

Abstract—Diet analysis of 52 loggerhead sea turtles (*Caretta caretta*) collected as bycatch from 1990 to 1992 in the high-seas driftnet fishery operating between lat. 29.5°N and 43°N and between long. 150°E and 154°W demonstrated that these turtles fed predominately at the surface; few deeper water prey items were present in their stomachs. The turtles ranged in size from 13.5 to 74.0 cm curved carapace length. Whole turtles ($n=10$) and excised stomachs ($n=42$) were frozen and transported to a laboratory for analysis of major faunal components. Neustonic species accounted for four of the five most common prey taxa. The most common prey items were *Janthina* spp. (Gastropoda); *Carinaria cithara* Benson 1835 (Heteropoda); a chondrophore, *Veleva veleva* (Hydrodia); *Lepas* spp. (Cirripedia), *Planes* spp. (Decapoda: Grapsidae), and pyrosomas (*Pyrosoma* spp.).

Diet of oceanic loggerhead sea turtles (*Caretta caretta*) in the central North Pacific

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Loggerhead sea turtles are circum-global, inhabiting temperate, subtropical, and tropical waters of the Atlantic, Pacific, and Indian Oceans. In the Pacific, loggerhead sea turtles have been found in nearshore waters of China, Taiwan, Japan, Australia, and New Zealand and are seen in offshore waters of Washington, California, and northwestern Mexico (Dodd, 1988; Pitman, 1990). Nesting in the North Pacific Ocean occurs in Japan; there is no known nesting in the eastern North Pacific (Márquez and Villanueva, 1982; Frazier, 1985; Bartlett, 1989). Trans-Pacific migrations of juveniles have been documented from mitochondrial DNA analyses of individuals found feeding off Baja California. Bowen et al. (1995) identified these Baja sea turtles as originating from Japanese rookeries, although a small percentage come from Australia. Recent research indicates that all loggerhead sea turtles found in the oceanic realm of the central North Pacific Ocean are of Japanese stock (Dutton et al., 1998). Tagging studies in Japan and the Eastern Pacific also demonstrate transpacific migrations of loggerhead sea turtles between the

east and west Pacific (Balazs, 1989; Resendiz et al., 1998; Uchida and Teruya¹).

Recent oceanic satellite tracking studies of loggerhead sea turtles indicate that they are active in their oceanic movements. These turtles follow subtropical fronts as they travel toward Japan from east to west across the Pacific Ocean, often swimming against weak geostrophic currents (Polovina et al., 2000; Polovina et al., 2004). One hypothesis discussed in Polovina et al. (2000; 2004) suggests that this species obtains prey items from the subtropical fronts along which they travel. A sharp gradient in surface chlorophyll is observed along the main frontal area where these turtles are commonly encountered. This frontal area, the transition zone chlorophyll front

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¹ Uchida, S., and H. Teruya. 1991. A) Transpacific migration of a tagged loggerhead, *Caretta caretta*. B) Tag-return result of loggerhead released from Okinawa Islands, Japan. In International symposium on sea turtles '88 in Japan (I. Uchida, ed.), p. 169–182. Himeji City Aquarium, Tegarayama 440 Nishinobu-sue, Himeji-shi, Hyogo 670, Japan.

