CONSIDERATIONS ON THE MIGRATION OF THE LEATHERBACK TURTLE, *DERMOCHELYS CORIACEA* (L.), IN THE JAPANESE AND ADJACENT WATERS[1)]

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With 3 Text-figures

The leatherback turtle, *Dermochelys coriacea* (L.), is indeed a peculiar species among the living members of the order Chelonia. Not only it attains the greatest size, but it lacks the bony carapace intimately united with vertebrae and ribs that is commonly seen in other chelonians. The animal has been adapted, it is considered, to the pelagic life in the sea for a much longer time of phylogenetic evolution and more perfectly than other species of sea turtles, and consequently its bony plates have been markedly reduced (VÖLKER 1914). Owing to this peculiarity in carapace structure, a classification system was once widely circulated, in which the present species constituted, together with a few of its extinct ancestral forms, the suborder Athecae against the Thecophora including all other kinds of turtles and tortoises.

The leatherback turtle is widely distributed in tropical and subtropical seas throughout the world, and is occasionally transported to temperate regions by ocean currents. In tropical and subtropical seas, the species is said to be but rarely seen as compared with other sea turtles such as the loggerhead, *Caretta*, the green turtle, *Chelonia*, and the hawksbill, *Eretmochelys*. This seems, however, to be a superficial phenomenon. Since the leatherback prefers offshore waters to shallow bays or lagoons, there may be less opportunity of observing it (SMITH 1954). If this is true, the leatherback is expected to have more chance to be carried to higher latitudes by offshore-flowing ocean currents. In fact, there are as seen later a considerable number of records of occurrences of this species along the coasts of the Japanese Islands which are mostly situated in the temperate region and are washed by two strong warm currents, namely the Kuroshio originated in the tropical seas and its branch, the Tsushima current.

From an oceanographic point of view, the leatherback turtle may be

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considered as a living drift-bottle being carried by warm currents, and analyses of records of its occurrences will be helpful to clear out the processes of transportation and transformation of the tropical and subtropical surface water masses containing the population of the leatherback turtle within them.

In these years, I have been trying to gather records of occurrences of this sea turtle in the Japanese and adjacent waters as many as possible and have just published the list of all of them (NISHIMURA 1964). On these data, it is intended in the present paper to trace the migration patterns of this tropical animal in the temperate waters around Japan. I wish to acknowledge my indebtedness to Dr. Takasi TOKIOKA of the Seto Marine Biological Laboratory for his kindness in reading and improving the manuscript.

Occurrences of the turtle in respective areas and seasons

In Text-fig. 1 are shown the places of capture of the leatherback; they extend from the southernmost district of Japan northward to the central Maritime coast of Russia and the northwestern and northeastern coasts of Hokkaido Island. As the diversity found in the seasons of occurrences of this animal in different regions is considered to be of a great significance, the frequency of occurrences in respective geographical subdivisions and months is shown in Table 1, and the season or seasons of the most frequent occurrences are put for each subdivision in Text-fig. 1.

