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Cold and warm years in South Spitsbergen coastal marine ecosystem

ABSTRACT: The comparison of the years 1981/82 and 1984/85 on the background of long term climatic observations on Svalbard suggest that two seasons compared belong to extremely different ones with regard to the sea ice, air temperature and biological phenomena. Despite meteorological and hydrological differences, the phytoplankton bloom and breeding period of major crustaceans were placed in the same time of the year. Differences were noted in the structure of zooplankton community, abundance of sea birds and mammals.

Key words: Arctic, Spitsbergen, climatic changes, marine biocenoses.

1. Introduction

The long term changes of climatic and hydrographic conditions and their influence on life in the sea was an object of many works performed mainly in North Atlantic region (Lee 1952, Blacker 1957, Vibe 1967, Cushing and Dickson 1976, Taylor and Stephens 1980).

Most of environmental and biological factors following such long term changes are influenced also by short term mezo-scale fluctuations within a period of 2—5 years (Vibe 1967, Mandel 1976).

Those mezo-scale climatic and hydrographic changes were not yet described as a particular phenomenon in Arctic, although some authors have noted their importance in this area (Adrov 1959, Tantsura 1959, Swerpel and Węsławski in press).

Coastal marine ecosystem of South-West Spitsbergen is an area of extensive studies performed recently by Polish oceanographers and marine biologists (i.a. Urbański et al. 1980, Węsławski 1983, Węsławski and Kwaśniewski 1983, Różycki 1984, Swerpel 1985, Różycki and Gruszczyński 1986, Stempniewicz and Węsławski in press, Swerpel and Węsławski in press). In view of the coming possibility of commercial oil drilling on the shelf of South Spitsbergen the problems of seasonality and natural year to year differences in biocenoses become even more important.

The aim of the present study is to describe two climatically different years on South Spitsbergen and to find whether or not these differences have influenced the functioning of investigated ecosystem.

2. Material and methods

All observations were carried out during two winterings in Polish Polar Station in Hornsund (77°N, 15°E) in 1981/82 and 1984/85; data from other years were taken from literature cited.

Hydrological measurements were performed by W. Moskal (1981/82), and R. Moroz (1984/85) by means of reverse thermometers. Air temperature was measured at 2 m level above the ground and calculated in 5 days medium values. System of season description was adapted after Baranowski (1977) as following: winter days with temperatures below −2.5°C, spring and autumn days with temperatures over −2.5°C but below +2.5°C, summer days with temperatures over +2.5°C.

Satellite charts of ice pack drift were kindly given to us by dr Hans Martin Henriksen from Norwegian Meteorological Observatory in Longyearbyen (Svalbard).

Breeding period of crustaceans was defined as the time between the appearence of first females of *Gammarus setosus*, *Gammarus oceanicus* and *Gammarellus homari* with eggs in marsupium and the first females with empty marsupium found. Those three species were chosen as abundant and common inhabitants of the upper littoral zone, the most exposed to climatic influence.

The beginning of phytoplankton bloom was estimated as a time when pelagic algae were at first visibly abundant in surface waters colouring them brownish-green. Such a rough estimation was used since phytoplankton bloom in Arctic is very intense and clearly recognizable by eye.

3. Results

The run of air temperature for both years compared is shown in Fig. 1. Summer and autumn temperatures are not very different while

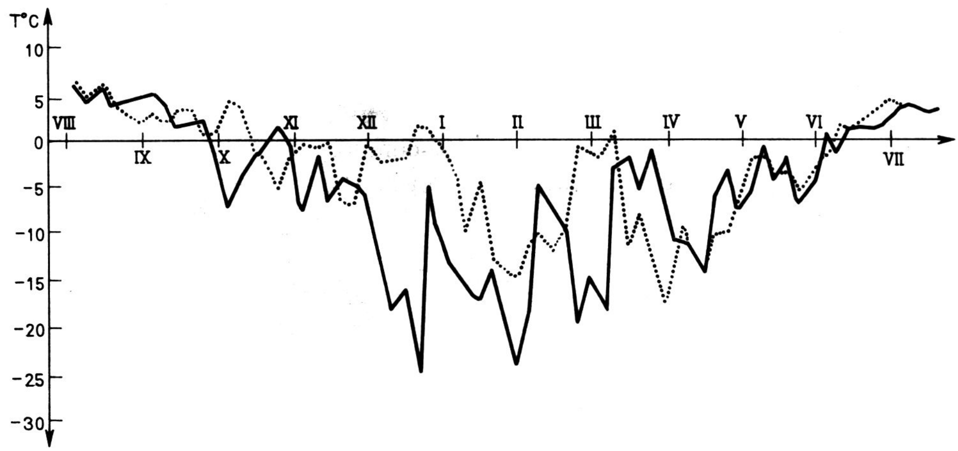

Fig. 1. Air temperature (medium values in pentades at 2 m above the ground) in 1981/82 (solid line) and in 1984/85 (dotted line)

