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A Review of Biological Studies on Sea Turtles in Japan

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Abstract: To clarify the research history of sea turtle biology in Japan, a total of 256 scientific publications are reviewed in relation to the following six categories: taxonomy, distribution, development, genetics, ecology and ethology, and local research activities. The oldest scientific study project was started in 1880 on Chichijima Island of the Ogasawara Islands to conserve the stock of green turtles as a food resource. This study is still continuing and allows us to grasp the fluctuation in numbers of turtles captured. On the other hand, taxonomic study of Japanese sea turtles, which was initiated in 1907 by L. Stejneger, achieved little progress until the 1960–70's when Nishimura clarified the correct species names of Japanese members and their distributions. In the 1980's, many volunteers started research on the loggerhead turtle in its nesting sites at various localities in Japan. With the advance of research activities, ecological information has been accumulated for several nesting beaches and reported mainly in local publications. These publications, mostly written in Japanese and not circulated widely, are difficult to obtain for researchers abroad and usually neglected or unnoticed by them, or in the worst case, even by Japanese researchers. However, some of these studies include important information, as examplified by the data accumulated nearly 50 years for nesting fluctuation on the Ohama and Kamouda Beaches. Therefore, they are actually of great value in considering biology and conservation of sea turtles.

Key words: Sea turtles; Japan; Natural history; Review

Sea turtles occurring widely in seas from tropical to temperate regions, have the largest distribution range of extant reptiles. They are similar morphologically to their ancestors that appeared in the Mesozoic era, and are therefore considered as valuable in the study of the evolutionary process. Nevertheless, all species of sea turtles are now deemed to be drasticaly decreasing in number, mainly due to human pressure, and thus, sea turtles are now treated as symbolic animals in discussing environmental problems in many parts of the world. Movements to conserve these animals are very active and people of all levels from personal to government participate in this activity. Biological studies of sea turtles are also very active. For example, a database made by Dr. Bolton of Florida University has accumulated more than ten thousand references on the biology of sea turtles by 1996 (Sea Turtle Association of Japan, 1997).

Japan, situated in the northwestern Pacific, has several species of sea turtles in its surrounding seas, and studies of these animals have been made in various fields in this country. However, there has been no work that summarizes studies on Japanese sea turtles, although there is a review that introduced studies made outside Japan (I. Uchida, 1982a, b, 1983a, b, c, 1984, 1994). Further, due to poor presentation, the existence of some literature is sometimes concealed although researches or studies have actually been done. These studies are often ignored even among Japanese researchers, not to say among foreign students. In this short article, we would like to introduce summaries of biological studies of sea turtles in Japan, such as taxonomy, distribution, development, genetics, ecology and ethology, and local research activities.

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SYSTEMATICS

Five species of sea turtles have been known to occur in the seas around Japan (I. Uchida and Nishiwaki, 1982), i.e., one dermochelyid, the leatherback turtle, *Dermochelys coriacea* (Vandelli, 1761), and four cheloniids, the loggerhead turtle, *Caretta caretta* (Linnaeus, 1758), the green turtle Chelonia mydas (Linnaeus, 1758), the hawksbill turtle *Eretmochelys imbricata* (Linnaeus, 1766), and the olive ridley turtle *Lepidochelys olivacea* (Eschscholtz, 1829). Identification and application of scientific names to these species were in confusion until relatively recently, and proper taxonomic arrangement

was made in the latter half of the 1960s.

It is Stejneger (1907) that first described sea turtles inhabiting the seas around Japan. He listed four species, i.e., *Dermochelys schlegelii* (Garman, 1884), *Caretta olivacea* (Eschscholtz, 1829), *Chelonia japonica* (Thunberg, 1787), and *Eretmochelys squamosa* (Girard, 1858) as Japanese members. Of these, it is apparent that *D. schlegelii* is currently synonymized with *D. coriacea*, *C. japonica* with *C. mydas*, and *E. squamosa* with *E. imbricata*. However, it is not clear whether *Caretta olivacea* corresponds to *C. caretta* or *Lepidochelys olivacea*. Stejneger (1907) himself did not examine a specimen of his *C. olivacea* and the figure cited as that species in Plate XXXIV of his book looks like *L. olivacea*. However, since *L. olivacea* is a rare species in Japan, it seems more likely that he wrongly described *C. caretta* as *C. olivacea*. These two species are often confused since they are morphologically quite similar and both are variable in the number of pleurals, which is one of the diagnostic characteristics in the classification of sea turtles.

