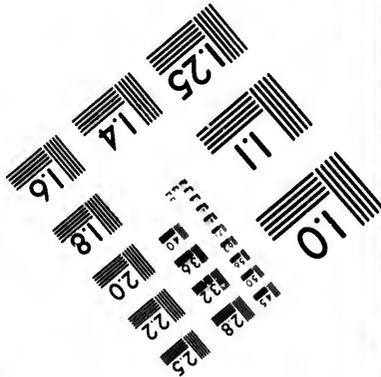
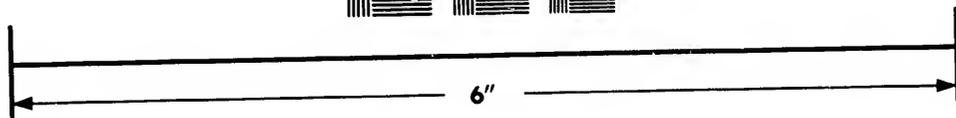
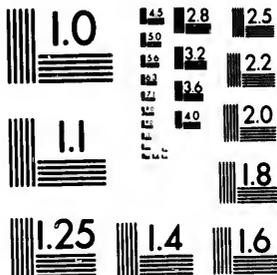


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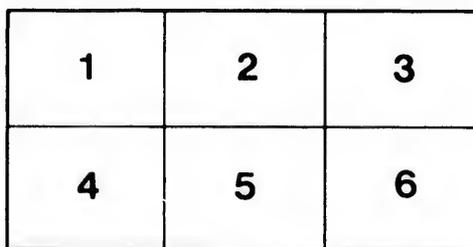
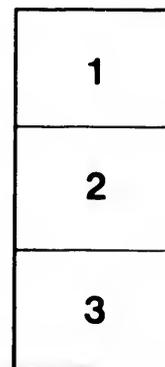
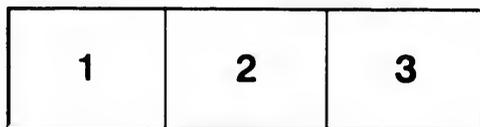
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REPORT

OF

ICE AND ICE MOVEMENTS

IN

BERING SEA AND THE ARCTIC BASIN,

BY

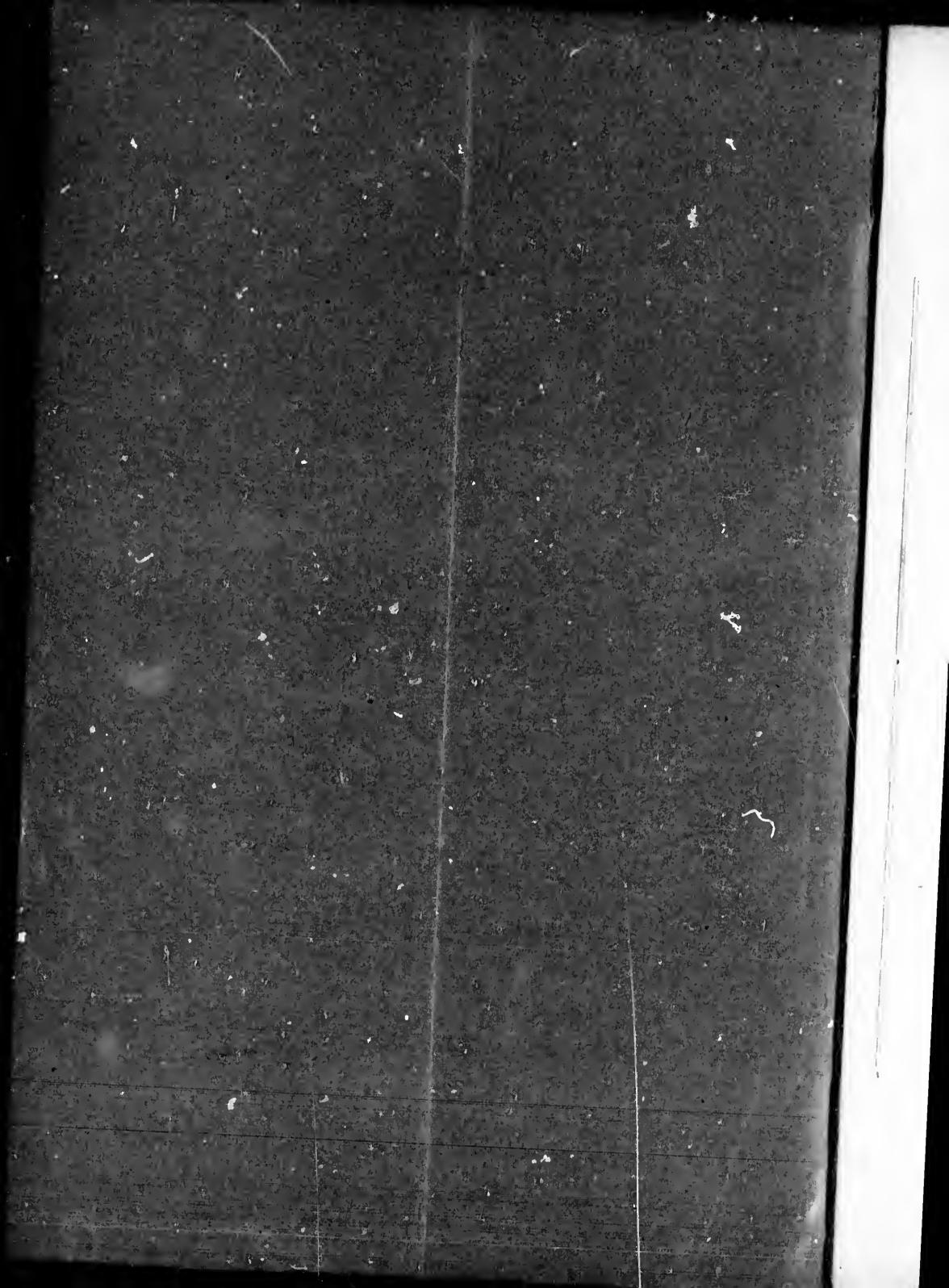
ENSIGN EDWARD SIMPSON, U. S. N.

UNDER THE DIRECTION OF

LIEUTENANT COMMANDER CHAS. H. STOCKTON, U. S. N.,

Commanding U. S. S. "Thetis."

WASHINGTON:
U. S. HYDROGRAPHIC OFFICE,
1890.



No. 92.



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WASHINGTON:
U. S. HYDROGRAPHIC OFFICE,
1890.

