, Eng.: Reports of the International Whaling Commission, Special Issue 5, 1983), p. 143-146.
8. W. Gillies Ross, *Whaling and Eskimos: Hudson Bay 1860-1915.* Ottawa: National Museum of Man, Publications in Ethnology No. 10, 1975.

PRESENT WHALING: POLICY, QUOTAS AND METHODS; WHALE POPULATIONS

by

Joost G. van Beek

Summary

At the start of this century the hunting of the yet unexploited rorqual species became possible: the era of the modern whale hunt started. At first this hunt was concentrated in the Antarctic, afterwards it shifted to the North Pacific. Just after the second World War the International Whaling Commission was established, which up to the present is charged with the proper conservation of whale stocks. During the first 25 years only quotas for Antarctic stocks were fixed. These were too high and expressed in an odd unit (*B*lue *W*hale *U*nit). The exploitation of other stocks was only regulated by fixing closed seasons and minimum size limits. These measures proved to be completely inadequate to prevent serious overexploitation. During the sixties quotas were reduced and in 1972 the BWU abolished. In the early seventies quotas were also fixed for North Pacific and Atlantic stocks. In 1975 the *N*ew *M*anagement *P*rocedure was adopted, which was a great improvement in whale management and resulted in the protection of most fin and sei whale stocks. Furthermore the Commission's decisions were based, more so than previously, on the advice of the *S*cientific *C*ommittee. The recent adoption of two other regulatory measures greatly influences whale management: (a) the prohibition of the use of factory ships, except for the catch of minke whales (1979); (b) a moratorium on commercial whaling from 1985 onwards, which could only be adopted because of the recent great increase in non-whaling member states. Four whaling countries lodged an objection against the adoption of the moratorium.

The NMP aims at stabilizing stock levels at about the maximum sustainable yield level. Each stock is classified in one of three categories depending on the ratio of the current to the initial stock size. The permitted catch depends on the category, but whaling is prohibited on stocks which are smaller than a certain percentage of the initial stock size.

The SC assesses the status of the stocks using data from catch-per-unit-effort, mark-recovery and/or sightings. At present the NMP no longer operates well, owing to problems in adequately assessing the initial stock size and in determining the yield level. The Commission has also been concerned

with aboriginal whaling. A specific management scheme was adopted in 1982. The jurisdiction of the commission over small cetacean management is questioned by several states, among other reasons owing to their 200 miles zone policy.

Introduction

Dutch sailors participated in Arctic whaling during the seventeenth and eighteenth centuries, and the Netherlands were involved a second time in whaling in this century during the period 1946-1964. The second era of Dutch whaling activity, which took place in Antarctic waters, was not very successful. This is illustrated by the following incident: when the Dutch factory ship sailed from Amsterdam in 1946 many people escorted it and even the national anthem was played. Six months later after the ship's return from Antarctic waters public sentiment had changed. The result of the first trip was a disappointment, the number of whales caught had been far below expectation and so were the profits. This situation did not change until the Netherlands stopped whaling in 1964. Nowadays the Netherlands is one of the so-called conservationist countries, which plead for a moratorium on all commercial whaling. This Dutch point of view can be seen as paying off a debt of honour. The above-mentioned facts explain why so many Dutch scientists are interested in the study of whaling history or whale management. Whaling is part of our history.

In this paper the modern whale hunt, which took place in all waters during this century, will be discussed. The first part of this article consists mainly of a historical review of the regulatory measures taken by the International Whaling Commission. The second part deals with the current management procedures and their scientific basis, whilst in the third and fourth part whale hunting by aboriginals and the management of small cetaceans will be briefly discussed.

Historical review

The discovery of the explosive harpoon, the harpoon gun and the steamship at the end of the nineteenth century made it possible to hunt the fast swimming baleen whale species. Until then it had been impossible to hunt these species because of their high swimming speed and the fact that animals of these species sink after being killed. The introduction of the slipway in the stern of a ship at the start of the twentieth century greatly enhanced the range of whaling operations, because ships equipped with such a slipway, the so-called factory ships, could operate on the high seas far from land. At first modern hunting was concentrated in Antarctic seas, south of 40° southern latitude. The blue and humpback whale stofks[1]) in this area were decimated mainly by Norwegian and English hunters chiefly operating from factory ships. After the second World War the hunt gradually shifted towards smaller whale species such as the fin and sei whale, which were then also overhunted by Norwegian, English, Russian, Japanese and Dutch whalers. When the stocks of these species declined the smallest baleen whale species became the target: the minke whale. So, in Antarctic waters the pelagic hunt shifted from the big to the small whales (Fig. 1).

After the second World War pelagic catching of baleen whales also took

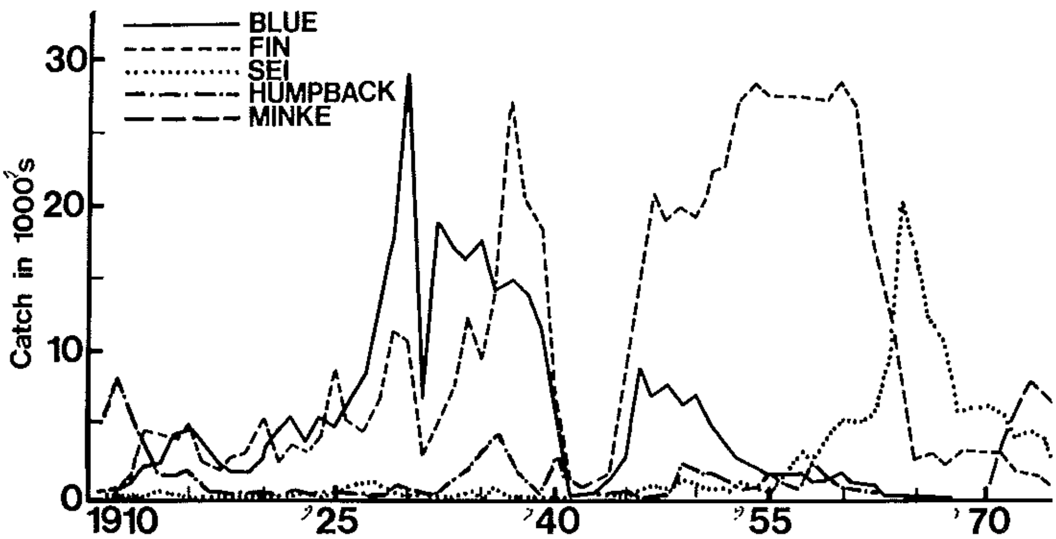

Fig. 1. Catch of baleen whales in the Southern Hemisphere during this century (from Allen, 1980).

place in the North Pacific, but here only Japan and the Soviet Union were involved. More or less the same catch sequence occurred, with the fin and sei whale being the prefered species (Fig. 2). The catch in this area did not reach such high levels presumably because of the smaller sizes of the stocks. Before the second World War a few factory ships operated in the North Atlantic, however in this area most whales were caught from land stations. Both in the nineteenth and the twentieth century the sperm whale was hunted. Figure 3 shows the world catch of sperm whales in relation to the total catch of baleen whales during this century. From the fifties onward the catch of sperm whales increased and the sperm whale became a main target of the whaling industries, especially in the North Pacific.