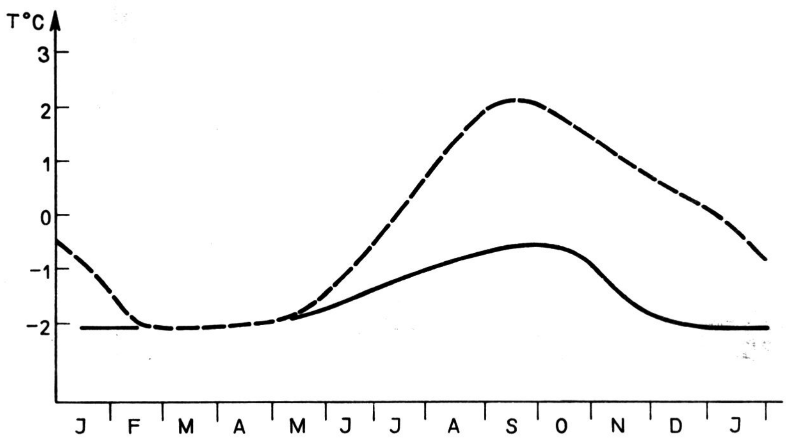

Fig. 2. Near bottom water temperature from Isbjørnhamna in 1981/82 and in 1984/. Data compiled after Swerpel (unpubl.), Moskal and Zajączkowski (unpubl.) a own observations; solid line — 1981/82, dotted line — 1984/85

significant differences were observed in mean temperatures of winter months. Such differences have influenced the duration of winter in 1981/82, almost 30% longer than winter in 1984/85 (Tab. 1).

Differences in temperatures of near bottom water layer (Fig. 2) were small in absolute values (up to 3°C), but the duration of the period with negative water temperatures was significantly longer in 1981/82 than in 1984/85 (10 and 5 months respectively).