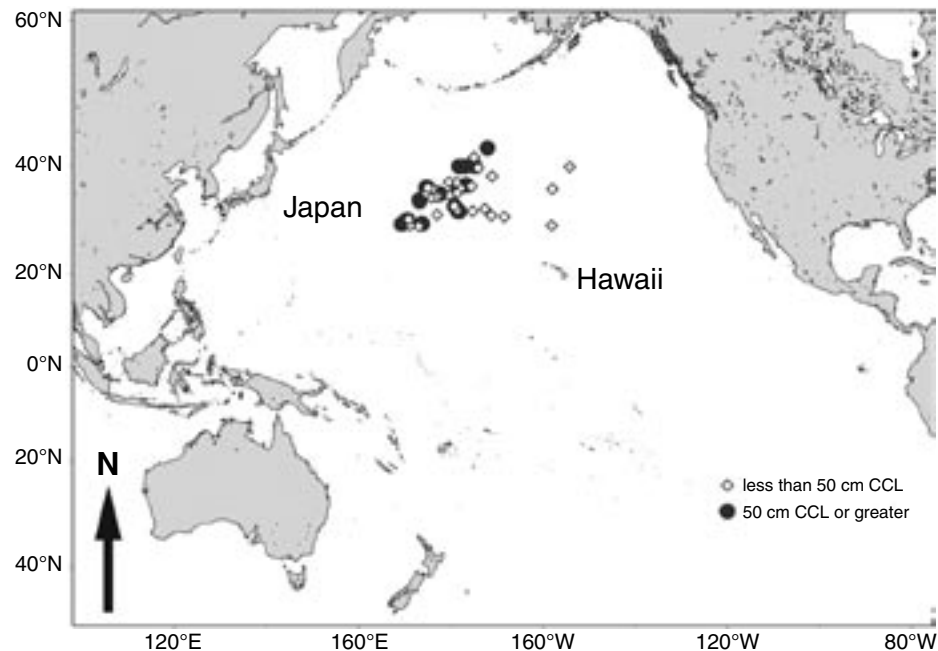


Figure 1

Distribution of loggerhead sea turtles (*Caretta caretta*) incidentally captured in the international high seas driftnet fishery in the central North Pacific Ocean. Turtles smaller than 50 cm curved carapace length (CCL) are shown as open diamonds and those larger than 50 cm CCL are shown as black circles.

(TZCF), is an area of concentrated phytoplankton that also collects and attracts a variety of neustonic and oceanic organisms—many of which may be potential prey times, as well as predators, of oceanic-stage loggerhead sea turtles in the Pacific. Polovina et al. (2000, 2004) have suggested that the turtles are foraging along the TZCF.

The duration of the juvenile oceanic stage for loggerhead sea turtles in the Pacific is currently unknown. In the Atlantic, juvenile turtles inhabit the oceanic zone for approximately 10 years (Bjorndal et al., 2000). Based on growth analyses (Zug et al., 1995; Chaloupka, 1998), it is probable that this sea turtle from the Pacific can have a similar extended oceanic stage, which in some cases may last until sexual maturity (30+ years).

Understanding the diets of sea turtles is important for their conservation. Foraging studies have been done with oceanic-stage turtles in the Atlantic (Van Nierop and den Hartog, 1984). However, there is a paucity of information regarding the foraging ecology of oceanic-stage loggerhead sea turtles in the Pacific. Such information can help identify important food resources and foraging areas necessary for guiding decisions regarding the management of endangered sea turtle populations (Bjorndal, 1999). The objective of the present study is to determine the diet composition of loggerhead sea turtles from the central North Pacific Ocean and to discuss the possibility of interactions between these turtles and commercial fisheries that may occur as a result of the foraging behavior of these sea turtles.

Method

National Marine Fisheries Service (NMFS) observers between 1990 and 1992 obtained 52 dead loggerhead sea turtles. These specimens were taken as bycatch in the international high-seas driftnet fishery, which targeted squid and albacore (Wetherall et al., 1993). NMFS observers recorded capture position and sea surface temperature aboard commercial driftnet vessels. Samples were collected between latitude 29.5°N and 43°N and longitude 150°E and 154°W (Fig. 1). A total of 10 whole specimens and 42 excised stomachs were frozen and transported to a Honolulu laboratory for analysis. Stomachs were removed from whole specimens and all stomachs were examined from anterior to posterior. Gross observations of stomach contents were made and the contents were sorted to the lowest identifiable taxonomic level by using a dissecting microscope. Major fauna were identified, quantified by volume, and the percent contribution (to stomach contents) of each major organism was calculated (Forbes, 1999). Presence of jellyfish or other jellies were identified by presence of tentacles, nematocysts, and whole or partial individuals. *Planes* spp. were identified from descriptions of Spivak and Bas (1999). Frequency of occurrence of major components was calculated by dividing the number of stomachs in which the prey item occurred by the total number of turtle stomachs examined. Percent sample volume was calculated for all prey items by summing the total volume of each prey item and dividing it by the total volume of all

prey collected. Summing the total volume of each prey item and dividing it by the total stomach volume for those samples, where the prey item was present, yielded the mean percent volume. Regression analysis was done to determine if any correlation existed between sea surface temperature, sample volume, and size of turtle.

Results

Loggerhead sea turtles collected in our study were found widely distributed over the central North Pacific Ocean and there was no apparent difference in distribution

between size classes (Fig. 1). The turtle specimens ranged from 13.5 cm to 74.0 cm curved carapace length (CCL, Fig. 2); the mean was 44.8 [± 14.5] cm CCL. Figure 2 shows the distribution of turtles in each 10-cm size class. Sea surface temperatures in the area of capture ranged from 16° to 20°C. There was no correlation between size of turtle and sea surface temperature in the area of capture ($F=0.58$, $r^2=0.01$, Fig. 3).