Later, in 1963, Nakamura and Uéno listed five species of sea turtles from Japan, i.e., *Chelonia mydas japonica* (Thunberg, 1787), *Eretmochelys imbricata squamata* Agassizi, 1857, *Caretta caretta gigas* Deraniyagala, 1933, *Lepidochelys olivacea olivacea* (Eschscholtz, 1829), and *Dermochelys coriacea schlegelii* (Garman, 1884), in their famous book "Japanese Reptiles and Amphibians in Colour". However, scientific name of *L. olivacea* was adopted for loggerhead turtle which breeds in the southern part of Japan and a similar, but rarer turtle was called the larger loggerhead, *C. caretta*, in their book (Nakamura and Uéno, 1963). This misidentification seems to have been caused mainly by the scarcity of turtle specimens or live animals reared in aquariums, and difficulties in obtaining literature including original descriptions in those days, and at the same time, Nakamura and Uéno (1963) seem to have been greatly influenced by the description in Stejneger (1907). Later, Uéno (1969) removed *C. caretta gigas* and listed the remaining four species of sea turtles in the second edition of "New Illustrated Encyclopedia of the Fauna of Japan" published by Hokuryukan. He wrongly assigned the name *L. olivacea* for the Japanese loggerhead turtle, and this misunderstanding lasted till the 1970's as seen in the fourth edition of "Fishery Zoology" written by Tanita (1975).

While misuse of the scientific names of the loggerhead turtle continued, Nishimura (1967a, b) and Nishimura and Hara (1967) reviewed capture records and relevant literature of Japanese loggerhead turtles. By including their own data from specimens collected in Shirahama, Wakayama Prefecture, they studied the morphology of this turtle in detail. As a result, they clarified that two species, *C. caretta* and *L. olivacea*, were included among turtles called the loggerhead turtle in Japan up to that time. According to these authors, *C. caretta* is the commonest species that breeds in south Japan, while the sea turtle which is slightly smaller and less frequently collected is *L. olivacea*. It would not be too much to say that the list of Japanese sea turtles was corrected and the basis for subsequent studies was established by these works. Nakamura and Uéno (1968) followed this classification in the fourth edition of "Japanese Reptiles and Amphibians in Colour".

Few studies based on qualitative analyses have been made on intraspecific geographical variation in morphology of sea turtles because of difficulty in preservation and transportation of specimens due to their large body size. Kamezaki and Matsui (1995), however, analyzed geographic variation in the skull morphology of the green turtle from six regions of the world including Ogasawara. Also, skull morphology of the loggerhead turtle has been compared between populations from Japan and Australia (Kamezaki, 1994a).

Distribution

It was Nishimura who first did systematic studies on the distribution of sea turtles occurring around Japan. He first collected records of the leatherback turtle, *D. coriacea*, mainly stranded on Japanese coasts. Because the records were found concentrated in the winter season and around the coasts of the Japan Sea, he considered that turtles which invaded the Japan Sea in summer froze to death or became weak at the low water temperatures in winter and eventually drifted and became stranded on the coasts (Nishimura, 1964a, b). He also made it clear that the olive ridley turtle, *L. olivacea*, does not nest in Japan. He summarized the distributions of loggerhead nesting sites in Japan, and of the loggerhead and the olive ridley turtles in the northwestern Pacific (Nishimura, 1967). He further compiled Japanese records of the hawksbill turtle, *E. imbricata* (Nishimura and Yasuda, 1967) and the olive ridley turtle (Nishimura *et al.*, 1972), and considered that centers of their distribution are situated in more southern regions and that these turtles migrate

to Japan along the Kuroshio Current. From these contributions, it was made clear that the loggerhead turtle has breeding sites in southern regions of the Japanese mainland, whereas the leatherback, olive ridley, and hawksbill turtles are only migrating in the seas adjacent to Japan.