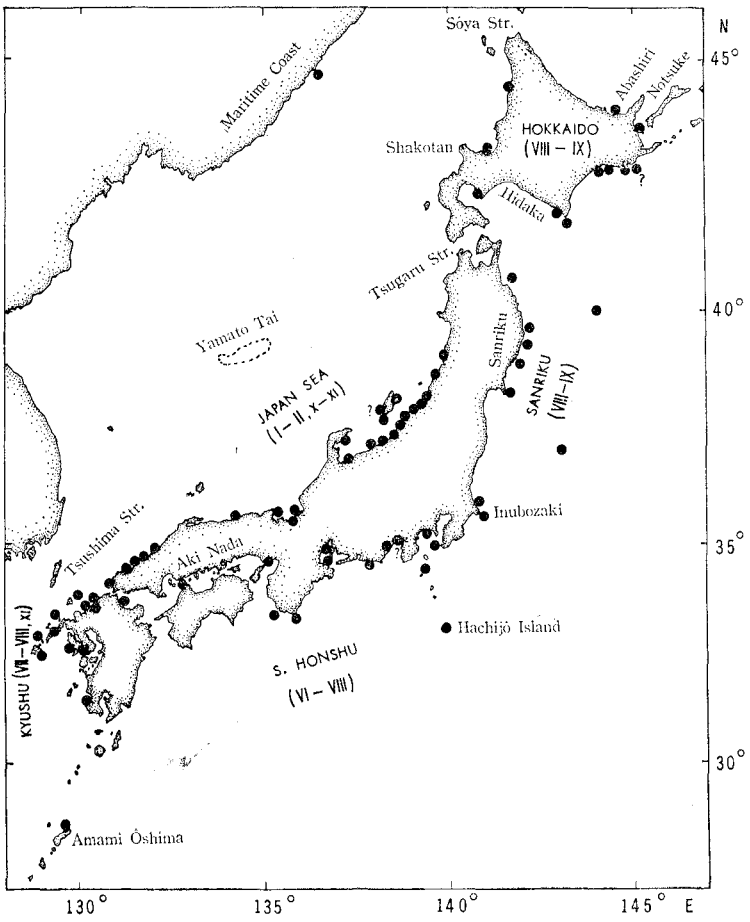
Table 1. Frequency of occurrences of the leatherback turtle in respective months and geographical subdivisions in the Japanese waters (1614–1963).

	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Kyushu	—	—	2	2	1	1	3	1	—	—	1	—
Japan Sea coast of: Southern Honshu	—	—	—	—	—	1	1	1	—	—	—	—
Japan Sea coast of: Northern Honshu	—	—	—	—	1	1	1	—	6	6*	—	—
Hokkaido	—	—	1	5*	2	1	—	—	—	—	—	—
Sanriku	—	—	—	>4	1	—	1§	—	—	—	—	—
Pacific coast of Southern Honshu	1**	4	2†	2	1	1	—	—	—	—	1‡	—

* Including respectively a doubtful record with uncertain identification.
** Identification doubtful.
§ This record was made at a point 110 nautical miles southeast of Kinkazan.
† An occurrence was recorded from the western part, Aki Nada, of the Inland Sea of Seto.
‡ This record was made at Hachijô Island.

It is easily seen from this figure that the occurrence of the leatherback is almost confined to the summer season, June to September, along the Pacific coast of Honshu Island and on the whole coasts of Hokkaido. This pattern

of occurrences appears quite natural for this animal of a tropical epipelagic life that may extend its northern limit of distribution to the farthest during the warmer season of the year. It is therefore quite noticeable that, along the Japan Sea side of Honshu, particularly of the northern wing of this arcuate island, the greater part of the leatherback records are obtained during the



Text-fig. 1. Geographical distribution of the records of occurrences of the leatherback turtle in the Japanese waters.

The records with uncertain identification are noted by a question mark. The Roman numerals in parentheses indicate the months of the peak of occurrences in respective regions, and the smaller Roman numerals used for the Japan Sea and Kyushu regions denote the months of the smaller peak of occurrences.

term from January through February, when the surface water is chilled intensively. At a glance, this fact seems to be decidedly surprising; during the period in question the temperature of coastal waters at these localities is

lowered to the annual minimum which is less than the annual maximum by more than 15°C! Apparently, this seems to contradict the fact that the leatherback is a tropical animal. Another small peak of occurrences may be discernible in October to November for the region mentioned above. In the neighboring waters of western Kyushu, two peaks of occurrences are likewise recognized, one in summer, July to August, and the other in early winter, November. The single record from the central Maritime coast of Russia was made in summer (TARANETZ 1938).