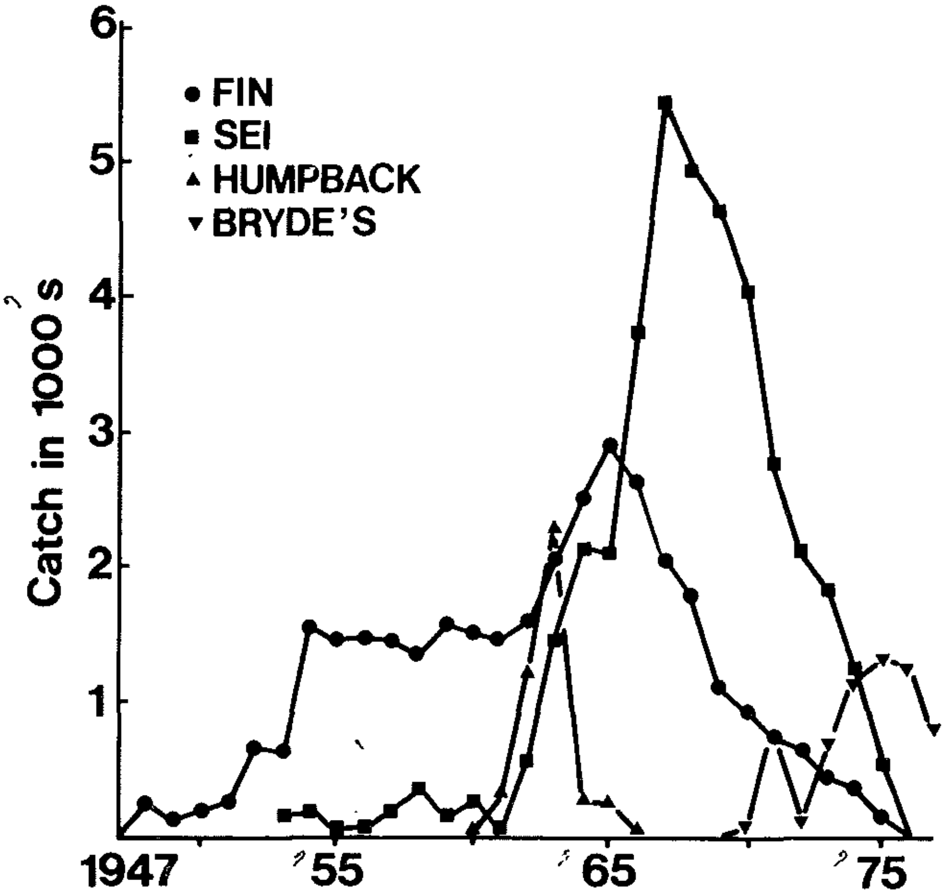

Fig. 2. Pelagic catch of baleen whales in the North Pacific during 1947-1977 (from Allen, 1980).

Most whale species live in the high seas, which in legal terms means that no state has jurisdiction over these species and everyone can exploit them. The management of these resources has to be done internationally. In 1946 the whaling countries established the whaling treaty which at present is still in force: The International Convention for the Regulation of Whaling. Already during the thirties a whaling treaty was in force, but it was of limited scope. In addition to this, several national measures regulated, to some extent, the whale hunt in those days. The 1946 Convention established the *I*nternational *W*haling *C*ommission which was charged with the proper management of whale stocks. The most important regulatory measures taken by the Commission suring the forties and fifties will now be described. Table 1 gives them in abbreviated form.

1. From the beginning the Commission prohibited the commercial catch of gray and right whales; also the killing of calves and lactating females was prohibited.

2. A quota for the pelagic baleen whale catch in the Antarctic was fixed, however the quota was expressed in an odd unit, the *B*lue *W*hale *U*nit. One unit was equal to one blue whale, two fin whales, two and a half humpback whales or six sei whales. This unit was biologically unsuitable and made it possible to shift from one species to another, a practice which clearly does not protect a given species against overexploitation. Besides, the level of the quota was far too high: during the fifties about 15000 units a year were allowed to be caught.
3. Minimum size limits were fixed, for example the catching of fin whales smaller than 50 feet in the Northern Hemisphere was prohibited.
4. Closed seasons and areas were designated. For instance: factory ships were not allowed to operate in the North Atlantic; the pelagic blue whale catch in the Antarctic was restricted in time and the Pacific sector of the Antarctic was made into a baleen whale sanctuary for a number of years (1948-1955).
5. Specific measures in the Antarctic waters for the pelagic humpback whale catch were taken, namely a species quota, a sanctuary during several years in the Atlantic sector of the Antarctic, and a hunting season of only a few days.