Winter ice cover in Hornsund (Fig. 3) varied in both years with regard

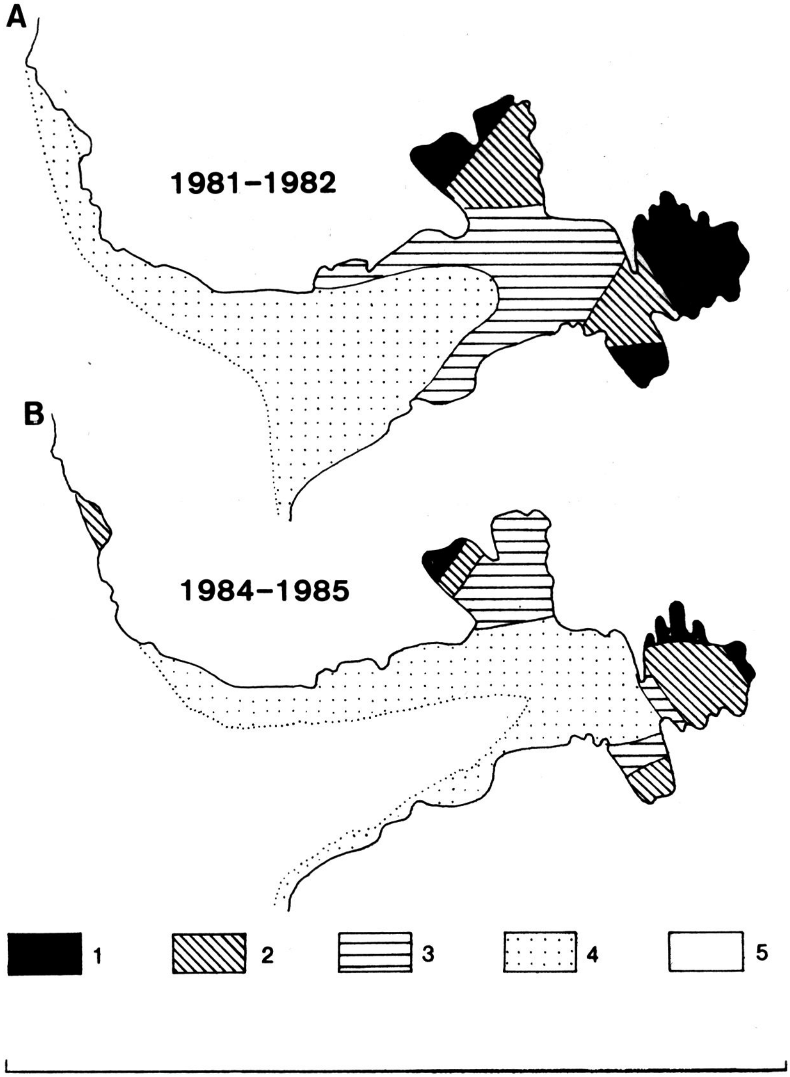

Fig. 3. Winter ice in Hornsund in 1984/85. 1 — 4 to 6 months of fast ice cover, 2 — 2 to 4 months of ice cover, 3 — 1—2 months of ice cover, 4 — less than one month of ice cover, 5 — no winter ice cover (only drifting pack ice)

to the duration of ice cover and its area. In winter 1984/85 a large part of fiord was not covered at all by ice and area of thick fast ice cover was small. Winter 1981/82 was characterized by solid fast ice cover lasting in innermost fiord basins until late July (Fig. 3).

Ice pack drift during its maximal extent in March was similarly displaced in both years, but in 1984/85 ice fields were not present along SW Spitsbergen coast in contrast to March 1982 (Fig. 4).

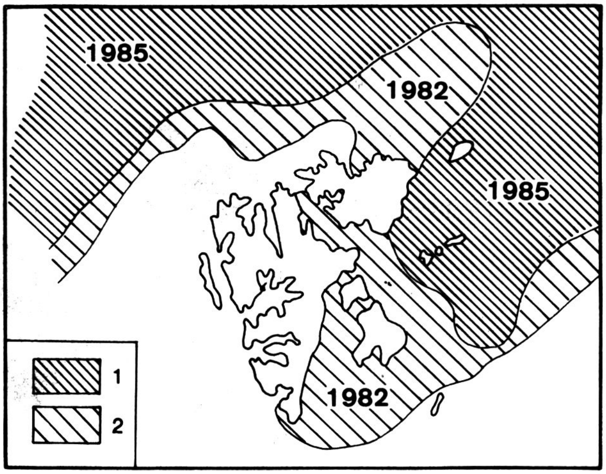

Fig. 4. Minimal ice pack limits around Svalbard in March 1982 (scarce hatching) and in March 1985 (dense hatching). Data from ice distribution maps. Longyerbyen Meteorological Observatory

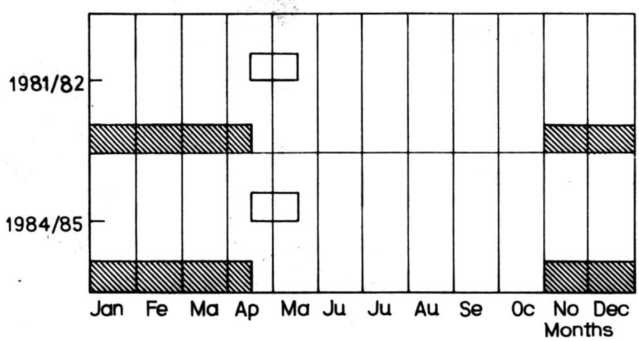

Fig. 5. Timing of phytoplankton bloom (clear bars) and eggs incubation in *Gammarus setosus*, *G. oceanicus* and *Gammarellus homari* (hatched bars) in both years compared