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U. S. HYDROGRAPHIC OFFICE,

WASHINGTON, D. C., *January 2, 1890.*

The accompanying account of Ice and Ice Movements in Bering Sea and the Arctic Basin is one of a series of valuable reports received from the U. S. S. *Thetis*, upon the completion of her recent cruise in those waters.

Those dealing with hydrographic information were published and distributed under the form of Notices to Mariners, as being the manner best calculated to reach the maritime community, while those relating to special subjects, such as the following, whose importance to navigators in the localities mentioned cannot be over-estimated, will appear in pamphlet form.

Lieutenant Commander Stockton, and officers serving with him, have greatly contributed to our knowledge of the waters and coasts of North-western Alaska, and the recent cruise of the *Thetis* has been as remarkable as it has been successful in its results.

HENRY F. PICKING, *Captain, U. S. N.,*
Hydrographer.

1890.

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REMARKS.

In order to make the cruise of the U. S. S. *Thetis*, during the summer of 1889, in the waters of Bering sea and the Arctic ocean as full and as useful as possible, I directed several of the officers of the *Thetis* to observe and report upon various subjects connected with those waters and the portions of Northwestern Alaska visited by us. The following report by Ensign Edward Simpson originated in that manner.

CHAS. H. STOCKTON,

Lieutenant Commander, U. S. N.

U. S. S. *Thetis*, off Navy Yard, Mare Island,

December 13, 1889.

(3)

LETTER OF TRANSMITTAL.

U. S. S. "THETIS,"

SITKA, ALASKA, *November 18, 1889.*

SIR:—In obedience to your verbal order to report on the subject of "Ice," as it is found in Bering sea and the Arctic ocean in the vicinity of Bering strait, and especially with regard to its movements under the influences of the prevailing currents and winds, I have the honor to submit the following report.

In making this report, I have collected data from the following sources: The captains of five steam whalers and eleven sailing vessels; the reports of the "Cruises of the *Corwin*," in 1881 and 1885; "Little Joe" Tuckfield, of the Mackenzie river; Mr. Leavitt, of the Cape Smyth whaling station; Mr. Wolfe, of the Cape Sabine coaling station; Mr. J. W. Kelly, of the Cape Sabine and Point Hope stations; F. Birk (seaman), of the U. S. S. *Rodgers*; Mr. Grey, of the Pribyloff islands; Mr. R. Neumann, of St. Michaels and Ounalaska; and the experiences of the U. S. S. *Thetis* during the summers of 1888 and 1889.

Respectfully submitted,

EDWARD SIMPSON,

Ensign, U. S. Navy.

To Lieutenant Commander CHAS. H. STOCKTON, U. S. Navy,
Commanding U. S. S. *Thetis*.

ICE AND ICE MOVEMENTS

IN

BERING SEA AND THE ARCTIC BASIN.

Report of the ice as found in Bering sea and the Arctic basin in the vicinity of Bering straits, and its movements under the influence of the prevailing currents and winds.

General description of the ice in different localities.—The "Arctic pack" which never melts, consists of hard, blue ice, made up of fields of comparatively level ice, as much as 1 mile in diameter, which are surrounded and interspersed with hummocks, from 20 to 40 feet high. Along the edge of the pack "leads" are found running into it for short distances in different directions; when the pack moves it goes in a body, and these leads are continually changing, opening and closing, so as to make it impossible for a vessel, once caught in the pack, to proceed at will. A vessel so caught is unmanageable, even should she escape being crushed, and all the whaling captains agree that, if it is found impossible to get out before young ice makes, nothing can be done except to abandon her.

In the spring, with the prevailing southerly winds and northerly currents, the pack breaks off from the shore ice and moves north, the northern limit of its southern edge varying in latitude, as will be shown further on, and is held north until the fall, when it again moves south. During these summer months ice melts, evaporates and disappears, so that, when the pack returns south, the old ice probably does not come below the latitude of Icy cape in a body, unless it does so well off shore.

I can find no record of the old pack being seen from the shore in the fall below Icy cape, such portions of the old ice that are found below that latitude being composed of detached and much broken floes.

The shore ice and flaw ice is that which remains fast to the shore after the pack moves off, and which gradually breaks off and follows the pack in floes and floebergs. It becomes scattered and is quickly affected by varying winds and currents, and vessels, fitted for ice work, can work through it quite readily, so long as young ice is not forming.

When a vessel has worked into floe ice until it becomes too heavy for her to proceed, she ties up to the ice and awaits a shift of wind. It is surprising how quickly a shift of wind will change the appearance of ice in a few hours, making wide leads where shortly before the ice was heavily massed. When young ice is making, it forms very rapidly between the cakes of floe ice, joining all in a solid mass, and locking a vessel, so caught, very quickly.

Large, hummocky floes, which drift or are forced up into shoal water, and become grounded, are known as "ground ice," and it is to these that vessels secure to seek shelter in gales from fast drifting floe ice or during temporary settings in of the pack. These pieces of ground ice are recognizable, when there is a current running, by the wake they leave, or by the height of the "overhang" of their former water-line above the surface of the water.

Vessels, forcing their way through floe ice, always avoid striking ground ice, on account of the great risk of being "stove" on it, and also the impossibility to move it. One whaling captain describes making fast inshore of a floe of ground ice, showing only a few feet above the water, which was forced inshore by the pack until it was as high as his fore-yard.

"Young ice" is the name given to new ice just forming. During cold weather, when the wind is light or calm, young ice forms very rapidly. In the vicinity of the pack, with northerly winds in early October, it can be seen shooting off in forks from the edge of the pack so rapidly that vessels, keeping along its outer edge, are out of sight of the pack in a few hours. When not in the vicinity of the pack, young ice forms in spots, which spread out like oil upon the water and soon join in a solid sheet. It forms first from the pack and floe ice, and then from the shore, and spreads out until the whole ocean is covered in a few days. During a cold, calm night it forms to a thickness of from 1 to 6 inches. The best of the whaling steamers that go into the Arctic can probably steam at the rate of 9 knots in open water, but can barely force their way through young ice of 5 inches in thickness at 3 knots an hour.

The ice in Bering sea, although it is made up entirely of young ice every year, may be divided into two kinds, viz, that which forms in the

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late fall and early winter, and is telescoped and piled into heavy masses during the shifting gales, and, secondly, that which forms in the late winter and early spring in the spaces left by the old ice moving. This solid ice probably does not extend to the southward of St. Matthew island, while the ice below it as far as the southern limit is made up of the newer ice and detached floes of well-broken ice.