Even since then, information has been scarce regarding distribution of sea turtles because of difficulties in obtaining records. Meanwhile, Miyawaki (1989a, b, c, 1994) studied compositions of species and body sizes of sea turtles that were incidentally caught with fishes at Kushimoto of the Kii Peninsula. He reported that the green turtle is the most abundant, followed by the loggerhead and hawksbill turtles, and that the olive ridley and the leatherback turtles are rare in the coastal waters of the Kii Peninsula. Kamezaki and Hirate (1992) reported the carapace length distribution of the hawksbill turtle from the Yaeyama Island Group. On the coasts facing the Japan Sea, stranding records of sea turtles have been made and sea turtles are thought to be killed by the drop in water temperatures in winter (Honma and Yoshie, 1975; Honma and Kitami, 1976; Honma and Aoyagi, 1986; Honma et al., 1987; Matsumura, 1996; Matsumura and Yamashita, 1996; Nomura, 1993; Yamashita, 1995). In the adjacent waters of Japan, immature loggerhead turtles of young to subadult stages have rarely been found (I. Uchida, 1973), but recently, records of their discovery are slightly increasing (I. Uchida, 1973; Honma and Aoyagi, 1986; Honma et al., 1987; Tachikawa, 1989; Miyawaki, 1994; Maeda and Kimura, 1995). For the green, hawksbill, olive ridley, and leatherback turtles, distributions in the seas around Japan have been summarized (Kamezaki, 1994b, c; Suganuma, 1994a, b).

With regard to the distribution off the coast of Japan, the loggerhead turtle is known to occur in the East Chinese Sea and in the seas around the Ogasawara Islands. This information has been obtained from crews of survey ships for oceanic fishery (Nakahigashi and Nishimura, 1989; Nishimura and Nakahigashi, 1990, 1992). Recapture of marked individuals is an effective method for understanding distribution ranges of Japanese sea turtles. The results of mark and recapture survey for females that nested in Miyazaki have been reported (Iwamoto et al., 1985; Nakashima and Nakamura, 1994). Further, young loggerhead turtles released in Japan are reported to have been recaptured off the western coast of North America (S. Uchida and Teruya, 1991). Similarly, as to the loggerhead, one individual that nested on Yakushima Island was recaptured in the Philippines (Oomuta, 1993), and another that nested on Miyakojima Island of Okinawa Prefecture was recaptured in Vietnam (Sadoyama et al., 1996). These records are notable for understanding distribution of Japanese populations of the loggerhead turtle. More recently, analyses of mtDNA revealed that loggerhead turtles distributed in the north Pacific and off the western coast of North America belong to the populations that nest in Japan (Bowen et al., 1995).

Nishimura (1967) summarized information regarding distribution of breeding sites of the loggerhead turtle in Japan, and listed 42 sites that range from Kashima-nada beach of the Pacific and Yumiga-hama beach (Shimane Prefecture) of the Japan Sea to Yakushima. More recently, it is reported that nesting sporadically occurs in more northern localities [Ishikawa Prefecture in the Japan Sea side (Tokumoto, 1984; Matsumura, 1996), and Hitachi City of Ibaraki Prefecture (Shinada, 1994)]. These localities seem to represent the northernmost nesting sites for the loggerhead turtle. On the other hand, the green turtle has long been known to nest on the Ogasawara Islands. According to Kurata and Hirose (1969), who compiled the records of turtles on the islands, older records can be traced to ones made by refugees and government patrolmen in the Edo era. In this way, it was already known in the beginning of sea turtle studies in Japan that the species breeds on the Ogasawara Islands.

Among the Nansei (= Southwestern) Islands, a sea turtle survey was first made on Yakushima Island. Kajihara and I. Uchida (1974), and Kanno (1980), made surveys of the loggerhead nesting at Kurio and Inaka beach, respectively, and reported that the green turtle also nests on this island. Misaki (1978a, b, c) and Miyawaki (1981) surveyed Kuroshima Island of the Yaeyama Group, the southernmost island of the Nansei Islands, and reported that both the loggerhead and hawksbill turtles breed on this island. From these studies, it was made clear that the three species, loggerhead turtle, green turtle, and hawksbill turtle breed in Japan (I. Uchida and Nishiwaki, 1982). Later in 1984, Okinawa Expo-Aquarium made a survey by interviewing local people in the entire area of the Nansei Islands, and got results which suggest that beaches used by sea turtles are distributed widely in these islands (S. Uchida et al., 1984; S. Uchida, 1985). From 1983, surveys have been made on the Yaeyama, Miyako, and Amami