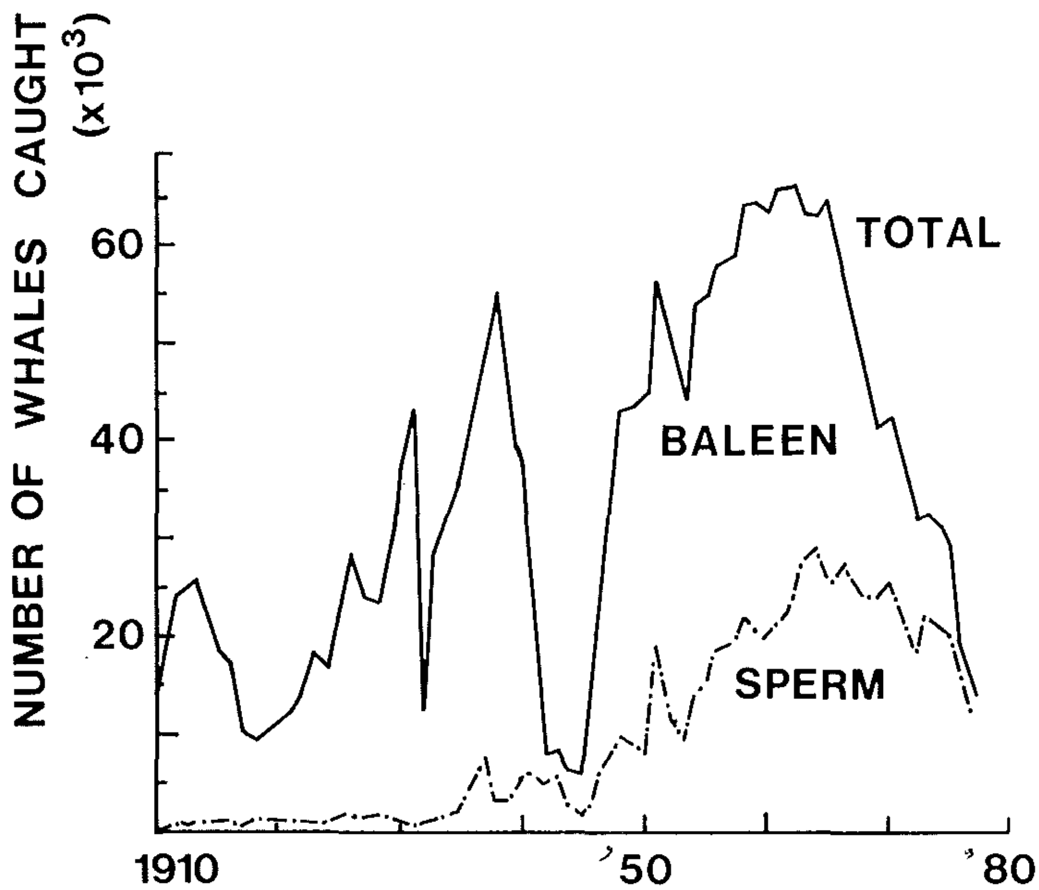

Fig. 3. Total annual catches of baleen and sperm whales in all oceans during this century (from Allen, 1980).

Table 1 Management measures taken by the International Whaling Commission, in abbreviated form.

From 1948	killing of the grey and right whale prohibited
	killing of calves and lactating females prohibited
	Antarctic quota: ±15.000 B.W.U.
	size-limits
	closed seasons
	closed areas
	specific measures for Antarctic humpback whale
From 1962	reduction of B.W.U. to 2300
1965-1967	worldwide protection of the blue whale (In the North Atlantic in 1960)
1963-1965	worldwide protection of the humpback whale (In the North Atlantic in 1953!)
From 1970	species quota for the North Pacific
1972	abolition of B.W.U.
	species quota in the Southern Hemisphere
1975	New Management Procedure adopted
1975-1977	protection for the fin and sei whale, except in the North Atlantic
From 1975	species quota for the North Atlantic
1979	Indian Ocean sanctuary
	pelagic moratorium except minke whales
From 1979	strong reduction of sperm whale quotas to 400
From 1980	action against outlaw whalers, mainly by NGO's
1982	commercial moratorium from 1986 onwards
	aboriginal management scheme

At the start of the sixties not only whale scientists were convinced that the whale stocks were heavily overexploited but also the whaling industry had to admit that the whale stocks were not a resource with an unlimited yield capacity, despite the measures taken. Three independent scientists were invited to advise on the management of the whale stocks in the Antarctic. Their first advice was the substitution of the species quota for the BWU, accompanied by a drastic reduction of the quotas. However, it was not till 1972 that the BWU was abolished, although the BWU quotas were reduced to about 2300 units at the end of the sixties. Their second advice - a complete protection for the blue and humpback whale - was followed up more quickly; during the first part of the sixties the blue and humpback whale were protected worldwide. A second break-through towards better whale management was achieved in 1972. In that year the special United Nations meeting on the environment adopted a whale moratorium resolution, which was passed on to the annual meeting of the Commission. The Commission, however, did not adopt the moratorium proposal but took other actions. It abolished the BWU and established species quota in the Antarctic seas.

(Actually in 1970 the species quota had already been introduced in the North Pacific). Moreover, within a few years a management scheme which aimed at stabilisation of the stock levels at the maximum sustainable yield level would be accepted - The *N*ew *M*anagement *P*rocedure. In 1975 this NMP was adopted and as a consequence (a) most fin and sei whale stocks were protected; (b) quotas were fixed by stock and based more than previously on scientific advice; (c) for the first time quotas were established for the whale hunt in North Atlantic waters.

In 1979 the Commission adopted a prohibition on the use of factory ships except for the minke whale catch, which had the effect of a complete protection for the pelagic sperm and Bryde's whale stocks. Also in this year a whale sanctuary was established in the Indian Ocean above 55° southern latitude. From 1979 on the quotas of sperm whale stocks exploited from land stations were reduced, down to about 400 in 1983. From 1980 on actions from non-governmental organisations like Greenpeace focussed attention on whaling outside the jurisdiction of the Commission (the so-called outlaw whaling) for example whaling from Taiwan and by catchers flying flags of convenience. The Commission prohibited trade in whale products derived from these operations, and this contributed to their cessation. In 1982 a moratorium on all commercial whaling from 1986 onwards was adopted, but four whaling countries - Japan, the Soviet Union, Norway, Peru - objected to it within the prescribed 90 day period and so this decision is not binding on them. At the same meeting the Commission adopted an aboriginal management scheme. In the Intermezzo the 1980 and 1983 quotas are shown and current whaling operations are briefly discussed.

Intermezzo

		1980		1983
minke whale	11	11758	11	10623
fin whale	2	504	2	287
Bryde's whale	2	724	2	701
sei whale	1	100	1	100
sperm whale	4	2203	1	400
	20	15289	17	12111

This table shows the 1980 and 1983 world quota for commercial whaling by species, the second and fourth column respectively. The numbers in the first and third column indicate the number of exploited stocks. Nowadays only one whale stock is commercially exploited in Arctic waters namely the

Eastern North Atlantic minke whale stock. The quota is 1690 whales and it is taken by Norwegian fishermen operating from small boats, which are also used for fishing. The 6 southern minke whale stocks are pelagically exploited by one Japanese and one soviet factory ship, while Brazil hunts minke whales out of one of these stocks from a land station. The southern minke whale quotas totalled 7072 whales in the 1982/1983 season, of which Brazil presumably will take about 600 whales and the two other countries an equal share of the remaining part. South Korean and Japanese fishermen operating with small catcher boats exploit two North Pacific minke whale stocks i.e. in the Okhotsk Sea, Sea of Japan, Yellow Sea and the eastern coastal waters of Japan. In the North Atlantic two other minke whale stocks are hunted: the Central and West Greenland stocks, by Icelandic fishermen and Greenlanders (aboriginal whaling). Both stocks are also exploited by Norwegian fishermen.