All the ice seen in the vicinity of the Pribyloff islands is broken floe ice that is influenced continually by the wind and tides. Vessels forcing their way north in the spring enter this new ice readily, if it is well broken, steamers forcing through it and running when necessary; and sailing vessels, when they have a fair wind, lashing their helms and letting the ship find her own way through it under easy sail. The heavy winter ice is always avoided, and the newer ice, when in large floes, is also very dangerous on account of their weight being sufficient to sink a ship should they come together.

A case of this occurred May 25, 1885, when the ship *Gazelle* tried to run out a gale between two ice floes and was crushed and sunk. Or a ship may be detained in this ice, as in the case of the steamer *Belvidere*, which was nipped and drifted forty-three days in the ice in the western part of Bering sea.

The heaviest patches of ice in Bering sea are met in the spring by vessels off cape Navarin or north of St. Lawrence island; and it is the ice that forms in the gulf of Anadir, where the strong northeast gales drive against the current and keep piling, grinding and telescoping the ice into heavy masses.

Southern limit of the ice.—Although there is a tradition existing in Ounalaska that one winter, years ago, the ice came down on the island in heavy masses; and in January, 1878, it was down on Akoutan island and in Oonimak pass, when several native boats were lost in it. The southern limit can safely be said to be in latitude 56° N., about 35 miles south of St. George island. Occasionally, as in 1886, no ice is seen at the Pribyloff islands, but generally after three weeks of north-easterly winds it comes down from the mouth of the Koskovine river in very much broken floes, and remains in sight, moving to the eastward and westward with the winds, until the spring, when a southerly wind soon drives it north. This generally occurs in the latter part of April, although in 1880 it remained so late that an iron steamer, the Alaska Commercial Company's steamer *St. Paul*, unfitted for encountering ice, was unable to effect a landing until June 1.

Whaling vessels, which are sheathed and fitted for ice work, take the ice about April 7-15, although a few do so as early as March 25. Those

entering Bering sea by Oumimak pass meet the ice in the latitude of St. George island, while those coming through Amoughta pass meet it in longitude 175° W., latitude 58° N. In longitude 180° it is found in latitude 60° N. about April 15. The most southern point I have found vessels reporting ice is latitude $56^{\circ} 10'$ N., longitude $171^{\circ} 30'$ W., on April 12, 1889; and several report meeting it in latitude $57^{\circ} 30'$ N., in about longitude 175° W., during the middle of April. The general contour of the southern limit of the ice in Bering sea is from Bristol bay to about 35 miles south of the Pribyloff islands, and then northwest in the direction of cape Omchinsky.

Spring movements of the ice in Bering sea.—The movements of the ice upon breaking up in the spring are due altogether to the currents and winds; and as the currents are greatly affected by the prevailing winds, navigators wishing to push north early should be influenced in their movements largely by them. While the pack remains solid in the middle of the sea, both sides are found navigable much earlier. This is due to the breaking up of the ice off shore by local winds, the northerly currents, and the currents setting out of the numerous rivers. Whether the east or west shore is the most open depends largely upon what the prevailing spring winds have been, strong easterly and northeasterly winds packing the ice heavily on cape Navarin and breaking it up on the east shore, and vice versa. On the west shore the current sets north-east well off shore, and although its speed is increased or diminished by prevailing winds, it is seldom that the current changes its direction to the southward. In 1886, the bark *Sea Breeze* during a northeast gale off cape Navarin, furled all sail, made fast to a floe of drifting ice, and in three days drifted 45 miles to windward. Off cape Navarin the current splits about 30 miles off shore, one branch following the trend of the coast in a southwesterly direction towards cape Omchinsky, and the other running to the northward into the gulf of Anadir and then off to the northeast, running strong between St. Lawrence island and Indian point.

In May, 1889, the bark *Abraham Barker*, when about 30 miles south-east of cape Navarin, encountered a northeast gale and drifted in well towards cape Omchinsky in the southwest current.

In the spring of 1887, the bark *Hunter* was nipped in the middle of the gulf of Anadir and drifted with the ice out of the gulf and to the northward of St. Lawrence island, passing very close to cape Chibukak.

On the east side of Bering sea, between St. Matthew and Nunivak islands, the set of the current is north. With prevailing northeast winds

it sets northwest, and with northwest and southwest winds, northeast. This northerly current continues past the east side of St. Lawrence island to King's island; from there it sets in toward Port Clarence, then follows the trend of the coast past capes York and Prince of Wales, and into the Arctic ocean. The current on the east side is not as strong as that on the west side, and north of St. Lawrence island the west shore from Indian point to the Diomede islands is invariably clear of ice before the east shore; consequently Indian point is the first objective point for vessels pushing their way north in the spring. The action of these currents is as follows:

Ice clears the Pribyloff islands about May 1. The pack moves north, the sides clearing ahead of the center, and vessels following the pack reach cape Navarin about May 10. Here the heavy ice, which forms in the gulf of Anadir by the young ice piling up under the influence of northeast winds, is met coming out of the gulf. This ice is set to the eastward by the spring southerly and westerly winds until it meets the strong northeast current, when it sets up into the channel between Indian point and St. Lawrence island; then the main body of it swings around on the north and northeast side of St. Lawrence island, where it lodges until the last of it breaks up and goes north during the middle of July. Young ice continues to form in Bering sea until May 10, and after that time it is not looked for. On April 12, 1888, the steamer *Orca* steamed for six hours through young ice in about latitude 60° N., longitude 178° E. It sometimes happens that vessels find a clear lead from cape Navarin to Indian point or St. Lawrence island as early as May 18, but this occurs only in exceptional seasons. As a rule, vessels that are determined to keep the west shore follow leads into the gulf of Anadir, steamers forcing through the broken ice, and sailing vessels hauling through it with ice hooks and steam winches; the former coming out into clear water off cape Bering about May 25, and the latter about June 10. When cape Bering is clear, Indian point can be reached without much difficulty. Should a vessel arriving near cape Navarin find the ice heavily packed in that vicinity, indicating prevailing easterly spring winds, she should not be misled by the space of open water that generally exists south of the cape, and which is about 50 by 25 miles in extent, but should follow the line of the pack to the eastward and try the eastern shore. By so doing she will probably find the edge of the pack in the longitude of St. Matthew island, in latitude 59° to 60° ; from there it will lead her close to the west coast of Nunivak island, from which position she should work up to the southeast cape of St. Lawrence island; thence she may work along the south side of the

island and find clear water from cape Chibukak to Indian point before the ice is open from cape Navarin to cape Bering. It is useless to attempt to pass to the northward of St. Lawrence island from the east side, as the heavy impassable ice, before mentioned as coming out of the gulf of Anadir, exists there much later than it does on the southern shore.