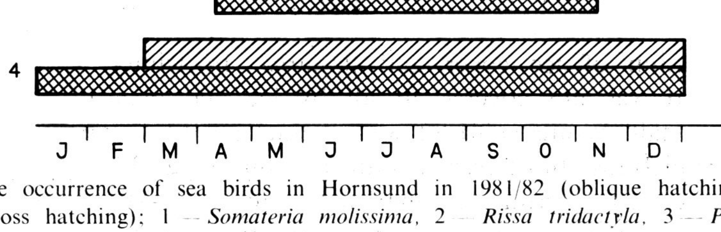

Fig. 6. The occurrence of sea birds in Hornsund in 1981/82 (oblique hatching) and in 1984/85 (cross hatching): 1 — *Somateria molissima*, 2 — *Rissa tridactyla*, 3 — *Plautus alle*, 4 — *Fulmarus glacialis*, *Cepphus grylle*

Table 1

Climatological characteristics of 1978—1985 period in Hornsund; data from 1978—83 after Rodzik and Stepko (1985)

Factor	1978/79	1979/80	1980/81	1981/82	1982/83	1984/85
mean air temp. C	−6.8	−4.2	−7.0	−5.2	−5.0	−2.7
mean wind velocity m/sek	5.1	5.3	5.5	4.8	5.6	4.4
duration of winter (days)	254	191	217	211	221	151
duration of spring (days)	29	31	45	33	35	47
duration of summer (days)	64	78	74	51	60	90
duration of autumn (days)	18	70	35	50	49	78

The begining of phytoplankton bloom and incubation of eggs among gammarid species covered the same or almost the same time in both years (Fig. 5).

Analyses of the planktonivorous sea birds diet permitted to outline the differences in macroplankton occurrence in both years compared (Tab. 2). Surface feeding kittiwakes and subsurface feedting little auks were used as plankton samplers. The significant difference in their diet reflects the feeding on different plankton community in summer 1982 and 1985.

Table 2

Dominant macroplanktonic species in sea birds diet — based on own observations — (analysis of 20 little auks and 10 kittiwakes from each year); n = number of stomachs examined

Species	June 1982, n = 30	May 1985, n = 30
Gammarus wilkitzkii	+ +	—
Apherusa glacialis	+ +	—
Euphausiacea	+	+ +
Themisto abyssorum	+	+ +
Themisto libellula	+	+ + +

\+ — single specimens
\+ + — abundant
\+ + + — very abundant

In cold 1982 dominating food item were the cryopelagic. Arctic species *Apherusa glacialis* and *Gammarus wilkitzkii*. In warm summer 1985 those species were absent and replaced in birds diet by subarctic *Themisto libellula*, *Themisto abyssorum* and boreal *Thysanoessa inermis*.

Marine birds presence in the investigated area is shown in Fig. 6. Warm 1984/85 year was characterized by longer period of birds staying

Table 3

Sea mammals observed in Hornsund in 1981/82 and 1984/85

Species	1981/82	1984/85
Pusa hispida	+ + +	+ +
Pagophilus groenlandica	+ +	+
Thalarctos maritimus	246 indiv.	66 indiv.

+ single specimens
+ + abundant
+ + + very abundant

in Hornsund than cold 1981/82. *Fulmarus glacialis*, *Cepphus grylle* and probably also *Somateria molissima* have stayed all over the 1984/85 in fiord area.

Ringed seals, greenland seals and polar bears were far more abundant in 1981/82 than in 1984/85 (Tab. 3).

Table 4

Comparison of cold and warm years within South Spitsbergen area — Hornsund Fiord

Observation	cold year 1981/82	warm year 1984/85
1. mean annual air temperature °C	−5.2	−2.7
2. mean annual sea temperature in 30 m depth	−1.5	0
3. duration of fast ice cover on fiord	6—7 months	3 months
4. presence of ice pack	March—September	March—May
5. foot ice duration	October—July	December—May
6. character of plankton community	Arctic/Atlantic, neritic, surface forms	Atlantic, open sea, mainly below 50 m
7. timing of phytoplankton bloom	April—May	April—May
8. eggs incubation period in gammaroid species (Fig. 5)	October—April	October—April
9. character of food base for most common sea birds	low biomass, easily accessible	high biomass, accessible with difficulty
10. average duration of sea birds presence in fiord	6—7 months	whole year
11. number of polar bears migrating through Hornsund area	246	66
12. tundra drainage and secondary nutrients transport from land to the sea	low	high

4. Discussion

The set of meteorological data from 1974—1982 compiled from Spitsbergen observatories by Troickij et al. (1985) confirms the presence of a short term (2—5 years) cycles of warmer and colder years. Changes of climatic conditions in Hornsund were described by Rodzik and Stepko (1985); they show remarkable differences especially for the mean year temperature of the air — hence the length of winter period. The deviations reach 60% from the medium value of 7 years period. Other meteorological characteristics like medium values of humidity, wind velocity air pressure are not so variable from one year to another in Hornsund (Rodzik and Stepko 1985). The most diverse were the air temperature, ice and snow cover (Pereyma 1983, Rodzik and Stepko 1985, IMGW unpubl. data).