The seasonal and geographical patterns of occurrences of the leatherback in the Japanese waters mentioned above are hardly understood, if we consider, as many biologists used to do, the seasonal variation of water temperature alone to be the most effective factor governing the distribution of the animal. To interpret the distribution of this animal appropriately, we have to seek some other factor or factors to explain the above-mentioned contradiction. What are then such factor or factors? It seems to me that the aspects of flowing or drifting of water masses in different seasons are the most significant factor to be considered, since the leatherback turtle is particularly adapted for oceanic life and its distribution and migration are considered to be strongly influenced by ocean currents. Upon this standpoint, I am going to propose here two possible hypothetical explanations for so confusing aspects of the occurrences of this tropical animal in the Japanese waters. It is left for future studies to determine which of the two explanations reaches nearer the truth.

Hypotheses for the migration pattern

Since it seems impossible that the leatherback turtle breeds on the main islands of Japan, the individuals captured or observed in the neighboring waters must have all been carried from their native waters in tropical seas by north-flowing warm currents. The leatherback turtle populations transported in this way may appear first off the Pacific coast of central to south Honshu and the west coast of Kyushu in early to middle summer, from June or July to August; the peak or the larger peak of occurrences in these districts (Text-fig. 1) may be shown by this initial approach of the turtle populations to the Japanese waters. The approach may doubtlessly be facilitated by the southeast monsoon prevailing in these months. It may be of interest in this connection to note that an occurrence was recorded at Amami-Ôshima, an island situated to the south of Kyushu, in June, 1956, of an individual which landed for spawning (personal communication from Mr. Kiyoshi ÔYA of the Chôshi Aquarium dated on May 12, 1960).

Consulting the general flow pattern of the warm currents (Text-fig. 3), it is supposed that a population of the leatherback is carried northward by the Kuroshio anlong the Pacific coast of Honshu up to a little beyond the Cape Inubôzaki (36°N Lat.) and then driven eastward far away into the central

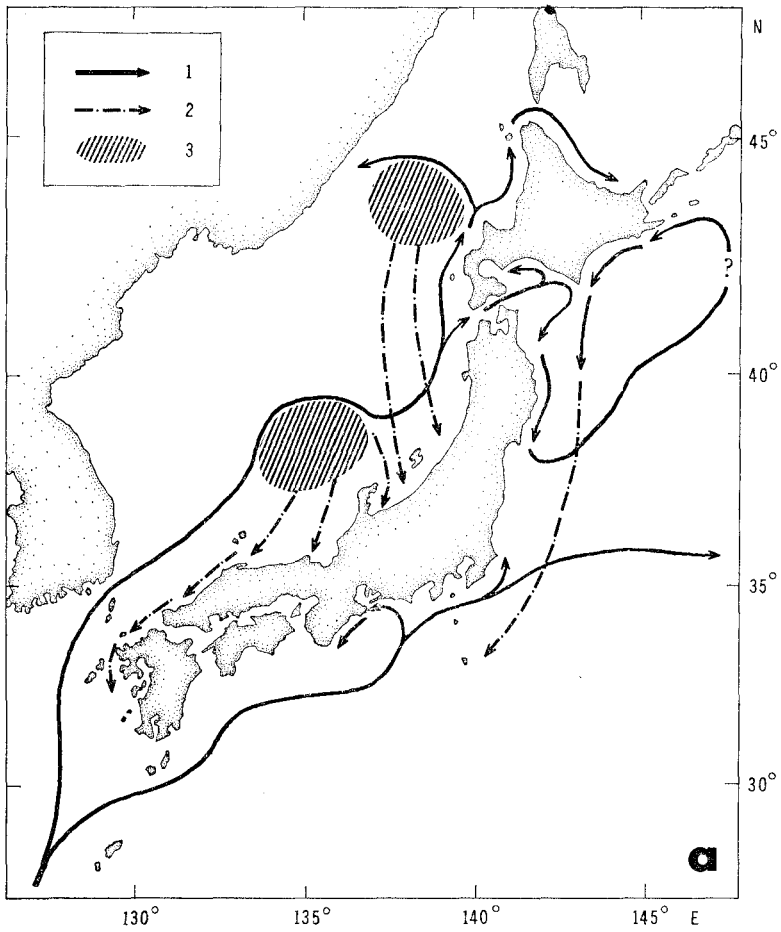
portion of the Pacific along the Kuroshio Extension. On the other hand, another population entered the Japan Sea through the Tsushima Straits will be carried adrift far off the coast by the offshore stream of the Tsushima current and therefore hardly discovered by coastal fishermen or inhabitants. This can be the reason for the complete lack of occurrences during the summer season along the Japan Sea coast of Honshu. It is well known that the Tsushima current issues three or, boldly speaking, two branches just after it enters the Japan Sea; they are all flowing roughly northeast, more or less making prominent meandering detours at certain areas on the way, which are particularly well developed along the offshore branch of the current (FUKUOKA 1957; SHIMOMURA & MIYATA 1957), and near the western entrance to the Tsugaru Straits they converge abruptly, draw near the Honshu coast and then the bulk of the water flows out to the Pacific through the straits (UDA 1934; KAJIURA et al. 1958; YASUI & HATA 1960). The water moved to the Pacific flows first eastwards and then turns to the south along the Sanriku coast; this is called the Tsugaru current (Text-fig. 3).