Groups, and the species composition of nesting turtles on each island group has been made clear. Also, these surveys found that about 60% of all sandy beaches on these island groups are utilized by turtles for reproduction (Kamezaki, 1986, 1989a, b, 1991a, b, 1994e). Kikukawa et al. (1996a, b) reported the distribution of breeding sites of sea turtles on Okinawajima and its adjacent islets. On these islands, nesting of the hawksbill turtle has been confirmed on Okinawajima and Minnajima Islands by Teruya (1994), and on Akajima Island of the Kerama Group by Hirate and Shimoike (1995).

Developmental Biology

Studies on developmental biology of sea turtles in Japan can be traced back to those of embryonic development by Mitsukuri (1894; 1896–98). Uchinomi (1943) also studied embryonic development using material from Shirahama, Wakayama Prefecture, and made a brief description. Later, a series of detailed studies were done on embryos of the loggerhead turtle (Fujimoto et al., 1979; Fujiwara, 1966, 1973, 1980; Kuwana et al., 1980). Kuratani (1987) did a detailed study on the development of optic regions of embryonic loggerhead turtle.

Biochemical studies of sea turtles during their embryonic development have been done by Japanese researchers. Tomita (1929) studied synthetic activity of urea and uric acid in embryonic loggerhead turtles and found that synthesis of urea exceeds that of uric acid. Fluctuations of substances other than urea and uric acid in the course of development were also studied: lactic acid (Sendju, 1929a), amino acids (Sendju, 1929b), ashes and calcium (Karashima, 1929a), fatty acid (Karashima, 1929b), total nitrogen (Nakamura, 1929), and cholesterol (Kusui, 1930). The chemical composition of loggerhead turtle eggs has been studied (Yamauchi et al., 1984), and a method for monitoring heavy metals has been developed by analysing heavy metals contained in eggs (Sakai et al., 1995).

The fact that the sex of an individual is determined by the temperature during early embryonic development, i.e., TSD (=Thermal dependence of Sex Determination), was found in sea turtles in 1980 (Yntema and Mrosovsky, 1980). Kamezaki and Kuroyanagi (1991) confirmed the existence of this mechanism in the Japanese population of the loggerhead turtle, and Tokunaga (1991) also made a similar report on the green turtle from Ogasawara. Later, Matsuzawa conducted more detailed studies on the mechanism of TSD, and the studies have by now resulted in formulation of a model for calculating sex ratios, and confirmation of sex ratios of hatchlings on the basis of sand temperatures of entire nesting sites in Japan (Matsuzawa and Sakamoto, 1994; Matsuzawa et al.,1996). Tokunaga (1994) summarized the mechanism of TSD in the loggerhead turtle.

Genetics

Genetic studies on sea turtles began with several papers on the number of chromosomes. First, Nakamura (1937) studied the chromosome number of the loggerhead turtle *Caretta olivacea* (=*C. caretta*, see taxonomic chapter above) and reported that the female had 51 and the male 52 chromosomes. He later revised the figure and gave the numbers 57 for females and 58 for males (Nakamura, 1949). Later, Makino (1952) reported that in the green turtle *Chelonia japonica* (=*C. mydas*), females had 55 and males had 56 chromosomes.

More recently, however, Kamezaki (1989b) denied the presence of sexual dimorphism in the karyotype of the loggerhead turtle, and reported that both sexes have 2n=56 chromosomes. He also reported that the both sexes of the hawksbill turtle have 2n=56 chromosomes (Kamezaki, 1990). By this time, karyotypes of the green turtle, olive ridley turtle, and leatherback turtle had been anlyzed by Bickham et al. (1980), Mohanty-Hejimadi (1986), and Medrano et al. (1987), respectively, and karyotypes of sea turtles were found to be very conservative. All species have 2n=56 chromosomes and are similar in chromosome morphology.