This eastern route is frequently undertaken by the whalers; indeed, some of them always take it in preference to attempting the western route, in order to reach open water off Indian point and meet the whales coming "head on" through the heavy ice to the southward. It is a mooted question by which route a vessel can get north at the earliest date; but I should recommend giving the preference to the west shore, and if that is found heavily blocked, then to lose no time in trying to force the ice, but follow the southern edge of the pack and attempt the eastern route, which will probably be found in that case comparatively open.

North of St. Lawrence island, the west side of Bering sea clears of ice much earlier than the east side, and vessels reaching Indian point find the ice broken into large floes around which they can work, outside of the shore ice, as far as East cape. The bay and shore ice break up at a much later date.

As seasons vary to a great extent, due to the prevailing winds, it is difficult to fix dates for the probable arrival of vessels at different places; but, as a general rule, steamers reach Indian point about May 25 to June 5, and St. Lawrence bay about June 10-25.

In 1882, the *Corwin*, after protracted westerly gales, reached St. Lawrence bay May 11, remained there a few hours and then returned south. Shortly after leaving, an easterly wind set the pack on again and closed the bay for six weeks. This shows that vessels which succeed in getting so far north at such an early date, only accomplish it under peculiarly favorable circumstances; and even then, at great risks, as the pack is not sufficiently broken up until the middle of June, in that vicinity, to enable vessels to proceed fearlessly.

The prevailing winds north of St. Lawrence island are southerly after April 15, and the pack breaks off at that time about 6 or 8 miles off shore. It comes in and moves off with the varying winds until June 15, when it breaks up and goes off to the northward.

The natives put their canoes in the water about May 15, showing that young ice has ceased to form. The shore ice and that in the bays breaks up and moves off from fifteen to twenty days after the pack disappears.

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In Norton sound the ice remains later, its time of departure varying with the strength and direction of the prevailing spring winds as much as three weeks on different seasons. Southerly and easterly winds clear the sound and westerly winds pile the ice in.

Young ice ceases to form in the vicinity of St. Michaels, May 1. The earliest arrival recorded at St. Michaels is May 25, 1875, when a schooner, commanded by an experienced man, reached that place. Captain M. A. Healy, U. S. R. M., reached St. Michaels during two successive seasons on June 5 and 8, and it is generally expected that vessels will arrive there June 10-15. The Alaska Commercial Company's steamers, which are not fitted for encountering ice, leave Ounalaska on their first northern trip about June 25, and reach St. Michaels safely, only encountering patches of drift ice, through which they can easily pick their way.

In 1880, which was a westerly season, the *Corwin* met heavy ice, June 11, in latitude $60^{\circ} 50' N.$, and, on July 9, when 16 miles from St. Michaels, was stopped by heavy ice, which cleared away a few days later.

The heavy ice between St. Lawrence and King's islands remains closely packed much longer than any other ice in Bering sea. It gradually melts and breaks up and sets north toward the straits at about 1 knot an hour, the last of it disappearing from July 5-15.

Fort Clarence being a good harbor, close to the straits and free from ocean swell, is the rendezvous for the vessels of the Pacific Steam Whaling Company's ships to meet the tender which supplies them with coal and provisions, and takes south the results of the spring catch. This bay, being well enclosed, clears of ice much later than the time of the departure of the pack along the shore. In 1885, the bark *Wanderer* anchored in Port Clarence June 25, which is the earliest date that it has been navigable for years. As a general rule, the tender to the whaling fleet arrives there, July 1-5, without encountering any heavy ice.

Spring movements of the ice in Bering straits.—The current through Bering straits sets north, and, when not influenced by prevailing winds, its rate is about 2 knots an hour. Protracted northerly gales, lasting a week or more, are sufficient to change its direction southerly, but upon the cessation of these winds it quickly sets north again. Strong southerly winds increase its rate to 3 knots. In the spring the current on the east side of the Diomedes is the strongest, but the west side of the straits, on account of the west shore being cleared by the northeast current to the southward, is the first to clear of ice, and is given the preference by vessels proceeding north.

In 1889, the *Thetis* passed between East cape and the Diomede islands without sighting any ice July 3, but on July 6 she met numerous patches of drift ice setting to the northward between cape Prince of Wales and the Diomedes. Although in 1880 the first vessels passed through the straits May 22, and in 1881 vessels had reached latitude 68° N. by May 31, these were exceptionally early seasons, the usual time at which vessels find the straits navigable being June 15-25. Unless it is an unusually late spring, vessels are sure to be through the straits by July 1, and, once through, the latitude of the Arctic circle is easily reached.

Spring movements of the ice in the Arctic ocean.—After passing through the straits the current on the east side takes a northeasterly direction, following the coast line and setting into Kotzebue sound; thence northwest, along the coast to point Hope, and around it, following the shore line up to point Barrow, where it goes off to the northeast. On the west side of the straits the current branches off to the northwest and follows the Siberian shore up past cape Serdze and and Koliutschin island, and thence off toward Herald island. The action of these currents is similar to that in the Bering sea, the pack breaking off first from the shore ice, at distances off shore varying from 2 to 10 miles, working off and on until it breaks up and goes north, followed later by the shore ice. Mention is sometimes made of an oval basin of open water, of varying extent, being found in the early spring, extending in a northwest and southeast direction on the Siberian side in the latitude of the Arctic circle. This probably exists every year, due to the retiring of the Arctic pack, the drift ice setting north from Bering sea being set off to the northeast and being insufficient in quantity to fill up both sides alike.

After passing through Bering straits the ice met is heavy, rough, hummocky ice, and vessels proceed cautiously, following the pack, and not getting between it and the shore ice if it can possibly be avoided. The pack moves north from both shores at about the same time, and cape Serdze is attainable, probably, a week before point Hope, which, as a rule, is reached by the first vessels bound north July 4.

Kotzebue sound, like all other enclosed bays, is blocked with ice later than the shore line to the northward of it, and its time of clearing depends upon the prevailing winds. A vessel, by following the shore line closely from cape Prince of Wales to cape Espenberg, working through the drift ice, which sets off shore, and through Bering straits, may reach the sound by July 5, and it is generally navigable July 10.

In 1880, which was a westerly season, the sound was blocked by ice July 12, while in 1881 at the same date, there was no ice to be seen

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there. As a general rule, heavy drift ice coming out of Kotzebue sound is found between cape Blossom and point Hope up to July 12. The current between these points runs rapidly, carrying the ice along at the rate of from 2 to 3 knots, and banking it closely together extending 10 miles off shore at point Hope after the pack has moved off from that vicinity.