It is strange that the turtles are caught in Hokkaido and Sanriku districts (and on the Maritime coast of Russia, too) almost exclusively in summer, namely a few or several months earlier than the frequent occurrences on the Japan Sea coast of Honshu. The turtles are supposed to be brought to those districts from the neighboring seas through the intermediary of the peripheral streams of the Tsushima current. And there may be suspected two possibilities to interpret such early occurrences in the northern waters.

One idea is that (Text-fig. 2a) the turtles are transported there quite rapidly passing through the Japan Sea on the swift main stream of the offshore branch of the Tsushima current. It had generally been believed that the velocity of the Tsushima current is 0.5 to 1 knot; but recent hydrographic observations discovered the existence, in the offshore main stream or the polar frontal zone, of a narrow but very swift flow with a velocity of up to 2 knots (Maritime Safety Agency, Japan 1950; MASUZAWA 1958). Results of the drift-bottle experiments made by KASAHARA (1958) in the northern Japan Sea show that even those motionless bottles travelled occasionally over a considerable distance at the drift speed attaining more than 1 knot and that sometimes a great part of the bottles released from a certain spot at the same time were recollected at an amazingly distant place within a limited time. These seem to suggest the existence of a rather narrow, non-dispersed belt of very swift streaming in the sea, just like the jet stream in the atmosphere. Thus, it is possible that if the leatherbacks take advantage of this swift stream they will be able to trepass the Japan Sea within a month*, and that they

* The whole course along the meandering main stream from the Tsushima Straits to the Tsugaru Straits measures about 850 nautical miles.