The 1981/82 season described here as cold year was not in fact the coldest of the years registred during last 7 years period in Hornsund (Tab. 1), as well as the 1984/85 was not the warmest of this period. Even so, the climatic differences between them are evident (Tab. 1).

The ice pack drift and fast ice cover are the most differentiating factors and can be regarded as indicators of cold or warm year. Ice pack drift is particularily changeable in Svalbard region from one year to another (Vinje 1977, 1985).

As it is shown in Fig. 5 the basic biological processes like phytoplankton bloom and breeding of more common invertebrates occurred in the same time of the years compared, regardless their hydrological and climatic differences. This confirms the opinions of Gurjanova (1957) and Dunbar (1968) that low temperatures are not a limiting factor for Arctic marine invertebrates biology. Most probably their breeding is controlled first of all by photoperiod as well as the timing of algae blooming. Unfortunatelly we were not able to find if there were any differences in the intensity of primary production or breeding succes of invertebrates in both years compared; anyway the timing of both phenomena was highly similar.

The prominent differences in birds diet indicate to the distinct differences in available food base (planktonic community). Species presented in Tab. 2 are regarded in literature as good indicators of Arctic water mass (*Apherusa glacialis, G. wilkitzkii*) oraz Atlantic waters in the Arctic (Euphausiacea, *Themisto abyssorum*) (Abramova 1956, Grainger 1963, Gobriunova and Suvalov 1964, Dunbar 1968, Dunbar and Harding 1968, Lomakina 1978). Both Arctic and Atlantic planktonic communities are of basic meaning for the sea birds diet in the area (Mehlum and Gjertz 1984, Lydersen Gjertz and Węsławski 1985, Stempniewicz and Węsławski in press). Atlantic warm water plankton occurs near Spitsbergen in the West Spitsbergen Current mainly in the depth of 50 200 m, its main stream is quite distant from the Spitsbergen coasts – up to 100 miles (Omdahl 1952, Blacker 1957, Tantsura 1959, Lovenskjøld 1964).

Arctic cold water plankton abundant in 1982 was connected with the presence of ice pack drifted by Sörkapp Current or with influxes of Barents Current (Swerpel and Węsławski in press).Arctic plankters occur near the surface and close to the shores, among ice floes. This means that birds searching for food in cold year fly for smaller distances for feeding than during warm year.

The presence of sea mammals in South West Spitsbergen is directly connected with ice pack range at Svalbard. Changes in abundance of polar bear, ringed and Greenland seals are caused mostly by increasing or decreasing of the ice pack range (Jezierski and Moskal 1984, Larsen 1984). Winter fast ice in the fiord is important as a habitat for ringed seals, since their breeding success is connected with duration and thickness of the ice cover on fiords (Ivašin, Popov and Capko 1972, Lydersen and Gjertz 1986). The cold year will bring both better breeding success for ringed seals and higher abundance of polar bears in coastal area.

What is in the background of climatic changes referred above? South Spitsbergen lays in the area of water mixation – warm Atlantic waters from West Spitsbergen Current (South Spitsbergen Current) and a complex of cold water currents: Sörkapp Current, Barents Current and Bjørnøya Current (Adrov 1959, Tantsura 1959, Swerpel and Węsławski in press).

The biggest and of the strongest influence upon the climate in the area is the West Spitsbergen Current, which is a distant arm of North Atlantic Current. The variability of this last current was observed by Taylor and Stephens (1980) who suggested northward and southward migration of the western wall of North Atlantic Current in different years. That migration caused probably the differences in outflow of West Spitsbergen Current along the West Spitsbergen observed by Mandel (1976).

Last years brought increasing interest in oil industry in South Spitsbergen shelf waters (Bergsager 1984). The possible oil spill would be far more dangerous for local marine environment during cold year, when planktonic life is concentrated in surface waters close to the shore in contrast to warm year, when birds are feeding away from the coasts and main plankton biomass is situated much lower below the surface.