Japanese whalers exploit from a number of land stations on the east coast of Japan one Bryde's whale stock and the only sperm whale stock of which exploitation is still allowed. The other Bryde's whale stock is exploited from a Peruvian land station. Iceland exploits the sei whale and one fin whale stock from a land station located on the west coast. Spain exploits the other fin whale stock from its Atlantic coast (2 land stations). The distribution of the 1983 world quota over the whaling countries is: Japan 38%; USSR 27%; Norway 16%; South-Korea 8%; Brazil 5%; Iceland 4%; Spain 1% and Peru 1%.

The adoption of a moratorium without the support of all whaling countries must be considered against the background of the current composition of the Commission. This composition has changed greatly during the last four years, as can be seen in figure 4. The adoption by the Commission of regulatory measures related to the management of whale stocks needs a three-quarters majority in the Commission. During the initial period of the Commission most member states were whaling countries. Subsequently a number of whaling countries ceased their operations: Britain in 1963, the Netherlands and New Zealand in 1964, the USA in 1971, Canada in 1972, South Africa in 1975 and Australia in 1978. During most of the time the membership of the Commission has been fairly constant. However, during the last five years many non-whaling countries have joined the Commission in order to assist in achieving a more conservationist whale management, namely West Germany, the People's Republic of China, and some small Caribbean states. Also a number of whaling countries joined, namely Chile, Peru, Spain and South Korea. At the last annual meeting (34th) the Commission had 39 members of which 8 were new. The current whaling countries are listed in the Intermezzo. Although in the past the whaling

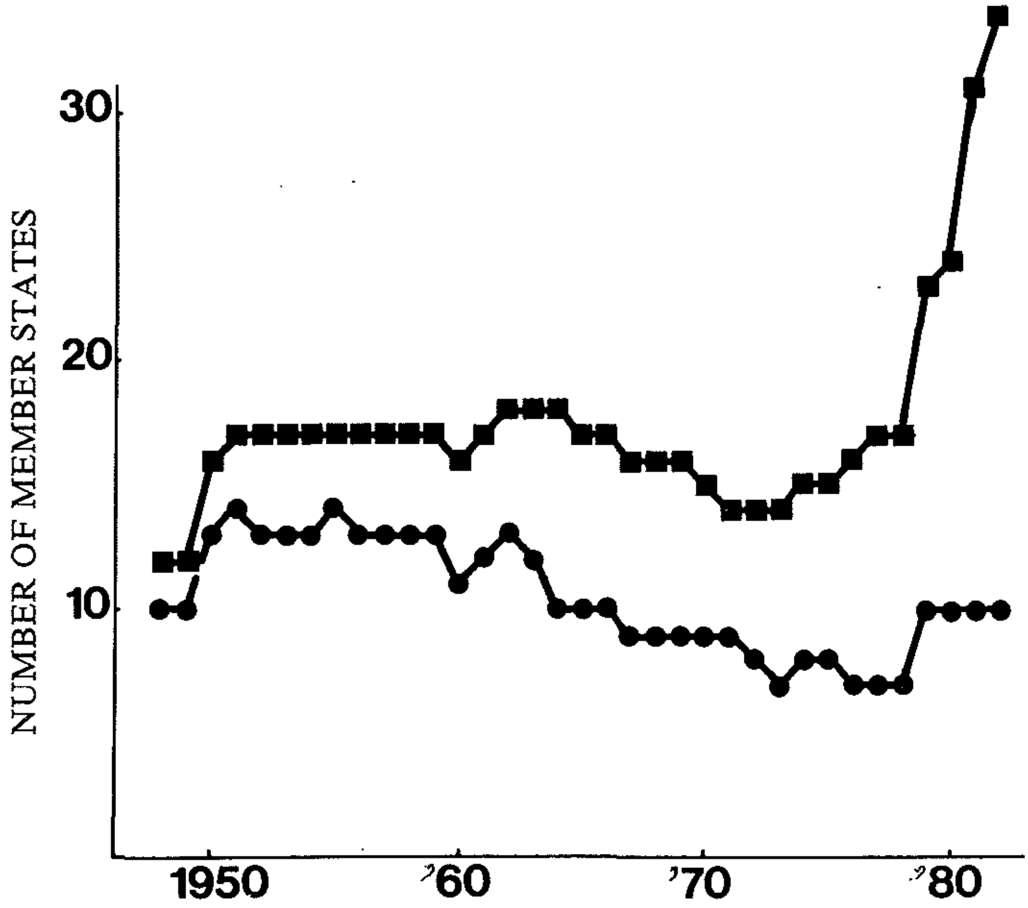

Fig. 4. Trend in the number of member states of the IWC (■) and in the number of member states which are whaling (●).

countries have held up necessary measures for some time, they ultimately agreed upon them, even the NMP. At this moment, however, the non-whaling countries have a three-quarters majority in the Commission and so in theory can impose any measure upon the remaining whaling countries. This happened at the last meeting of the Commission with the moratorium proposal. Some of the arguments behind a moratorium will be discussed below, here only a general argument will be mentioned. Despite all the regulatory measures, the Commission was unable to prevent serious over-exploitation of the major stocks: the blue and humpback whale stocks have been heavily depleted and some are on the verge of extinction or already extinct and most fin and sei whale stocks are also below 50% of the initial size. These facts, which are shown in Table 2, demonstrate the past incapability of the Commission to manage whale stocks properly and for quite a few countries to form the general argument to support a commercial moratorium. All currently exploited stocks, mainly minke and Bryde's whale, should be given the benefit of the doubt before stocks of these species are also depleted through improper management. The whaling countries oppose this view by arguing that the whales ought to be managed on a stock-by-stock basis because great differences between stocks exist in the level of knowledge about their status. Moreover, the current management scheme, which in their view is a scientifically based procedure, can prevent serious overexploitation.