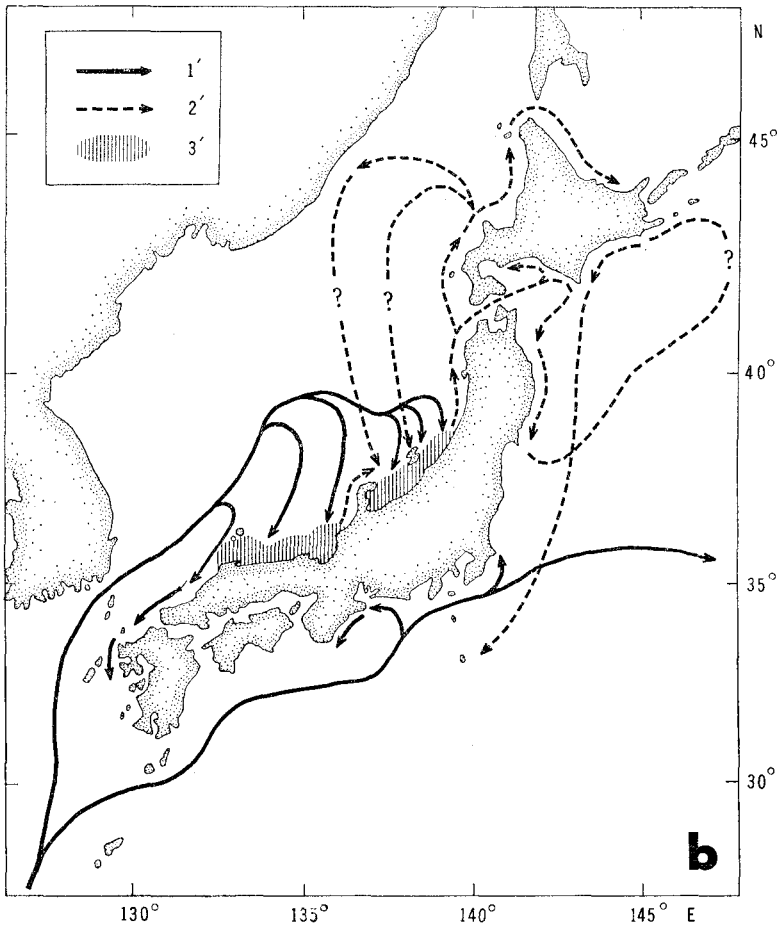
may reach the west entrance to the Tsugaru Straits by the end of July or August after they entered this sea in the early summer. A part of them would go through the straits and possibly in no time appear off the southeastern coast of Hokkaido and the Pacific coast of Sanriku district. They would first be carried by the Tsugaru current to the coast of Hidaka district of Hokkaido and then the Sanriku coast of Honshu, but later around off Kinkazan (38°15′N Lat.) they would turn the course offshore probably along the Oyashio front (KAWAI 1955) or the terminal strong stream of the Tsugaru current to the



Text-fig. 2. Illustrations explaining the two hypotheses for the migration pattern of the leatherback turtle in the neighboring waters of Japan.
In the first hypothesis (**a**), the turtle is assumed to reach every part of the entire Japanese waters within the year of immigration; while in the last hypothesis (**b**), the animal is assumed to pass the winter in the Japanese waters and continue its northward migration next year. (*Continued to the opposite page*)

northeast (Text-fig. 3). A part of the leatherbacks thus transported far in the northwestern North Pacific would come back again to the southeastern waters of Hokkaido possibly taking advantage of the south-flowing current of a gyre always located off the middle Kurile Islands (SUGIURA 1958).

On the other hand, the population of the leatherback remaining in the Japan Sea would continue drifting northward along the west coast of Hokkaido and eventually penetrate into the Okhotsk Sea through the Sôya or La Pérouse Straits, riding on the Sôya current (Text-fig. 3), as fas as off Abashiri and



1.–Probable migration routes followed by the animal during the season from early summer to autumn; 2.–The same during the season from autumn to winter of the same year; 3.–Supposed retaining area; 1′.–Probable migration routes taken by the animal in the first year (early summer to late autumn) of immigration to the Japanese waters; 2′.–The same in the second year (spring or early summer to winter); 3′.–Wintering area. For further explanation see the text.

Notsuke Channel in the easternmost part of Hokkaido Island (Text-fig. 1). At these localities, the leatherbacks were caught in middle September and in middle October, respectively. Around Shakotan Peninsula on the west coast of the same island, the warm current issues a flow to the west (Text-fig. 3; Maritime Safety Agency, Japan 1951), and the turtles might drift along this westward current and then reach the Maritime coast of Siberia without any great difficulties.

As mentioned previously, the Tsushima current meanders intensively at certian places in the Japan Sea, where remarkable convergence or divergence can be observed. Some leatherbacks, it is supposed, may be trapped and enclosed in gyres formed in that way on their way of drifting northward.