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5. References

Abramova V. D. 1956. Plankton kak indikator vod različnogo proizhoždenija v morjah Severnoj Atlantiki. — Trudy PINRO, 9: 69—92.

Adrov M. M. 1959. Novyje dannyje po gidrologii severo-zapadnoj časti Barentsogo Morja. — Trudy PINRO, 11: 5—26.

Baranowski S. 1977. Subpolarne lodowce Spitsbergenu na tle klimatu tego regionu. — Acta Univ. Vratisl., Studia Geogr., 393: 1—157.

Bergsager E. 1984. Letting etter olje og gass. — In: Det Beste (ed.), Svalbard vart nordligste Norge. Oslo, 260—266.

Blacker R. W. 1957. Benthic animals as indicators of hydrological conditions and climatic change in Svalbard waters. — Fish. Invest. London, Ser. 2, 20: 1—49.

Cushing D. H. and R. R. Dickson. 1976. The biological response in the Sea to climatic changes. — Adv. Mar. Biol., 14: 12—122.

Dunbar M. J. 1968. Ecological development in polar regions. — Prentice Hall Inc., Inglewood Cliff, New York, 119 pp.

Dunbar M. J. and G. Harding. 1968. Arctic ocean water masses and plankton, a reprisal. — In: J. E. Sater (ed.), Arctic drifting stations. Arct. Inst., North America, 315—326.

Gobriunova Z. S. and V. S. Suvalov. 1964. Zooplankton po sboram ekspedicii na l/r "Litke" v 1955 g. — Trudy A.A.N.I.I., 259: 378—387.

Grainger E. H. 1963. Copepods of the genus Calanus as indicators of Eastern Canadian waters. — In: M. J. Dunbar (ed.), Marine distributions, Montreal, 68—94.

Gurjanova F. F. 1957. Kratkie rezul'taty gidrobiologičeskih issledovanij Mezenskogo zaliva letom 1952 g. — In: Materialy po kompleksnomu izučeniju Belogo morja, v. 1, Izd. AN SSSR, Moskva, 252—281.

Ivašin M. B., L. A. Popov and A. S. Capko. 1972. Morskije mlekopitajuščije. — Izd. Piščevaja Promyšl'., Moskva, 300 pp.

Jezierski J. and W. Moskal. 1983. Niedźwiedź polarny (*Ursus maritimus*) na Svalbardzie. — In: Polskie badania polarne 1970—1982, Rozprawy UMK Toruń, 300—307.

Larsen T. 1984. Population biology of the polar bear (*Ursus maritimus*) in the Svalbard area. — Norsk Polarinst. Skr., 184: 1—127.

Lee A. J. 1952. The influence of hydrography on the Bear Island Cod fishery. — Cons. Perm. Int. Explor. Mer. Rapp. et Proc. Verb., Copenhagen, 131: 74—102.

Lomakina N. B. 1978. Eufauzidy mirovogo okeana (Euphausiacea). — Nauka, Leningrad.

Løvenskjøld H. 1964. Avifauna Svalbardiensis. — Norsk Polarinst. Skr., 129: 460 pp.

Lydersen C. and I. Gjertz. 1986. Studies on the Ringed seal (*Phoca hispida* Schreiber, 1975) in its breeding habitat in Kongsfjorden, Svalbard. — Polar Res., 7: 57—64.

Lydersen C., I. Gjertz and J. M. Węsławski. 1985. Aspects of vertebrate feeding in the marine ecoysytem in Hornsund, Svalbard. Norsk Polarinst. Rapp., 21: 1—57.

Mandel S. Z. 1976. Uroven' vody v Barentsburgie kak pokazatiel' postuplenija atlantičeskih vod v arktičeskij bassejn. — Trudy A.A.N.I.I., 319: 129—137.

Mehlum F. and I. Gjertz. 1984. Feeding ecology of sea birds in the Svalbard area, a preliminary report. — Norsk Polarinst. Rapp., 161: 1—41.

Omdahl K. 1952. Drivisen ved Svalbard 1924—1939. — Norsk Polarinst. Medd., 72: 1—21.

Pereyma J. 1983. Climatological problems of the Hornsund area, Spitsbergen. — Acta Univ. Vratisl., 714: 134 pp.