Tabel 2 Estimates of the current number of whales in proportion of the initial number in two areas (from Allen, 1980).

	Southern Hemisphere	North Pacific
Blue whale	5	30
Humpback whale	2	11
Fin whale	21	38
Sei whale	19	22

The New Management Procedure

Fig. 5 gives a graphical picture of the NMP. For every stock the *S*cientific *C*ommittee of the Commission, which is made up of whale biologists and biomathematicians, calculates a catch limit according to defined rules. The hypothesis behind the NMP is that a stock which is reduced below its initial size has a net production - the so-called yield - because the recruitment rate is always greater than the mortality rate. Because of this net production a stock will return to its initial size of the exploitation ceases. But, if one takes this yield the stock will remain stable. The yield depends on the ratio of the current to the initial stock size. One accepts that in baleen whales the maximum yield is reached at 60% of the initial level - the *m*aximum *s*ustainable *y*ield level - and that the yield then equals 4% of that level - the maximum sustainable yield.[2])

The NMP distinguishes three stock categories. (1) Protection stocks are stocks below 54% of the initial size. No commercial catch is permitted from these stocks. (2) *S*ustained *M*anagement *S*tocks are stocks having a current stock size between 54 and 72% of the initial level. The catch limits for stocks belonging to this category and with a current level at or above MSY-level equals 90% of MSY. This catch limit decreases towards zero for stocks below MSY-level. (3) Initial Management Stocks are stocks having a current size above 72% of the initial size. The catch limit is 90% of MSY. Two features of the procedure are worth noting: (a) the 54%-level, below which all commercial whaling is prohibited. This is a highly progressive character, which does not occur in most other fisheries treaties; (b) the application of a 10% safety factor.

A first question to be asked is: does any evidence exist that baleen whales have a net production? Several whale biologists have found that in an exploited stock the pregnancy rate increases and the age at sexual maturity decreases, figures 6 and 7. These stock parameters presumably change because of the higher food supply per whale which has been caused by a lower number of whales in the feeding areas as a consequence of the exploitation. The yield is realized by these changed stock parameters. This whole phenomenon if often described as the density dependent response of a stock. There is a possibility that other stock parameters, such as the juvenile and adult mortality rate, are also subject to change. Unfortunately, it is not possible to observe this in whale stocks, since these parameters cannot be assessed adequately. Recently some scientists have shown that the increase in pregnancy rate might be partly spurious and due to the method of analysis used (Mizroch and York, 1982). Also, a decline in the age at sexual maturity can be simulated if errors are made in ageing the whales (Cooke and De la Mare, 1982). So, although there is some evidence that an exploited baleen whale stock has a yield, the exact level of it remains unclear.

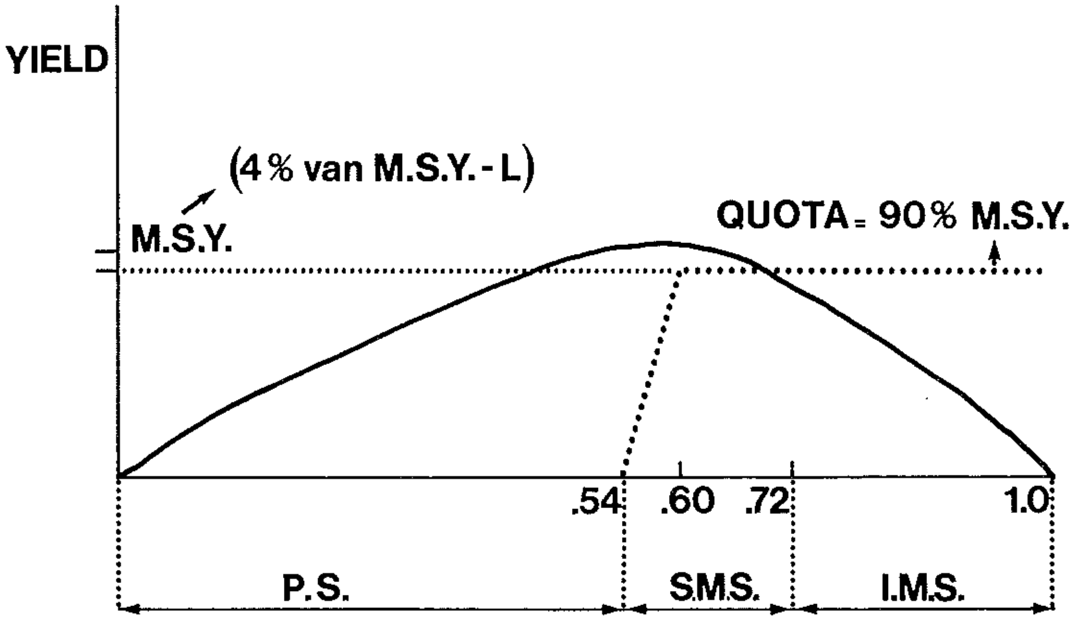

Fig. 5. The assumed yield curve of baleen whale stocks. The absciss gives the ratio of the current to the initial stock size. The ordinate values are 10-fold enlarged compared with the absciss values. The large dotted line gives the quotas. The maximum sustainable yield is indicated as m.s.y. and occurs at 60% of the initial stock size level. The stock categories of the New Management Procedure are Protection Stock -PS-, Sustained Management Stock -SMS- and Initial Management Stock -IMS-.