All 52 stomachs examined contained prey items; the level of fill varied from 6 mL to 1262 mL. Items found in the anterior portion of the stomach were the most identifiable and contents varied between turtles. Unidentifiable remains were located mainly in the posterior end of the stomach or the intestines if a whole gastrointestinal tract was analyzed. Only one of the samples analyzed included an entire gastrointestinal tract.

A taxonomic listing of diet items identified for the loggerhead sea turtles of the central North Pacific is shown in Table 1 along with frequency of occurrence and mean percent sample volume of each prey item. The six most common (frequent) prey items were identified. These included *Janthina* spp., which occurred in 75% of samples, and *Planes* spp., which occurred in 56% of samples. *Lepas* spp. occurred in 52% of the samples, and *Carinaria cithara* was found in 50% of samples. *Verella vellella*, was found in 25% of the samples, and pyrosomas were found in 21% of samples (Table 1). Other common food items found in stomachs were fish eggs (25% of stomachs), salps, amphipods (46% of stomachs), small fish, and plastic items (35% of stomachs, Table 1). Some plastic items included small plastic beads, thin plastic sheets, polypropylene line, and even a small plastic fish, which had been an individual soy sauce container. Although *Verella*, pyrosomas, and salps were represented as prey items in our samples, other types of jellies may not have been well represented because their soft bodies may dissolve more quickly in stomach acids. It is also possible that unidentified jellies may comprise the unidentified remains, which occurred in 71% of stomachs and comprised 13.8% of total sample volume; however, a portion of the unidentified remains were likely masticated portions of identified prey items. Table 2 shows the mean percent prey item volumes for the six most common prey items. The six most common prey items can be ranked from largest to smallest mean volumes in

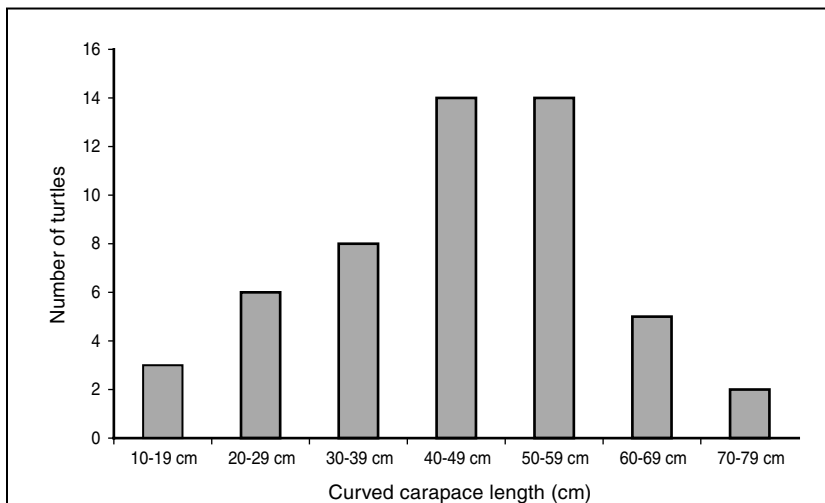


Figure 2

Size distribution for the 52 loggerhead sea turtles (*Caretta caretta*) obtained as samples in the high-seas driftnet fishery. Sizes were grouped into 10-cm size classes.

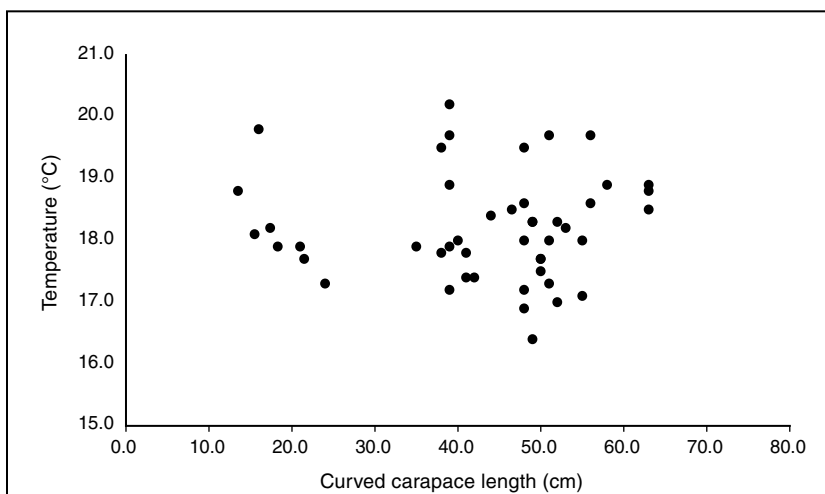


Figure 3

Relationship between curved carapace length (CCL, cm) of loggerhead sea turtles (*Caretta caretta*) and sea surface temperature (SST, $n=52$).