Rodzik J. and W. Stepko. 1985. Climatic conditions in Hornsund (1978—1983). — Pol. Polar Res., 6: 561—576.

Różycki O. 1984. Distribution of bivalves in the Van Keulen Fiord (Spitsbergen, Bellsund). — Pol. Arch. Hydrobiol., 31: 83—89.

Różycki O. and M. Gruszczyński. 1986. Macrofauna associated with laminarian algae in coastal waters of West Spitsbergen. — Pol. Polar Res., 7: 337—351.

Stempniewicz L. and J. M. Węsławski (in press). Outline of trophic relations in Hornsund (SW Spitsbergen) with special reference to Sea birds. — In: R. Z. Klekowski (ed.), Man, landscape and animal life in High Arctic, Ossolineum, Wrocław.

Swerpel S. 1985. The Hornsund Fiord: Water masses. — Pol. Polar Res., 6: 475—496.

Swerpel S. and J. M. Węsławski (in press). An outlook on the Surface Currents near Spitsbergen. — In: R. Z. Klekowski (ed.), Man, landscape and animal life in High Arctic, Ossolineum, Wrocław.

Tantsura A. J. 1959. O tečenijah Barentsogo Morja. — Trudy PINRO, 9: 35—54.

Taylor A. H. and J. A. Stephens. 1980. Latitudinal displacements of the Gulf Stream (1966—1977) and their relation to changes in temperature and zooplankton abundance. — Acta Oceanologica, 3: 145—149.

Troickij L. S., E. M. Zinger, W. S. Korjakin, W. A. Markin and W. I. Mihalev. 1985. Oledenenije Spitsbergena (Svalbarda). — Nauka, Moskva, 75 pp.

Urbański J., E. Neugebauer, R. Specjer and L. Falkowska. 1980. Physico-chemical characteristics of waters of Hornsund Fiord of SW Spitsbergen (Svalbard archipelago) in summer 1979. — Pol. Polar Res., 1: 43—52.

Vibe C. 1967. Arctic animals in relation to climatic fluctuations. — Medd. om Gronland, 170: 1—227.

Vinje T. E. 1977. Sea ice conditions in the european sector of the marginal seas of the Arctic 1966—1975. — Arbok Norsk Polarinst. (1975), 163—174.

Vinje T. E. 1985. Drift, composition, morphology and distribution of the sea ice field in the Barents Sea. — Norsk Polarinstitutt, Oslo, pp.

Węsławski J. M. 1983. Observations on the coastal Amphipoda of the Hornsund Fiord (South-West Spitsbergen). — Pol. Arch. Hydrobiol., 30: 199—206.

Węsławski J. M. and S. Kwaśniewski. 1983. Application of biological indicators for determination of the reach and origin of sea currents within the region of Spitsbergen. — Pol. Arch. Hydrobiol., 30: 189—197.

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6. Streszczenie

Porównano dwa zbiory obserwacji meteorologicznych, hydrologicznych i przyrodniczych dokonane w czasie całorocznych pobytów w Polskiej Stacji Polarnej w 1981/82 i 1984/85 r.

Oba porównywane lata należą do skrajnie różnych pod względem średniej temperatury, długości trwania zimy, warunków lodowych. Sezon 1981/82 określono jako zimny rok, zaś sezon 1984/85 jako ciepły rok na Spitsbergenie.

Za wyraźnymi różnicami hydrologiczno-klimatycznymi idą różnice w występowaniu planktonu (w zimnym roku dominuje plankton arktyczny, w ciepłym — atlantycki), długości pozostawania ptaków morskich u wybrzeży (dłużej w ciepłym roku) oraz liczebności białych niedźwiedzi i fok we fiordzie (liczniejsze w zimnym roku).

Nie zauważono natomiast różnic w sezonowości zakwitu fitoplanktonu oraz inkubacji jaj u pospolitych obunogów przybrzeżnych. Oba te procesy miały miejsce w tym samym czasie, w obu porównywanych latach.

Jak się wydaje, środowisko morskie Spitsbergenu może być bardziej wrażliwe na stres zewnętrzny (np. wyciek ropy naftowej) w roku zimnym, gdy życie koncentruje się przy powierzchni i u wybrzeży, niż w roku ciepłym, gdy główne żerowiska ptaków są odsunięte od brzegów Spitsbergenu.