Recently, phylogenetic analyses using DNA sequences are becoming popular for many animal groups, and have been done for sea turtles as well. Comparisons of intraspecific variations have been made for the loggerhead turtle (Bowen et al., 1994) and the green turtle (Bowen et al., 1992; Karl et al., 1992) populations including Japanese ones, and phylogenetic positions of the loggerhead turtle population nesting in south Japan and the green turtle population nesting on Ogasawara have been estimated.

On the other hand, occurrence of natural hybrids among different sea turtle species has been reported: apparent hybrids are reported between loggerhead and hawksbill turtles (Kamezaki, 1983a), between green and hawksbill turtles (Hirate and Kamezaki, 1994), and between loggerhead and green turtles (Kamezaki et al., 1996). Kamezaki and Namikawa (1984) tried to detect the genetic origin of putative hybrids of loggerhead and hawksbill turtles by

analyzing isozyme polymorphisms.

Growth

The first report on the growth of sea turtles in Japan was made on loggerhead turtles reared at the Seto Marine Biological Laboratory of Kyoto University at Shirahama, Wakayama Prefecture (Uchinomi, 1943). Later, records for growths of loggerhead turtles in captivity were reported by I. Uchida (1967), Kondo (1968), and Kanno(1982). Among these, I. Uchida (1967) reared hatchlings of loggerhead turtles for four years and a half, and obtained a growth curve and calculated a formula denoting changes in relative values of character dimensions such as head length. Nuitja and I. Uchida (1982) reported differential growths in captivity due to different diets.

Besides the loggerhead turtle, records for the growth of hatchlings have been made for the green turtle from Yakushima Island (Kanno, 1982) and the hawksbill turtle from Kuroshima Island of the Yaeyama Group (Ui, 1979, 1980). Formulae for the growth of body weight relative to carapace length have been provided for five species of Japanese sea turtles (Aquarium in the Kinki and Chugoku Region of J. A. Z. G. A., 1981).

On the other hand, the growth of sea turtles in nature is generally studied by recapturing tagged and released individuals. In Japan, the growth of female green turtles that nest on Ogasawara Islands has been studied by this method (Tachikawa, 1991). The growth of a hawksbill turtle (Kamezaki, 1987) and a green turtle (Kamezaki et al., 1995a) from the Yaeyama Group has been recorded from tagged and recapture surveys.

Ecology and Ethology

Most ecological and ethological studies of sea turtles are concerned with nesting on sandy beaches. Few Japanese studies have been made systematically, and most are mere descriptions.

Uchinomi (1943), who did a good review of breeding ecology of sea turtles in Japan, reported that the nesting season of loggerhead turtles at Shirahama, Wakayama Prefecture, was from early June to late August, and that nesting occurred 10–20 times in a nesting season. On the other hand, Kondo, a teacher of science at Hiwasa Junior High School of Tokushima Prefecture, studied loggerhead turtles that nest on the Ohama beach of Hiwasa-Cho Town. He began studies in 1950 with the help of his pupils and published the results later (Kondo, 1968). Although done as a part of educational programs at a junior high school, this study includes such wide topics as morphology, taxonomy, nesting ecology, embryonic development, growth, and behavior of hatchlings, and is of very high caliber when evaluated by the scientific standards of those days. In his report, the numbers of nests during the nesting season in 1950–1954 are recorded and the distribution of nesting sites in Tokushima Prefecture is described. Relationships between frequency of nesting and environmental conditions such as climate, weather, age of the moon, wave height, and sea water temperature are statistically analyzed, but no correlation is found in any factor. By dissecting a postnesting female which had died accidentally, Kondo (1968) found some eggs left unoviposited, and estimated that a female would oviposit more than twice within one nesting season.

In 1967, the first detailed survey of nesting ecology of the loggerhead turtle was made at Kamouda beach of Tokushima Prefecture. Biologically minimum size (I. Uchida, 1986, 1990), time spent for nesting, body weight, clutch size (I. Uchida, 1981, 1990), and temperatures in the nest were reported (I. Uchida and Kajihara, 1977). By the mark and recapture method, some females were confirmed to nest more than once in one nesting season (I. Uchida and Kajihara, 1977). Kajihara and I. Uchida (1974) made a study on the nesting ecology of the loggerhead turtle at the Kurio beach on Yakushima Island. It should be noted that they estimated the total number of female loggerhead turtles visiting nesting sites on Tanegashima and Yakushima Islands and Kochi and Tokushima Prefectures to be 500.