Table 1

Percent occurrence and percentage of total sample volume (volume of prey for all stomachs combined) for prey items (listed to lowest taxonomic order) found in loggerhead sea turtles (*Caretta caretta*, $n=52$ turtles).

Prey group	Occurrence (%)	Percent volume (%)
<i>Carinaria cithara</i> Benson 1835	50.0	43.8
<i>Janthina</i> spp. (includes <i>J. janthina</i> and <i>J. prolongata</i> = <i>J. globosa</i>)	75.0	14.4
<i>Lepas</i> spp. (includes <i>L. anserifera</i> Linnaeus 1767 and <i>L. anatifera anatifera</i> Linnaeus 1758)	51.9	6.7
<i>Veleva veleva</i> Linnaeus 1758 (by-the-wind-sailor)	25.0	10.6
<i>Planes</i> spp. Dana 1852	55.8	1.2
<i>Pyrosoma</i> spp.	21.0	3.4
Fish eggs (<i>Hirundichthys speculiger</i> and unidentified spp.)	25.0	1.9
Cephalopoda (squid and octopus fragments and paralarvae)	21.2	0.5
Debris (plastic, styrofoam, paper, rubber, polypropylene, etc.)	34.6	0.3
Debris (wood, bird feathers)	11.5	<0.1
Salpidae	13.5	0.5
Family Sternoptychidae (hatchetfish)	7.7	0.1
<i>Electrona</i> sp.—Myctophidae	1.9	0.1
Gammaridea and Hyperiidea amphipods	46.2	<0.1
Thecosomate pteropods	13.5	<0.1
<i>Cavolinia globulosa</i> (Gray 1850)	11.5	<0.1
POLYCHAETA (polychaete worms)—Alciopidae	5.8	<0.1
ISOPODA	3.8	<0.1
MYSIDACEA—mysid	3.8	<0.1
<i>Creseis</i> sp.	1.9	<0.1
PHAEOPHYTA (brown algae)— <i>Cystoseira</i> sp.	1.9	<0.1
EUPHAUSIACEA—euphausiid	1.9	<0.1
Unidentified tunicate spp.	13.5	1.0
Unidentified jellies	13.5	0.5
Unidentified crustaceans	5.8	0.5
Unidentified remains	71.2	13.8

the following order: 1) *Carinaria cithara*, 2) *Pyrosoma* spp., 3) *Janthina* spp., 4) *Veleva veleva*, 5) *Lepas* spp., and 6) *Planes* spp.

Mean sample volume was 370.2 [± 319.4] mL. Size of loggerhead sea turtles did not influence the volume of prey items for turtle sizes 35–70+ cm ($F=0.11$, $r^2=0.05$). However, the smaller turtles did have smaller volumes of prey items present in their stomachs, because all turtles 13–34 cm had less than 80 mL total stomach volume (Fig. 4). The size of the turtle did not appear to be a factor in the type of prey ingested. The one exception may be *Veleva veleva*. Turtles smaller than 30 cm CCL in our sample did not ingest this prey item, albeit sample size for less than 30-cm turtles was relatively small compared to the number of 40- and 50-cm size class turtles (Fig. 2); therefore, this apparent trend may not be the case for the general population.

Of the six most common prey items, *Carinaria cithara* had the highest percent sample volume, 43.8% of total sample volume. In general, percent volumes of *C. cithara* were high; 20 of the 27 turtle stomachs

Table 2

Mean percent volume and percent volume ranges for the six most frequently observed prey items found in driftnet captured loggerhead sea turtles (*Caretta caretta*).