From about the middle of October onwards, the cold northwest monsoon begins to blow from the continent and icreases its strength with time. This monsoon is distinguished for its frequent attacks and severity lasting throughout the whole winter (TAKAHASHI 1955), and the Japan Sea is exposed directly to its rage. It is doubtless that there may be rapidly generated in the upper layer of the sea prominent drift-currents toward the south to southwest by the stress of this icy, violent and lasting wind. As such drift-currents become prevailing, the surface stream pattern in the Japan Sea must be quite altered. Offshore gyres will disappear and leatherbacks retained there will be released and driven to south or southwest by the above-mentioned drift-currents eventually to arrive at the west coasts of Honshu and Kyushu (Text-fig. 2a). While, the leatherbacks adrift in the Pacific waters must be carried southward after late autumn by the prevailing Oyashio current, and possibly by the drift-currents induced by monsoon, too, much more offshore the northeastern Honshu as far as to Hachijô Island, around which island a leatherback was caught in March (Text-fig. 1).

For the presence of two peaks of occurrences along the Japan Sea coast of Honshu as a whole, it is possible to assume that there are two gyres in the present marginal sea, one in the southern while the other in the northern portion (Text-fig. 2a). The peak in the late autumn seen along the western Honshu and Kyushu might be shown by turtles released from the southern, nearer gyre, while the midwinter peak seen along the northern half of Honshu by those coming from the northern, farther gyre.

The other idea explaining the early occurrences of the leatherback turtle in the northern districts is based on the possibility of the animal passing the winter in the Japanese waters. The turtles caught in the Hokkaido, Siberian and Sanriku waters might not belong to the population rapidly carried there by swift streams of the warm currents within the same summer, but to the population having passed the winter in the Japan Sea and transported there

in the spring of the next year (Text-fig. 2b). This idea does not need any drift of an unduly high speed, which in the preceding idea is of an essential importance. According to this view, the leatherback turtles having passed the Tsushima Straits in the period July to August will be drifted rather slowly in the offshore area of the Japan Sea and reach the central part by September or October. There they will encounter the break of the northwest monsoon and gradually be driven toward the west coasts of Honshu and Kyushu ; the smaller peak of occurrences in late autumn in these districts may mark the initial stage of approach of the animals to the coast. The turtles will pass the winter somewhere in the coastal waters of these districts.

From January to February the northwest monsoon attains the peak and the water temperature along the west coast of the northern Honshu begins to drop to 8°–10°C. It is very probable that under such circumstances of low temperature and rough weather the tropical animals will be more or less weakened and often exhausted to be stranded ; in fact, the majority of occurrences during this season are recorded by stranded individuals. On the other hand, the minimal water temperature along the coast of the southwestern Honshu, attained in February, is 10°–14°C, considerably higher than that along the northern Honshu. And there the leatherbacks will be able to maintain their life without being weakened to be stranded and resultantly there may not be found the midwinter peak of records in this district.