Later, the Wildlife Society of Miyazaki, which had conducted research on nesting of the loggerhead turtle on Miyazaki beaches, published the first original paper on the nesting ecology of Japanese loggerhead turtles in the Japanese Journal of Ecology (Iwamoto et al., 1985). On the basis of the data gathered between 1977 and 1983, they reported that the number of nests fluctuated triennially and that post-nesting, tagged females migrated to the East Chinese Sea. Some of these latter females have been recaptured (Nakashima and Nakamura, 1994). It is also reported that on Fukiage beach of Kagoshima Prefecture (Imai and Akiyama, 1983), on Yakushima Island (Yakushima Sea Turtle Research Growp, 1991, 1992, 1993, 1994, 1995, 1996), and on Senri beach of Minabe Town, Wakayama Prefecture (Goto, 1996), tagged,

post-nesting females migrate to the East China Sea.

Among other topics on nesting ecology of Japanese loggerhead turtles, the number of nestings and the internesting interval within one nesting season (Nishimura and Oomuta, 1993; Kurihara and Oomuta, 1994), different carapace lengths of females among different nesting sites (Kamezaki et al., 1995b), and hatching in nature (Samejima, 1994a; Uemura, 1983a, b, c) have been reported. In the Yaeyama Group, an integrate survey was made of coasts where sea turtles nest, and vegetation, nature of sands, size of sandy beaches, and offshore topography were thoroughly studied (Environmental Agency of Japan, 1992). On the basis of these data, environmental factors that are related to nesting sites of turtles have been analyzed (Kamezaki et al., 1992).

On the Ogasawara Islands, the green turtle has been studied by the Ogasawara Fisheries Center of Tokyo Prefecture, headed by Kurata (Kurata and Hirose, 1969; Kurata, 1981). As stated earlier, it was long known that the islands have nesting sites of the green turtle, and turtles provided important food resources for immigrants to these islands by whom a huge number of turtles were collected. Release of hatchlings from artificial hatcheries for the conservation of the green turtle as a resource, can be dated back to 1876. The number of turtles caught has been recorded from 1880, and we can study the long-term fluctuations in the population size of turtles. According to these records, the number of green turtles rapidly decreased in Ogasawara. Data obtained by recapture of tagged turtles have also been gathered, and it is now clear from these data that both the post-nesting females and young turtles migrate from the Japan mainland to the coasts of the Nansei Islands (Kurata and Hirose, 1969; Kurata, 1981). In this way, Ogasawara is a unique place where studies have been conducted over 100 years, and even now, active research is under way mainly by the Ogasawara Marine Center (Inaba, 1992; Ogasawara Marine Center, 1994, 1995, 1996; Sato, 1993; Suganuma et al., 1994; Tachikawa, 1991; Tachikawa and Sasaki, 1990; Tachikawa et al., 1994, 1995, 1996).

Yoshioka and Samejima (1989a) and Kajihara and I. Uchida (1974) classified nesting behavior and recorded the time spent for each episode. I. Uchida (1982c) divided beaches at Kamouda into blocks and tried to find properties of sites that are frequently used for nesting. Behavior of turtles in the ocean has also been studied with new techniques. Soma (1985) attached radio transmitters to loggerhead turtle females that nested on beaches of Omaezaki and traced their oceanic migration after nesting. Yano and Tanaka (1991) attached ultrasound transmitters to nesting loggerhead turtles and traced behavior during internesting periods. By putting TTRs (Time Temperature Recorders) and TDRs (Time Depth Recorders) on nesting females and recovering these recorders later at their next nesting, diving behavior of sea turtles during internesting periods was studied in detail (Sakamoto et al., 1990a, b, 1993; Naito et al., 1990), and ecophysiological studies were also made on body temperature during successive nestings (Sato et al., 1994, 1995). From the record of temperature fluctuations in the stomach of turtles, Tanaka et al. (1995) showed that female loggerheads do not take food during internesting periods within one nesting season. In Ogasawara Islands, the movement of postnesting female green turtles was observed by tracing light floats pulled by them (Horikoshi et al., 1993). In order to control behavior of the loggerhead turtle for its protection, experiments on its sense and behavior have been done in the captivity (Nishimura, 1994).