In the vicinity of point Hope and cape Lisburne the pack breaks off about 3 miles from the shore, from April 5 to May 25, and moves off and closes in again with changing winds, gradually working off to the northward and westward. Young ice forms in the spaces thus left to about 5 inches in thickness, and gradually gets thinner until it disappears about May 15.

The time of departure of the shore ice varies greatly. In 1886 it moved off July 13, and in 1889, June 14.

By following the shore ice, natives make the trip from point Hope to cape Lisburne in canoes as early as June 1, but it is not safe for vessels to enter the lead thus made until the solid pack has moved to the northward.

Drift ice remains in sight until July 10-25.

As the prevailing spring winds are southerly, there is always more or less open water close inshore in the bight to the eastward of cape Lisburne after May 1.

On account of the contour of the shore line and the banking of the Kotzebue sound ice around point Hope, with prevailing southwest winds, vessels can break through the strip of drift ice off cape Lisburne and find an anchorage off cape Sabine before they can make the point Hope anchorage. Point Hope is the rendezvous of the New Bedford Whaling Fleet to meet the tender sent up with supplies. The leading vessels generally reach there July 4, and the tender arrives from July 5-10, without encountering very much ice.

Vessels have arrived at cape Lisburne as early as June 17, and then again have been until July 25 getting to point Hope; but these were exceptional cases, and probably illustrate the extreme cases of open and late seasons.

Whales are seen off point Hope as early as April 23, showing that ice-holes must be plentiful at that early date.

From cape Beanfort to point Barrow the pack moves gradually north, clearing from point to point. Vessels cannot attempt to force it, but follow closely, being cautious not to get between it and the shore ice. A shift of wind to the westward brings the pack in on shore when a few

hours before it was out of sight from the land. Off shore the pack moves to the northward more slowly.

The current setting along the Siberian shore changes to the northward and sets up toward Herald island at the rate of about 1 knot an hour, carrying the ice up in that direction, so that late in the fall it has formed a gap in the pack, extending about 30 miles north of Herald island, known as "the Hole." The result of this northerly current and the northeast current along the Alaska shore, combined with the prevailing summer southwest and southeast winds, is that the center of the pack in this Arctic basin moves slower than the sides, and, with the addition of drifting floes, a point of ice is formed, extending well to the southward. This point is found in from longitude 160° W. to 170° W., and is known as "Post-Office point," as it makes a natural meeting place for vessels cruising to the eastward and westward to communicate and exchange news. On very open seasons, with prevailing southwesterly winds, Post-Office point has been found as far to the eastward as longitude 157° W.

I have been unable to collect much data to determine the spring movements of the pack in the vicinity of Herald island. In 1881, which was an exceptionally open season to the westward, vessels were within sight of Herald island July 20, and on July 30 the *Corwin* landed men there, having passed considerable ice midway between there and cape Sabine. On August 12 of the same year she succeeded in forcing her way through very heavy floe ice and landed men on Wrangel island. In 1885, the *Corwin* met solid packed ice as far as the eye could reach, in latitude $69^{\circ} 32'$ N., longitude $174^{\circ} 15'$ W.

Following the coast north of Icy cape, vessels always have to take more or less risk. If the pack is not far off shore it is liable to shut in for several days at a time on the different capes, when vessels may anchor in the bights or moor to ground ice until the pack sets off shore again.

The dates of the probable arrival of vessels at different points vary greatly with different seasons. In 1879, about August 20, the fleet was stopped by the pack at Blossom shoals; a few vessels worked around, and about 15 miles into the bight to the eastward, but returned within a week.

On August 9, 1885, there was heavy drift ice on Icy cape, but vessels worked through it, and, on August 10, anchored at point Marsh. On August 14 of the same year the ice was packed in solid on point Franklin, but vessels then between cape Smyth and that point lay safely under the lee of ground ice, and succeeded in getting south by August 19, when

the pack moved off shore with a shift of wind and cleared the Sea Horse islands.

In 1881, the pack was in on Blossom shoals July 21, and on July 25 it was in sight from the shore 25 miles to the southward of Icy cape, and the "blink" was strong to the southwest. This was an average season.

In the vicinity of point Barrow, during the early spring, the pack breaks off from the flaw, or shore ice and moves off and on, young ice forming in the gap thus made until the middle of May. After the early part of June, when the pack moves off, it begins to take a northwest movement and continues to do so until it is gone. This movement, on and off of the pack, continues until about July 15, after which time heavily massed floe ice, much broken and closely jammed together, may be looked for. The shore ice leaves the beach July 15-25, but remains in sight until the middle of August, or perhaps all summer. On exceptional seasons the pack remains on the point all the year around. In 1879 and 1886, point Barrow was shut in.

In 1888, the steamer *Orea* reached the point July 4, which was the earliest arrival on record.

In 1880, the pack was only 4 miles off the point August 25, when the first vessels arrived there. These are about the extreme dates of vessels arriving during seasons when the point is open, the average date of arrival being August 10-12.

To the eastward of point Barrow the conditions of the ice are very uncertain, and it is advisable for all vessels going out of sight of point Barrow to be prepared to spend at least one winter in the Arctic. When the pack moves off shore it does not proceed very far, and the shore and drift ice is found extending from its edge well in shore.

The currents from the rivers clear the bays of drifting ice, and strong winds from west to northeast, by way of south, clear the pack from the different points.

Winds from west to northeast, by way of north, bring the heavy floe and pack ice down on the points, and vessels so shut in are very liable to be imprisoned, especially should young ice set in before the southerly winds arise.

The current running along the west shore of Alaska sets off north-east from point Barrow, and to the eastward of that the movements of the ice are due entirely to winds, river currents and "witch currents."

These "witch currents," which is the name given them by the whalers, seem to be peculiar to this locality. Some mention them as existing in the neighborhood of Port Clarence, but I believe these to be only

counter tidal currents. "Witch currents" are visible on the surface of the water as swirls and eddies, and are shifting and disappearing. Vessels in close proximity will be moved by these currents in different directions at the rate of 3 or 4 knots.

When the *Thetis* was moored to the ice off Lion reef, large floes of ice, within a radius of half a mile, were observed moving in three different directions, and were apparently uninfluenced by the wind, their motion being entirely due to strong local currents. At another time, to illustrate the danger attached to these currents, when moored to ground ice and riding head to wind, with the drift ice setting by on either side and astern, a large floe, under the influence of a "witch current," moved rapidly at right angles to the general ice movement, and swung in around the stern of this vessel before she could be gotten out of the way, completely enclosing her in heavy ice. She was worked clear in an hour and a half; but had young ice been forming at the time, the situation would have been attended with considerable danger.