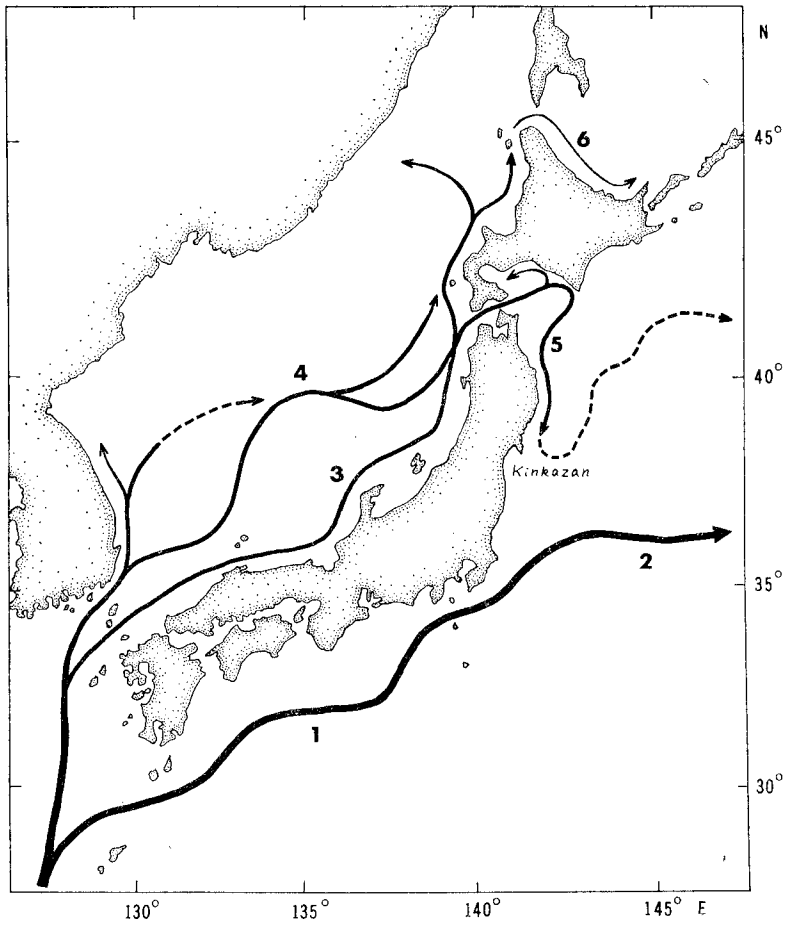
In the next spring, possibly May or June, the turtles having successfully passed the winter in the Japan Sea will turn again to their northward migration taking advantage of resumed north-flowing currents along the Honshu coast, and reach the waters off Hokkaido, Sanriku and Siberia by summer.

Discussion

The midwinter occurrences of tropical-subtropical pelagic animals on the west coast of Honshu, especially of its northern half, is a very peculiar phenomenon in the zoogeographical aspects of the Japan Sea (NISHIMURA, unpublished manuscript). Besides the leatherback turtle, the balloonfish, *Diodon holacanthus* L., the ocean sunfish, *Mola mola* (L.), the sharptail ocean sunfish, *Masturus lanceolatus* (LIÉNARD), the dealfish, *Trachipterus ishikawai* JORDAN & SNYDER, the argonaut, *Argonauta argo* L., the giant flying-squid, *Thysanoteuthis rhombus* TROSCHEL, a rhizostome medusa, *Stomolophus nomurai* (KISHINOUYE), etc. may be cited as representatives of such animals. These animals are common in having their origins or start of their migrations all outside the Japan Sea, and it is the Kuroshio and the Tsushima current that transport these animals into the Japanese waters. Their migration or drift patterns resemble one another and are of course essentially similar to that of the leatherback discussed in the present paper. And on the principle throughout all of these patterns the following two points concerning the hydrographic characteristics of the Japan

Sea may be inferred: (1) the offshore branch of the Tsushima current has larger volume transport than the coastal one in that the former seems to be much more effective than the latter in carrying various pelagic animal populations of the tropical or subtropical origin, and (2) prominent drift-currrents toward south to southwest are generated during the winter season, which drive the offshore surface water together with the involved pelagic animal populations to the west coasts of Honshu and Kyushu.

That the offshore branch is the main stream of the Tsushima current is now generally accepted by physical oceanographers (Maritime Safety Agency,



Text-fig. 3. Schematic representation of the flow pattern of the main warm currents in the neighboring waters of Japan.
1.–Kuroshio; 2.–Kuroshio Extention; 3.–Coastal stream of Tsushima current; 4.–Offshore stream of Tsushima current; 5.–Tsugaru current; 6.–Sôya current. The broken lines indicate insufficiently known currents.

Japan 1950; FUKUOKA 1957; SHIMOMURA & MIYATA 1957; KAJIURA et al. 1958). In fact, it is estimated that, during the warmer season of the year, the volume of the water passing through the western channel of the Tsushima Straits, which gives rise to the offshore branch and further the second and third branches, is about three times as large as that through the eastern channel of the same straits continued to the coastal or the first branch of the Tsushima current (SUDA 1938; MIYAZAKI 1952).