With regard to ecology of sea turtles in the open sea, Kamezaki and Hirate (1992) reported migration of immature hawksbill turtles in the Yaeyama Group, and Kamezaki (1984) reported stomach contents of the hawksbill turtle. As to food habits, Yamaguchi et al. (1993) examined the stomach contents of stranded loggerhead turtles, and Kuroyanagi and Masuda (1992) studied the feces of captured olive ridley turtles. Kamezaki (1994d, 1995) and I. Uchida (1985) reviewed cases in which turtles mistakenly fed on plastic debris that is regarded as one cause of turtle decrease.

Local Research Activities in Japan

It is very important to accurately grasp fluctuations in population size of sea turtles, since these animals are now remarkably decreasing in many parts of the world. As the most effective measure, the numbers of nesting females, nests, and landings are recorded at beaches, and these records can be compared between different breeding seasons. A survey of this kind was first made at Ohama beach in Hiwasa Town of Tokushima Prefecture, and next at Kamouda beach of the same Prefecture. Later, with the rise of human interest in conservation of nature, surveys of sea turtle nesting began to be made in many parts of Japan chiefly by local volunteers

from the 1970's to the 1980's. In the following paragraphs, we will list nesting sites for which the number of nestings or landings per season has been reported. These numbers can be viewed as indicators of the scale of the nesting site.

In Okinawa Prefecture, Yaeyama Marine Park Research Station was established in 1978 on Kuroshima Island of the Yaeyama Group. From that year to the present, the number of nests and other data relating to oviposition of loggerhead turtles and hawksbill turtles on the western beaches of the island have been recorded (Misaki, 1978a, 1978b, 1978c; Miyawaki, 1981; Hirate, 1988; Nomura, 1988; Kamezaki, 1987, 1989; Hirate and Iwase, 1991; Hirate et al., 1994; Sato et al., 1995).

More recently, research has also been done on the Ibaruma beach of Ishigakijima Island and on the southern beaches of Iriomotejima Island (Sato et al., 1995), or on the beach of Gusukube-Cho Town on Miyakojima Island (Iwai et al., 1993). On Okinawajima Island, research was started in 1992 at the Odo beach of Itoman City by members of the Expedition Club of the University of Okinawa (Wakatsuki and Teruya, 1996).

On Yakushima Island of Kagoshima Prefecture, research on landing and oviposition of sea turtles started in 1985 at Inakahama beach of Nagata, and records have been gathered in each season since then (Yakushima Sea Turtle Research Group, 1985, 1986, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996). On the mainland of Kagoshima Prefecture, T. Akiyama, then a student of the Faculty of Fisheries of Kagoshima University, began research on nesting ecology and conservation activity in 1981 at Fukiage beach (Imai and Akiyama, 1982, 1983, 1984). This research has been taken over by the Marine Turtle Research Group of Kagoshima University (Kakinuma et al., 1988; Ueda, 1989; Iwakiri, 1990; Matsuura, 1992; Harada, 1993; Nakayama, 1994, 1995; Nagatani, 1996). On Nagasakibana beach, situated at the southernmost tip of the Satsuma Peninsula, frequency of nesting, and nesting behavior have been recorded since 1989 (Samejima and Yoshioka, 1989; Yoshioka and Samejima, 1989b, 1990; Samejima et al., 1992; Samejima, 1993, 1994b, 1995, 1996). Also in Kumamoto Prefecture, a smaller number of sea turtles are breeding in areas around Amakusa district, and Yoshizaki and Mori (1992) reported the situation in these areas.

In Miyazaki Prefecture, surveys of nesting ecology of the loggerhead turtle have been made since 1976 by the Wildlife Society of Miyazaki on beaches around Miyazaki City (Miyazaki City Education Board, 1977; Takeshita, 1977; Iwamoto et al., 1985, 1986; Nakajima, 1989, 1990; Wildlife Society of Miyazaki, 1979, 1980a, b, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996).