Vessels have never been far enough off shore to ascertain if these "witch currents" are peculiar to shoal water only, but they are probably due to the changeable currents made by the eddies and counter currents in the wake of large bodies of ground and perhaps moving ice.

The winds to the eastward are generally local, and even when strong are limited in extent; and vessels well to the eastward have no way whatever of telling the condition of the ice to the westward of them. Those who are drawing enough to push on to the eastward, run considerable risk, being guided to some extent by the amount of northerly winds they experience, of finding the different points closed by ice upon their return. The local winds affect the ice very rapidly.

On the evening of August 10, 1889, the *Thetis* moored to ground ice off Cross island, the drift ice having a perceptible movement to the westward. During the night a strong westerly wind sprang up, and by the next noon the ice was setting in heavy masses to the eastward at the rate of from 2 to 3 knots.

Again, after being shut in off Cooper's island from August 19 to 24, by the main pack, which had shut down on point Barrow, thirty-six hours of light breezes from ENE. to SE. moved the ice off shore and opened a lead to point Barrow, so that vessels leaving Manning point four days later than this ship, arrived twelve hours later at point Barrow without being forced to ram the ice at all.

A glance at the chart shows that Tangent point, cape Halket, Lion reef and Martin point are the principal projecting points of the coast,

and these are the points where the pack is found resting. If they are found clear, a vessel can proceed, finding the ice well broken and scattered along the bays in from 5 to 8 fathoms of water.

By following this course the *Thetis*, in 1889, reached Mackenzie bay August 15, finding heavy floe ice off point Tangent, and later the pack; closely packed rotten ice off cape Halket; the pack about 4 miles off Lion reef, and about the same distance off Martin point.

In the bays, the "shore" and "floe" ice were found in greater or less quantities close inshore, except in the lagoons, until to the eastward of Herschel island.

It is not prudent for sailing vessels to go at all to the eastward of point Barrow, but when the ice is well open they venture as far as Tangent point.

An exceptionally open season occurred in 1878, when the sailing fleet all reached Camden bay.

The steam whalers go as far as the ice will allow them, their objective point being the mouth of the Mackenzie river. As a general rule, they do not get farther than Return reef, and in 1888 succeeded in reaching Manning point. In 1889, which was an exceptionally open season, they went as far as Shingle point, Mackenzie bay, which is the first time this has been accomplished since 1850, when McClure and Collinson were searching for traces of Sir John Franklin.

In 1887, the ice was only open for two days from Camden bay to the Mackenzie river sufficiently to permit canoes to travel.

To the eastward of Herschel island clear water is found across Mackenzie bay. The current from the river holds the pack off, and all the ice in that vicinity is new ice formed every fall. This ice commences to break about May 20, and by June 1 it begins to thaw and the rivers commence running.

The pack breaks off from June 5-15, and the shore ice leaves July 1. Northerly winds may hold it in sight of the land for a few days, but by July 15 it is out of sight. This occurs every summer, and the line of demarcation between clear water and drift ice, bearing to the northward of Herschel island, is very pronounced. The natives report that this clear water extends off shore every summer 50 or 60 miles to the eastward of the Mackenzie river.

At Herschel island there is a perceptible tidal flow, the marks on the beach indicating a rise and fall of from 2 to 3 feet.

From July 15 until September 1, Mackenzie bay is clear of ice, then young ice forms, gradually increasing in thickness, and breaking up and

moving off with variable winds. By September 20, it forms to 2 or 3 inches in thickness, and by October 1-5 everything is frozen solid for the winter.

Northern limit of southern edge of the pack.—During the latter part of August and the beginning of September the southern edge of the pack reaches its northern limit, the sea to the southward being clear of ice, excepting occasional small drifting floes. The general line of the pack is from point Barrow, on the east side, to cape North, on the west side, and is very irregular between these points, varying greatly during different seasons.

The annexed tracing shows the edge of the pack as found for the last five years and for 1879. From it we see that the northern limit of the "Hole" in the vicinity of Herald island is, approximately, the same, while to the eastward different seasons vary as much as 150 miles in latitude. In 1879, Icy cape was the northern limit of the eastern end, and, this being a very closed season, the pack was little broken; 1886 shows an open season, and 1888 is a good example of the irregular line of the pack. Post-Office point is found varying in longitude from 163° W. to 168 W., and in latitude from 70° 55' N. to 71° 30' N. It shifts its position during the same season.

Fall movements of the ice in the Arctic ocean.—Young ice forms earlier to the eastward than to the westward, and to the eastward can be seen as early as August 15, making in a thin skim between broken and floe ice on calm nights and disappearing in the daytime. By September 1, it forms to an inch in thickness, and after September 20, it forms rapidly.

The prevailing winds are northerly after the first week in September, and soon bring the pack down to the eastward of point Barrow. As soon as this fall movement commences vessels should proceed to the westward of the point at once. As a general rule, the steamers return to point Barrow by September 10. In 1888, which was a very open year, the steamer *Orea* came out from the eastward September 20, but this was unusually late, the latest on record.

Sailing vessels cruising along the ice pack generally leave point Barrow for the westward August 15-25, and steamers September 10.

In the vicinity of point Barrow young ice begins to form around heavy ice September 15, and by September 22 it forms in open water, making rapidly along the beach after September 25. By this time the pack moves close inshore, scattering ice being found along the beach

about September 10. The young ice makes out to the pack September 30, and then the ice is in for the winter.

From October 1 until December 1, the pack is continually coming in and moving off, from 1 mile to out of sight. Young ice forms in the space thus made, which grinds and piles on the beach upon the return of the pack. After December 1, the ice makes fast to the bottom and stops grinding on the beach; a solid, stationary mass, which is termed the "flaw," extending from 4 to 8 miles off shore. On the edge of this flaw the pack continues to grind and pile, at intervals all winter, being set in by northwest gales, and off by northeast gales. During these offsets it moves from 1 mile to out of sight, and remains open from one to fifteen days, according to the duration of the prevailing gales. When these movements occur the pack goes in a body with the current. The current in the winter sets, as it does in summer, to the northward during southerly and easterly winds, and to the southward with northerly and westerly winds, except that it changes oftener, generally running three days each way, there seldom being forty-eight consecutive hours without any current.

The pack shuts down on Icy cape by November 1, and after that time there is no open water between point Barrow and Icy cape, except when the flaw opens. During closed seasons these times may vary, but the above dates indicate the average season.