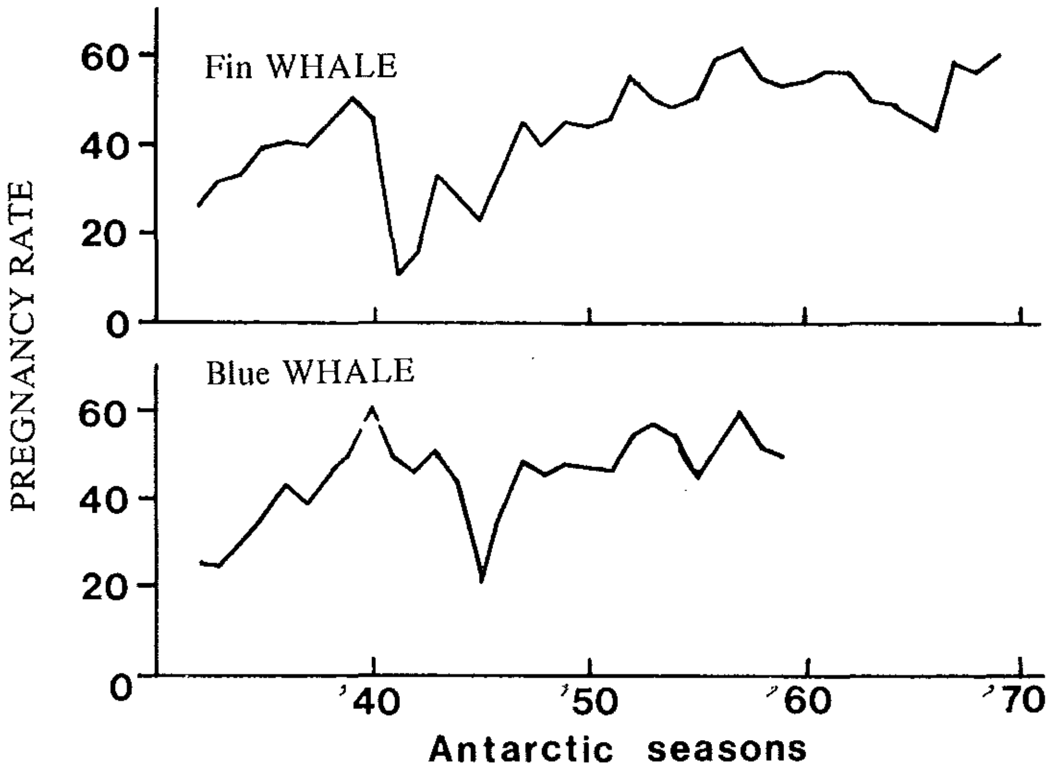

Fig. 6. Number of pregnant females as a percentage of the total number of mature non-lactating females caught each season in the Antarctic (from Gambell, 1973).

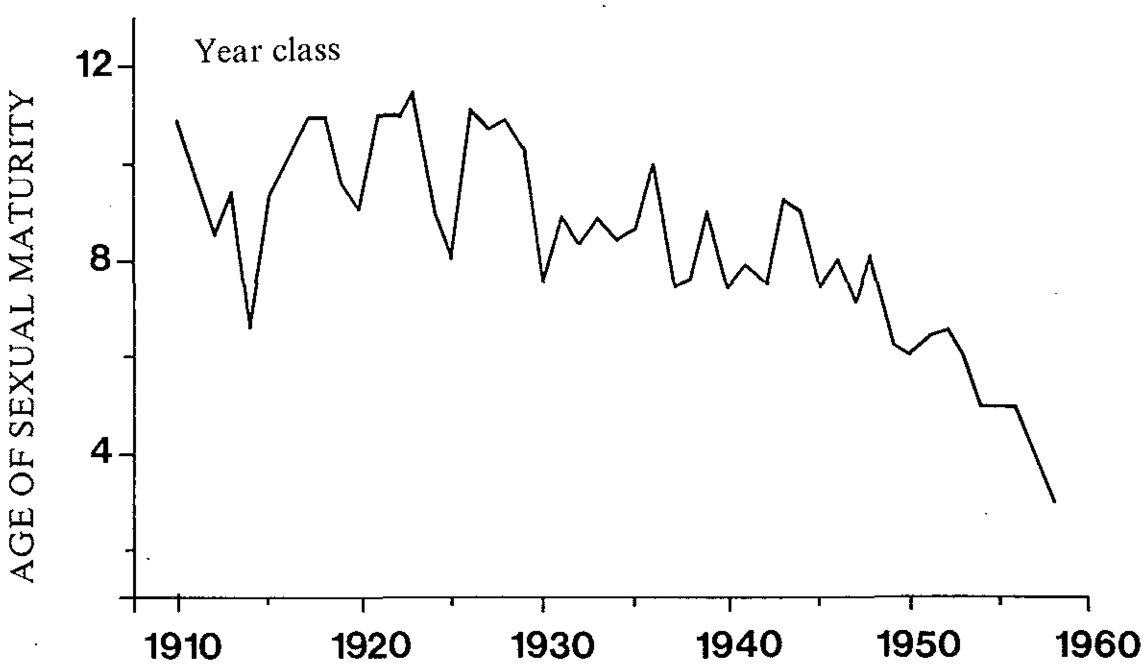

Fig. 7. Age at sexual maturity for different year classes of female fin whales in the Southern Hemisphere determined by the transition in the earplug growth layers (from Lockyer, 1972).

A second question is: how does the SC determine the ratio of the current to the initial stock size? Three types of method are currently used: The first type used the CPUE - *C*atch *P*er *U*nit *E*ffort - variable, which under certain conditions is an index of the stock size. Stocks which have been exploited for a relatively short time can be assessed with the modified Delury technique, in which the CPUE variable is regressed against the accumulated catches. Stocks exploited for a longer period of time can be assessed with an estimation model which minimizes the differences between observed and expected catches. The second type of method determines the current size of a stock by means of the markrecovery technique. Marks are shot into a high number of whales which in subsequent years are killed and the marks recovered. The number of recoveries in the catch is related to the stock size. Besides this some information about the migration pattern of the whales is obtained. In the third method the number of whales seen from vessels in a strip beside the track of the vessel is counted and extrapolated to a larger area. For instance: during the last four years international cruises were organized to the Antarctic pack ice to estimate the stock sizes of the southern minke whale.

Normally with the mark-recovery and the sightings methods only the current stock size can be estimated which implies that the CPUE method is crucial for the proper application of the NMP. However, many disadvantages are inherently related to the use of the CPUE variable. It not only varies according to the stock size but it is also dependent on factors like the weather, time in the season, efficiency of the catcher boats, etc. We can try to correct these other factors with elaborate mathematical procedures, but even after correction this variable fluctuates a great deal. Because of these problems only a few out of seventeen currently (for commercial purposes) exploited stocks can be classified and managed with the above-mentioned criteria of the NMP.

There is, however, a second criterium for classification in the SMS category, namely when a stock has remained at a stable level over a considerable period of time and under a regime of approximately constant catches. Then the catch limit is, in general, the average catch over the last one or two decades. The stable level of such a stock is assessed with a CPUE series. The problem with the CPUE variable as indicator of the stock status, as already mentioned, is that it fluctuates so widely that a significant decline is hard to detect. For instance: computer simulations show that in a stock with an assumed depletion of 50% in 20 years and a coëfficient of variation in the CPUE values of 50% (which is not an unusual variability) there is only a 35% chance of detecting a decline at the 5% level of significance (Beddington et al, 1982). Quite a few stocks are classified with this alternative criterium of a SMS. The other exploited stocks cannot for a variety of reasons be classified

Table 3 The classification of the commercially exploited stocks by species related to the assessment methods used, as proposed by the SC in 1982. SMS-1 and-2 mean classification based on the first and second criterium respectively.