However, the existence of prominent drift-currents in the Japan Sea during winter is not yet thoroughly confirmed by hydrographic observations, although results of the drift-bottle release experiments reported by some researchers seem to support this: TAMIYA (1955), for instance, mentioned that the drift-bottles released in early summer in the offshore area of the Japan Sea were mostly transported over a long distance to be recollected in northerly districts, while those released in late autumn or winter were carried in a short time toward the west coast of Honshu, only an insignificant part of them being transported to more or less remote waters.

At present, it cannot be decided which of these hypotheses is nearer the truth. Only it can be said that there are a few disadvantages in the second hypothesis, whilst no fatal one is noted in the first hypothesis.

The idea of the existence of certain areas retaining those animals in the offshore part of the Japan Sea as proposed in the first hypothesis may be to some extent supported by findings of drift-nets, buoys, etc. belonging to coastal fishermen, which apparently were lost from the coastal waters, transported offshore and accumulated in the central part of the sea near the Yamato Tai Bank (SHIMOMURA 1959). This idea can also be based on the hydrographic features of the Japan Sea: according to FUKUOKA (1962), there exists a semi-permanent warm water area off the region from the Oki Islands to Noto Peninsula, which is characterized by sinking of the surface water, namely by horizontal convergence. As to the existence of another, northern area of the same nature, is missing any sufficient evidence; although UDA (1952) indicates in one of his figures the existence of a whirling current, named "the Japan Sea central cold current", just near the region suspected to be the presumed northern retaining area.

The possibility of the leatherback wintering in the eastern or southeastern part of the Japan Sea, on the contrary, remains as yet unproved. It is, however, highly probable that some of those tropical animals mentioned previously do survive the coldest season there as does the balloonfish (NISHIMURA 1961). In this connection, it is noteworthy that some leatherback turtles caught on the coast of northwestern Honshu in the latter half of February, just prior to the season of the annual minimal water temperature, were found stranded still alive, though considerably exhausted (FUJINOKI & TONEGAWA 1957;

NISHIMURA 1960; etc.) Even if the possibility of wintering in the Japan Sea be demonstrated for the leatherback turtles, it remains still unsolved why any of them are never discovered along the coast of northern Honshu in the spring or early summer when they are supposed to start their renewed migration to the north; this presents another disadvantage to the second hypothesis.

Summary

1. In the Japanese and its adjacent waters, the records of occurrences of the leatherback turtle cover the entire region from Amami-Ôshima to the northwestern and northeastern coasts of Hokkaido (Text-fig. 1).

2. The season of frequent occurrences differs significantly in respective geographical subdivisions (Table 1); it is very strange that along the Japan Sea coast of Honshu, particularly of its northern part, the turtles are caught almost exclusively in midwinter from January to February, while the animal appears mostly in summer, June through September, on the whole coast of Hokkaido and the Pacific districts of Honshu including Sanriku.

3. Two hypotheses were proposed to explain the migration mechanism of the leatherback in the Japanese waters. Both hypotheses are related essentially with the drift of the pelagic animal population with the offshore stream of the warm current and with the drift-currents generated by the monsoon winds, particularly the northwest monsoon.

4. The first hypothesis (Text-fig. 2a) involves the existence of a very swift current belt within the offshore stream of the warm current, which may transport the turtle population to the northern waters in a very short time.

5. The last hypothesis (Text-fig. 2b) is accompanied with the possibility of the leatherback wintering in the Japan Sea and attributes the earlier occurrences of the animal in northern waters, i.e. Hokkaido and Sanriku, to the individuals having passed winter and reopened northward drift in the next early summer.

6. The midwinter occurrence of the leatherback along the west coast of northern Honshu is apparently correlated with the south- to southwest-flowing drift-currents prevailing in the Japan Sea throughout the whole winter season.

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