I may here mention a peculiar case of drift, which occurred in the winter of 1888-'89, which illustrates how the pack in this vicinity is constantly in motion all winter, and what different directions it takes. On August 3, 1888, during a heavy southwest gale at point Barrow, the bark *Young Phoenix* lost her rudder and anchors and drifted off into the pack and was abandoned. She was set off to the eastward and was last seen that fall 35 miles to the northward and eastward of Return reef September 11. She was next sighted and boarded on July 9, 1889, about 8 miles to the southward of cape Smyth, being found firmly fixed in the middle of a floe 2 miles in diameter. From there she was set off and disappeared to the northward and westward. What her track was during the winter is a subject of conjecture.

Off shore and to the westward, in the vicinity of Herald island and Herald shoal, the movements of the pack to the southward are very uncertain after September 20, and are due altogether to the winds. Strong northeast winds produce a current to the southwest which carries the pack to the southward, and the loose ice to the southwest, where it is set south along the edge of the western pack. Strong north-

west winds carry the floe ice towards the straits, closing on both shores about alike.

Young ice commences to form to a thickness of an inch or more during the last week in September, and it is not safe for a vessel to be north of Herald shoal after October 1. After that date, arms of the pack are liable to swing together and imprison a vessel; or loose floe ice, which was navigable during the day, will become so firmly fixed with young ice in a single night as to render it unnavigable even for steamers.

Instances of these kinds occurred in 1888 and 1879. In the former case (see tracing), thirteen vessels were cruising in the vicinity of Herald island until September 27, 1888, when being warned by the "ice blink" that the pack was closing to the southward, they proceeded south through a narrow gap, and found that they were shut in, what they had thought to be clear water to the southward only proving to be another hole. The ice was heavy floe ice, frozen together by young ice, and would have been impenetrable had not an unusual event occurred for that season of the year, in the shape of a southerly gale, which broke it up. This was followed almost immediately by a strong northwest gale, and selecting the weakest point of the pack, the vessels managed, by carrying on sail, to force their way out in the latitude of Herald shoal, longitude 175° W., on September 30. The tracing shows that the arm of the pack, which was found extending to the southward September 13, must have swung to the westward with northeast winds, and joining with the western pack, formed a double hole, enclosing the vessels.

The other case in which vessels were shut in, in this vicinity, was in 1879. The barks *M. Wollaston* and *Vigilant* were last seen to the northward and eastward of Herald island October 10, and were carried off in the pack, all hands being lost. Whether they were shut in by the pack or by young ice is unknown.

After September 26, young ice forms rapidly near Herald shoal, and after October 1-5, during calm nights or light northerly winds, it forms in thickness of from 1 to 6 inches in a single night. Being tempted by a scarcity of large ice during some seasons to remain in that vicinity a little later, vessels sometimes remain as late as October 10, or even later, but at times with disastrous results.

An instance of this occurred in 1879, when, on the night of October 18, the barks *Mercury* and *Helen Mar*, having worked clear of floe ice into open water, were shut in by young ice; it formed so rapidly that after it had been decided to abandon the weaker vessel, loads of a ton weight was dragged over the ice by parties of fifteen men, and the

Helen Mar only succeeded in getting through the straits, November 1, by carrying royals during a close reef gale, and driving through the quickly forming ice at the rate of 1 knot per hour.

These instances show that young ice is more dangerous in the late fall than the movements of the solid pack, and the limit of safety for vessels cruising in this vicinity is October 1, at Herald shoal. After that time they should work steadily to the southward.

A vessel once caught in the pack in this vicinity is carried off to the northward and westward, and it is only a question of time when she will be broken up and sunk by the working and grinding of the ice.

In longitude 170° W., the main pack seldom comes in a body below latitude 69° N., but vessels coming south in the late fall usually encounter heavy flow ice between cape Serdze, on the Siberian shore, and point Hope, on the Alaska shore. The northeasterly and northerly winds drive the loose floe ice from the edge of the pack along the western pack and down on the Siberian shore. Here it takes a turn to the southeast and follows the shore, in a southeasterly current thus made, until it reaches cape Serdze, where it is deflected off to the eastward toward point Hope, where the current turns it to the northward.

This accumulation continues increasing during the fall until young ice gets too heavy to allow the floe ice to be influenced by the wind. It banks heavily on the Siberian shore, and when met by vessels bound to the southward, is only avoided by working to the eastward, vessels sometimes having to pass very close to point Hope, and, in a few cases, well in toward Kotzebue sound, to pass around and get to the southward of it.

Vessels bound south from Herald shoal, steer to make a landfall at cape Lisburne or point Hope, in order to set a course for the straits and make use of soundings, and by so doing they generally avoid this accumulation of heavy ice. Strong northerly gales drive this loose ice down in the vicinity of the straits, northeasterly gales banking the west side, and northwesterly gales both sides alike.

In the vicinity of cape Sabine, young ice commences to make October 10-20. It moves off and on with southerly and northerly winds, the current rapidly changing its direction with shifting gales, until the early part of January, when it becomes fixed to the shore and remains so until it breaks up in the spring.

At point Hope the ice forms in the lagoons about September 25, but young ice in the ocean is as late forming as October 12, being heavy by October 25.

All the ice in this vicinity, in sight from the shore, is made up of young ice, which telescopes and piles until it forms heavy floes, the gaps freezing over with young ice and forming heavy pack ice by early spring. Occasionally a few scattering floes of old ice are drifted into this vicinity and held by the young ice, but as a rule it is all new ice.

Under the cliffs between cape Lisburne and point Hope, temperate springs exist which cut away the sea ice and keep a place of open water all winter.

Kotzebue sound freezes over and is closed to navigation by October 10-15.

Fall movements of the ice in Bering straits.—The regular set of the current in Bering straits in the fall is northerly, being stronger on the east side; but, the prevailing gales at this season being northerly, a change in the direction of the current to the southward is more common than in the spring. Northwest gales drive the loose ice down into the straits on both sides alike, but vessels leaving Herald shoal October 1, after passing the ice between cape Serdze and point Hope, seldom find enough heavy ice in the straits to retard their progress south. More ice is found on the east than the west side, but the east side is preferred on account of the contour of the bottom being better suited for soundings in thick weather.

An instance of the strong southerly current which is found existing in the straits after a protracted northwest gale is given by a whaling captain. While running from cape Serdze to make the Diomedes, he raised King's island instead; thinking it was the Diomedes, he swung off to the southward, and, when he had run up his distance for King's island, found himself off northeast cape of St. Lawrence island. This instance shows, conclusively, a southeast current on the Siberian coast and a southerly current in the straits.