	CPUE	Mark-recovery	Sightings	No/other
Minke whale	3 SMS-2		6 Unclassified	2 Unclassified
Bryde's whale	1 PS	1 IMS	(↔ 1 IMS)	
Sperm whale				1 Unclassified
Fin whale	1 SMS-1			1 Unclassified
Sei whale				1 Unclassified

Total	IMS	1 stock	based on NMP
	SMS-2	3 stocks	based on NMP
	SMS-1	1 stock	based on NMP
	PS	1 stock	based on NMP
	Unclassified	11 stocks	
		17 stocks	

with the NMP. Table 3 gives the assessment methods used for the commercially exploited stocks with the classification as proposed by the SC in 1982. This summary clearly shows the inadequacy of the NMP at this moment, which is mainly caused by two great problems, the unknown level of the density dependent response and the great variation of the CPUE variable.

The SC is unable to solve this inadequacy properly and therefore often suggests to the Commission a number of different catch limits for a particular stock. Most member states of the Commission respond to this by supporting the lowest catch limit, or a moratorium proposal. The Commission at its last annual meeting adopted a moratorium, mainly on the basis of historical - the past history of whale management -, scientific - uncertainties in the scientific assessments - and political - pressure by the public - arguments. Notwithstanding this fact, it can, in view of the four protesting countries, follow an alternative strategy towards a more conservative whale management, namely the adoption of a revised NMP. Such a revised NMP would include the application of safety factors which can reduce the catch limits (calculated on the basis of yield) by 50% and even 100%, depending on the relative stock size, number of assessments used, and the variation in parameter values. The Commission has been talking about such a revision for several years, but without definite results. This adoption would be the third break-through in the management of whale stocks by the Commission.

Aboriginal whaling

The Commission distinguishes two types of whaling operation, namely commercial and aboriginal whaling. A precise definition of current, aboriginal whaling activities is very difficult to give, mainly because of changes in the life of aboriginal people which have taken place during the last decades. A useful distinction between the two whaling operations is that the first type aims at maximizing profits whilst the second type aims at satisfying the subsistence needs of local, aboriginal people. aboriginal whaling only takes place in Arctic waters. Five whale stocks exploited by three different types of aboriginal are recognized namely

1. The Eastern Pacific gray whale stock, which is exploited by Siberian Eskimos with a quota of 179 animals. This stock is still recovering from nineteenth and early twentieth century depletion despite the aboriginal catch of about 150-200 whales per annum since the sixties and currently has an estimated size of about 20000 whales. The commission fixed a quota for the first time in 1977.
2. The Beaufort Sea bowhead whale stock, exploited by Alaskan Eskimos. In 1977 the Commission also fixed a catch limit for this stock for the first time. At this moment a block quota of 65 whales struck and 45 landed during 1981-1983 is in force. (A maximum of 17 landed per year). The status of this last viable stock of bowhead whales causes much concern: the stock level is estimated at 3000-4000 animals (which is far below the commercial protection level) and also the number of calves sighted has been very low. Therefore the SC proposed a zero quota to the Commission.
3. The West Greenland humpback, fin and minke whale stocks exploited by Greenlanders with quotas of 10,6 and about 200 respectively. The Commission already fixed a catch limit for the humpback whale stock in 1960, whilst the other two stocks were recognized as exploited by aboriginals in 1983. However, the quotas date back to 1976. With respect to the humpback whale stock the SC also advised complete protection based on the NMP. Besides the above-mentioned catch limit regulation, the Commission also adopted other regulatory measures, for instance that meat and other whale products may only be used for local consumption, in order to be sure that the aboriginal catch takes place in agreement with the non-commercial character of this type of whaling.

At the last annual meeting the Commission agreed upon an aboriginal management scheme besides the NMP. In this aboriginal scheme catches are prohibited below a certain critical level - the theoretical level which would give a breakdown in recruitment -, and catch limits for stocks above this critical level but below the MSY- level must be fixed in such a way that growth towards the MSY-level is possible. At the next meeting the SC will try to give its advice to the Commission on aboriginal catch limits within this scheme. Although it can easily be foreseen that this will hardly be possible because of the very limited dataset available for these stocks, the adoption of this scheme nevertheless can be seen as an improvement because it gives guidelines for research workers to obtain the required dataset as soon as possible.

Small cetaceans

Both formerly and nowadays the Commission only manages stocks of large whales, which means stocks of baleen whales, the sperm whale and the northern bottlenose whale[3]). A number of member states, among them the Netherlands, are of the opinion that no legal disabilities exist to regulate also the exploitation of the other toothed whales, usually called small cetaceans or whales[4]). However, quite a few countries, among them the Latin-American ones and Denmark, disagree with this view and claim that the Commission has no jurisdiction with respect to the exploitation of small cetaceans. They argue that the Convention ,and Commission were established with the intention to regulate only the exploitation of the large whales. Moreover, a number of small cetacean species live within the 200 miles zone, and coastal states shall cooperate in appropriate international organizations for their Article 65 of the Law of the Sea clearly states that in the case of cetaceans, states shall cooperate in appropriate international organization for their management. Without a consensus about this controversy within the Commission no management measures can be taken on an international level with respect to small whale species such as the narwal and beluga. Both species live in Arctic waters and are heavily hunted by aboriginals. Even if the Commission agrees that all whale species are covered by the Convention, some member states will oppose the taking of appropriate action. This strong opposition arises from the fact that most of these countries have a big, unregulated catch of small cetaceans; the Faroese (Denmark), for example, take several thousand pilot whales per year and Mexico has a large tuna fleet which incidentally kills many spotted and spinner dolphins.

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NOTES

1) A stock of whales is defined as a group of whales living in a certain area during a fixed period of time. One or more stocks constitute a population.
2) In sperm whales the SC also accepts a yield, especially in males, due to the polygnous behaviour of this species. The underlying model is far more complicated than in baleen whales and therefore is outside the scope of this article.
3) However, the prohibition on the use of factory ships, except for the minke whale catch, not only applies to baleen whales and the sperm whale but also to the killer whale.
4) Although some of these are bigger than the minke whale.