In Shikoku Island, the number of turtle emergences has been recorded since 1950 on the Ohama beach of Hiwasa Town in Tokushima Prefecture (Kondo, 1994; Nakahigashi, 1994). On Kamouda beach of Anan City of the same prefecture, pupils of Kamouda Elementary School have been keeping records of landings since 1954 (Kamouda Elementary School, 1989; Kamata, 1994). Records on these two beaches are among the longest records in the world, and are very important in understanding the fluctuation pattern of loggerhead turtle populations. Also in Tokushima Prefecture, the numbers of nests and landing tracks of loggerhead turtle have been recorded since 1981 on the Osato-Matsubara beach of Kainan-Cho Town by T. Noichi (Nii and Noichi, 1996).

On Senri beach in Minabe-Cho Town of Wakayama Prefecture, K. Goto and O. Uemura, both teachers at a local elementary school, began a survey in 1981. In 1990, a group of students from the Faculty of Agriculture, Kyoto University, joined the survey and biological data have been actively kept until the present (Goto and Uemura, 1989, 1994; Goto, 1990, 1991, 1992, 1993, 1994, 1995, 1996). Recently, similar surveys have been initiated in other parts of the Kii Peninsula, such as Kiho-Cho Town (Hagino, 1991) and Shima district (Wakabayashi, 1990, 1994), both in Mie Prefecture.

In Aichi Prefecture, records have been kept for oviposition of the loggerhead turtle around beaches of the Chita Peninsula since 1981 (Kuroyanagi, 1994). The loggerhead turtle is also nesting on the Atsumi Peninsula on beaches facing the Pacific, and the numbers of nests and tracks were studied in 1982 on Koiji-ga-Hama and Hii beaches of Atsumi Town (Kamezaki, 1983b). Similar surveys have been made since 1991 on beaches of Toyohashi City (Loggerhead Turtle Conservation and Research Society of Toyohashi City, 1992, 1994, 1995, 1996).

In Shizuoka Prefecture, the late Yoshiro Kawarazaki, then a teacher at an elementary school began conservation activity in 1972 at Omaezaki Town. Later, the activity was continued mainly by the Board of Education of the town, and records for landing and oviposition of turtles have been kept since 1973 (Omaezaki

Town Education Board, 1977; Omaezaki Town Loggerhead Turtle Conservation Group, 1993, 1994, 1995). At the sea of Enshu-Nada, research and conservation activities have been carried on since 1987 on the beaches of Hamamatsu City, which is adjacent to Omaezaki Town, by the Association of Hamamatsu Sanctuary (Matsuka, 1991). Similarly, in Arai-Cho Town and Kosai City, both situated to the west of Hamana-ko Lake, nests and tracks of loggerhead turtles have been recorded by local volunteers (Kato et al., 1993).

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要旨　日本におけるウミガメの生物学的研究

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日本におけるウミガメの生物学の研究の歴史を明らかにするために，256の論文を分類，分布，発生，遺伝，生態・行動，各地での調査活動に分けて概観した．わが国で最も古いウミガメに関する研究は，小笠原諸島父島で食料としてのアオウミガメの保護を目的に，1880年に開始された．この研究は現在でも継続されており，捕獲されたウミガメの個体数の変動を知ることができる．一方，日本のウミガメの分類学については1907年の Stejneger の業績に端を発するが，その後，西村が1960–70年代に日本に生息するウミガメの正しい種名と分布を明らかにするまで，ほとんど研究が行われることはなかった．1980年代になると日本各地のアカウミガメの産卵地で，地元のボランティアによる調査が始められた．これらの調査活動の高まりとともに，生態学的情報も蓄積されるようになり，主としてそれらは地方誌に発表された．これらの報告は主として日本語で書かれているうえ，広く流布しておらず，特に海外の研究者にとっては入手しにくく，無視されることもしばしばであった．しかしながら，これらの研究には，50年近く蓄積された大浜海岸や蒲生田海岸の産卵回数の記録に代表されるように，重要な情報も含まれている．したがって，これらの資料はウミガメの生物学や保護を議論する上で重要な価値を持っていると考えられる．

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