All vessels, steamers or sailing vessels, should be out of the Arctic by October 10. Cases have occurred in late seasons where vessels have voluntarily been as late as October 23 passing through the straits; or, in the case of the *Helen Mar*, in 1879, until November 1, at which time she forced her way through rapidly forming ice with great difficulty; but October 10 is as late as safety will permit of a vessel being north of Bering sea. After that time the ice forms and banks in the straits rapidly, alternately being solid across and then breaking up in leads and holes.

During these periods of solid ice the natives communicate across it from cape Prince of Wales to East cape. Such trips are always accom-

panied with much danger, but are accomplished by the Prince of Wales natives making a forced march to the "Little" Diomedé, where they meet the natives of the "Big" Diomedé, who have in turn been visited by the natives from East cape. These trips are made annually.

Fall movements of the ice in Bering sea.—In the northern part of Bering sea young ice commences to form in small quantities in the bays and along the shore, about October 15, as far south as Indian point. In St. Lawrence bay, after October 25, when the northerly winds prevail, it forms quite solid along the shore, while it still remains not solid enough to travel on in deep water. In 1881 it remained in this condition until November 31, too heavy to work a boat through, but too light to travel on, when in one night it froze solid. Very few pieces of old ice are seen, the whole formation being young ice which piles into heavy masses.

December 1, the ice is solid for the winter, the pack breaking off from 6 to 8 miles off shore, with shifting winds, until the spring southerly winds start it north. When the pack comes in at these times it forces the ice up 20 and 30 feet, forming hummocks of heavy ice. Off shore young ice, of sufficient thickness to impede and perhaps prevent a steamer's progress, forms from November 1-15, and at St. Lawrence island November 25.

On the east side of Bering sea, in Norton sound, and in the vicinity of St. Michaels, young ice forms in small quantities October 12-18, and by October 25-28 is strong enough to travel on. It forms for a "full duc" for the winter between November 1-10, and St. Michaels is considered closed to navigation for the winter after October 15.

All the ice found in Norton sound is made up of young ice, which forms every fall and entirely disappears during the following summer.

The ice continues to form, extending farther and farther to the southward, breaking up, piling, and telescoping with variable winds and currents, and so forms the Bering sea pack, which has its limit, as a solid mass, a little to the southward of St. Matthew island. To the southward of that, the ice found consists of detached floes, which are driven off from the mouths of the rivers on the Alaska side.

At Pribyleff islands it takes fully three weeks of northeasterly winds to drive the ice down on the islands, a northwest wind being unaccompanied by ice. This ice is looked for during the latter part of December or early January, and is continually in motion, with variable winds, being much broken up.

Some years the islands are free of ice.

The farthest south the ice has ever been known to extend is Akoutan pass, and this occurred about January 15, 1878, when it only remained a few days.

In order to illustrate the comparative danger of the ice in the different localities, I give the following list of casualties which have occurred from the ice during the last ten years, which list was furnished me by Mr. J. W. Kelly. From it we see that the great majority of casualties have occurred in the fall, by reason of the vessels endeavoring to remain too long in the Arctic before starting to the southward.

BERING SEA (SPRING).

1882: Bark *Suppho* stove and sunk off cape Navarin.

1885: April 15, bark *Rainbow* stove and sunk off cape Navarin. May 5, bark *Napoleon* stove and sunk off cape Navarin. May 25, bark *Gazelle* stove and sunk to the southward of St. Lawrence island, attempting to ride out a gale between two ice floes. Bark *Eliza* stove off St. Lawrence island and repaired. Bark *Dawn* stove off St. Lawrence island and repaired.

1886: Bark *John Carver* stove and sunk. Schooner *Page* stove, condemned and sent to San Francisco.

1889: Bark *Ladoga* stove off cape Navarin and sent to San Francisco. Bark *Ohio* (2d) stove and sunk off Nuvivak island.

ARCTIC OCEAN (SUMMER).

1881: *Daniel Webster* crashed 5 miles south of point Barrow, between pack and shore ice, while pushing ahead of the whaling fleet.

1882: Steamer *North Star* crushed between the pack and flaw, in sight of and to the southward of Cape Smyth station.

1883: Bark *John Howland*, stove off point Lay, was abandoned and set on fire at point Hope.

1884: Steamer *Bowheal* crushed between two floes between Icy cape and point Belcher. No fires lighted.

1887: Bark *Mary and Susan*, stove off cape Lisburne, repaired. Bark *Hunter*, stove off Icy cape, repaired.

ARCTIC OCEAN (FALL).

1871: Thirty-one vessels shut in and abandoned off point Belcher.

1876: Thirteen vessels caught of Sea Horse islands, were drifted to the northward and eastward of point Barrow and were abandoned.

1879: Barks *Mt. Wollaston* and *Vigilant* carried off in the pack to the northward and eastward of Herald island; were last seen October

15. Bark *Mercury* frozen in and abandoned off Herald shoal October 18. Barks *Mabel* and *Eliza* shut in off point Belcher September 15. The *Mabel* was abandoned, the *Eliza's* crew divided on both ships, a norther broke up the ice, and they brought out both ships.

1883: Bark *Abraham Barker* lost her rudder by being forced ashore by the pack on point Barrow. Bark *Mary and Susan* stove and abandoned off Herald island.

1885: Schooner *Clara Light*, September 14, while being towed from point Barrow by steamer *Alliance*, was cut down and sunk by young ice.

1888: Barks *Fleetwing*, *Young Phoenix* and *Mary and Susan* wrecked on the bar and in the ice at point Barrow in a gale August 5, and abandoned. Schooner *Jane Gray* lost anchors and stove by the ice in gale off point Barrow, August 5; drifted 60 miles to northward and eastward of the point, and was found capsized by U. S. S. *Thetis*; raised and repaired. Schooner *Ino* driven ashore by gale and ice at cape Smyth.

BERING SEA (FALL).

1885: Bark *Amethyst* missing; supposed to have been seen from Pribyloff islands. A vessel is reported to have been sighted from cape Lisburne in young ice October 18.

This list does not contain all the wrecks which have taken place in these waters, but simply those which have been caused by the ice alone.

The compass directions of currents, winds, bearings, &c., given in this report are magnetic.

In my opinion, all vessels entering the Arctic ocean and working the ice for a season, should be provisioned and prepared to spend at least one winter there, on account of the uncertainty of ice navigation.

In concluding this report, I can only state that the dates given are as close approximations as I could make, as different seasons vary greatly. In fact, the only point I have had no difficulty in obtaining a general agreement on from all parties interviewed is the fact that "No two seasons are alike in the Arctic."

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