SUMMARY OF THE PANEL DISCUSSION ON THE CONFLICT BETWEEN COMMERCIAL AND ABORIGINAL WHALING

by

Deborah Gottheil

Dr. Michael Tillman (USA) opened the discussion by stating that he was somewhat confused by the title given to the subject under discussion because he was not sure that a conflict presently existed between commercial and aboriginal whaling. The issue that was being raised before the International Whaling Commission ("IWC") by aboriginal whalers in their efforts to preserve their right to continue their aboriginal hunts is the difference between the two types of whaling. In Tillman's view, the only opportunity for conflict to arise between commercial and aboriginal whaling operations is when commercial operations deplete the whale stocks on which aborigines depend to a level which restricts the aboriginal hunts. Sin ce the advent of regulation of commercial whaling by the IWC, this situation seems to have been avoided; however, the Alaskan Eskimos are currently confronted with problems created by Yankee whalers in the previous century.

Tillman then noted that the IWC had acknowledged the differences between commercial and aboriginal whaling by adopting at its 1982 meeting separate management principles for aboriginal whaling. Generally, these principles allow whaling by aborigines to meet their subsistence needs on stocks that are otherwise protected from commercial whaling, if the stocks are above a certain minimum level (below which stocks cannot recover) and the level of take permits the stock to move toward the maximum sustainable yield level.

Dr. Raymond Newell (The Netherlands) asked how, since the IWC was set up to regulate commercial whaling, did aboriginal subsistence whaling become "confused" with commercial whaling.

Dr. Edward Mitchell (Canada) answered that when the International Convention for the Regulation of Whaling was initially being considered, some countries were reluctant to sign it because of its impact on indigenous whaling. This concern resulted in the inclusion in the Convention of the so-called aboriginal exemption clause.

Mitchell also expressed his concern that certain relevant definitions have begun to break down. For example, not all Alaskan aborigines are pure blood; some Eskimos are descendants of white men. In addition, products of an aboriginal hunt should not be sold, in his view. He stated that the Alaskan Eskimos have had a cash economy since the 1930's.

F.O. Kapel (Denmark) responded to the points raised by Mitchell in terms of the Greenland fisheries. Kapel stated that each situation must be viewed on an individual basis. The issue involves much more than a question of semantics; when looking at the idea of subsistence, one must consider what the products are meant for.

Paul Brody (Canada) asked how the Alaskan Eskimo hunt can be considered "aboriginal" if they relied on such technical innovations as the snowmobile.

Klaus Barthelmess (West Germany) responded that the use of such a technical improvement as a snowmobile should not disqualify the Alaskan Eskimos' hunt of bowheads as an aboriginal whaling operation.

Deborah Gottheil (USA) also stated that the use of the snowmobile did not alter the essential traditional nature of the Alaskan native harvest of bowhead whales. The snowmobile made it easier for the whalers to maintain contact with their families in their villages and to transport essential supplies, but the aboriginal nature of the actual hunt remains intact. Whalers use 16-18 foot skin boats with hand-held oars to approach the whale. As soon as they come up on the whale, the harpooner throws a darting gun that consists of a harpoon with line and float attached and a shell that a plunger triggers and fires into the whale. The gunner, using a shoulder gun adapted from those used by Yankee whalers in the previous century, shoots a bomb into the whale. Once a whale has been struck, other crews come to help tow the whale to the shorefast ice.

Gottheil also took up the points previously discussed by Mitchell. She pointed out that the issue as to whether the International Convention for the Regulation of Whaling applies to subsistence whaling by natives is the subject of litigation in the United States courts (presently "on hold" at the request of both parties). The Alaskan Eskimos are of the opinion that the Convention specifically excludes subsistence whaling by natives. With respect to the matter of whale products being sold by Alaskan natives, she pointed out that the only products of the bowhead whale being sold by Alaskan natives are handicrafts made from whale bone and baleen.

Drs. Ko de Korte (The Netherlands) asked about the impact of the whaling by Alaskan natives on the western Arctic stock of bowhead whales. Tillman (USA) responded that he did not know. He described the two approaches considered by the Scientific Committee of the IWC to determine the trend of the population. The first approach relies on numbers of calves that have been counted. The percentages that have been counted thus far are smaller than what is considered normal for baleen whales. Reliance on this approach leads to the conclusion that the stock is probably in decline. Most of the scientists, however, acknowledge the problems involved in seeing the calves and believe that the actual percentage of calves is higher. The second approach uses statistical models based on information for other baleen whales as well as the most current life history data on bowheads. Relying on this approach leads to the conclusion that the population may have been growing since 1915 (when commercial whaling on this stock ended) at a rate of about 1 percent per year, even while the Eskimos have been taking an average of 23 whales per year. Because the Scientific Committee always acts conservatively, it has recommended a zero quota.

Allan McCartney (USA) asked if there were anything else that could be causing problems for the bowhead population. Tillman responded that the United States Government is in the process of conducting extensive research on the impact of energy development in the Arctic seas to answer that question.

Mitchell (Canada) offered his views that the statistical models relied on by the Scientific Committee were not sufficient because the scientists do not have the necessary information on growth, age or ovulation rate of the bowhead. He also stated that it is possible that the calf counts are not underestimates because the bowhead is an ice edge animal, calves travel on the side of the mother that would allow them to be seen, and calves do not dive as often as the mother.

Gordon Broadhead (USA) stated that there have been sharp changes in the body of knowledge on the bowhead whale, which have all been positive. The risk element of removing 20 of 25 animals from a population of 4000 is very small, and that allowing such a harvest is essentially buying time until more information becomes available.

In response to a question as to whether or not the gray whale could be substituted for the bowhead whale, Tillman replied that the USSR redesigned their aborigines' culture by taking gray whales for them by catcher boat, and that the United States is unwilling to do the same to its aborigines. He also mentioned that the gray whale is not available to all the Alaskan whaling villages, it is more dangerous to hunt, its muktuk is not as good as the bowhead's and it lacks the cultural significance to the Alaskan natives. Mitchell stated that the bowhead does not have the flexibility in recoverability of the gray whale.

Drs. Van Beek (The Netherlands) stated that with regard to the first criteria of the IWC aboriginal management principles, the scientists believe that the western Arctic stock of bowhead whales is above the minimum level below which aboriginal whaling would be prohibited.

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