Prey item	Mean percent volume	Standard deviation ($\pm\%$)	Range
<i>Janthina</i> spp.	30.7%	34.8%	1–97%
<i>Carinaria cithara</i>	52.8%	33.1%	1–98%
<i>Lepas</i> spp.	19.1%	24.7%	1–99%
<i>Veleva veleva</i>	22.7%	29.4%	1–84%
<i>Planes</i> spp.	5.6%	10.1%	1–38%
<i>Pyrosoma</i> spp.	44.7%	33.7%	1–88%

had percent volumes greater than 30% with this prey item and a number of stomachs had percent volumes greater than 90%. *Janthina* spp. had the next highest

percent sample volume at 14.4%. The percent volume of *Janthina* was generally high; 15 of 37 turtle stomachs had greater than 30% volume of this species. Only 4 of the 13 stomachs with *Verella verella* had greater than 30% sample volume; yet *Verella* made up almost 11% of total sample volume, and one of the stomach samples was almost entirely filled (84% volume) with *Verella* prey. In the samples that contained pyrosomas, this prey item often comprised a high percent of the total gut content—up to 88% stomach volume—and 7 out of 11 stomachs had greater than 30% stomach volume of pyrosomas. *Planes* spp. comprised more than 30% of stomach volume in only 2 of the 29 stomachs containing this species. *Lepas* spp. often occurred in very high percent volumes (up to 99% of total gut content in one sample), although only 6 of 21 stomachs had percent volumes greater than 30% for *Lepas*.

Discussion

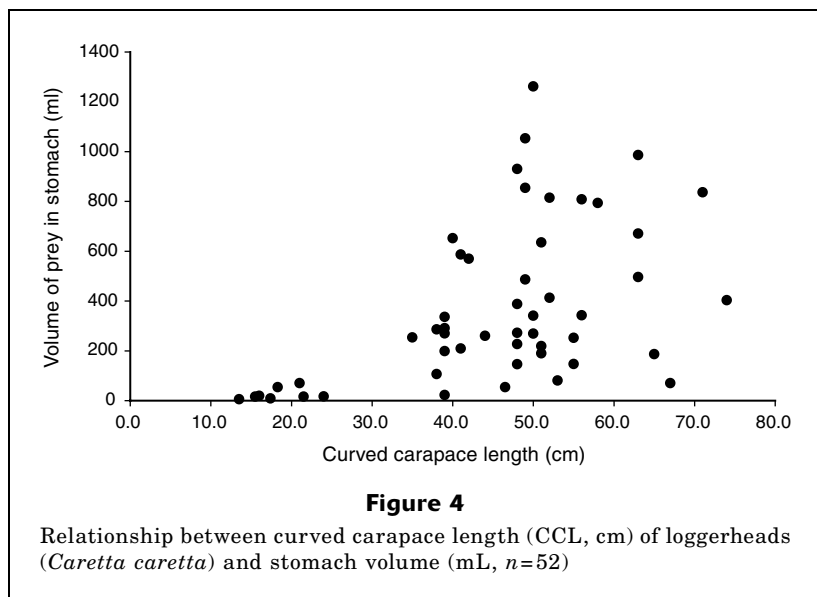
Prey items

Loggerhead sea turtles in North Pacific oceanic habitats are opportunistic feeders that ingest items floating at or near the surface. Availability of prey in the oceanic realm is generally characterized as patchy. This means that the majority of the ocean contains little to no forage, but in some areas high densities of prey can be found. This unpredictability of prey availability likely contributes to the opportunistic feeding behavior of the loggerhead sea turtle. The TZCF, an area of convergence created within the subtropical frontal zone by cooler denser water masses converging and sinking below warmer lighter water masses (Roden, 1991), may serve to help concentrate different prey items. Prey items such as *Verella* can often concentrate in large numbers in such areas (Evans, 1986). All size classes of this sea turtle

collected in our study were found between 16° and 21°C (Fig. 3), which typically are the temperatures that define the subtropical frontal zone and TZCF (Roden, 1991). Eighty-three percent of prey items that were recorded were found floating on the surface or were found on floating objects and would also likely be concentrated at convergent fronts such as the TZCF, driven there by the currents and winds (Polovina, et al., 2000; Polovina et al., 2004). It is suggested that this concentration of prey, along the convergent fronts, may be aggregating the loggerhead sea turtles traveling along this area, which are likely foraging on the increased densities of prey (Polovina et al., 2003a). Turtles in our study smaller than 30-cm CCL had very low volumes of prey in their stomachs. It is unknown whether the paucity of prey items in these turtle stomachs was related to the individual's size, e.g. they were physically not able to capture or ingest certain types of prey items, or perhaps to a lack of experience in foraging due to youth, given that turtles in this size range were determined to be between 1 and 4 years of age by Zug et al. (1995), or to other mitigating factors.

Another indication that loggerhead sea turtles are opportunistic feeders is the presence of oceanic, mesopelagic fish as prey items. The total number of fish (lanternfish and hatchetfish) in the samples was low (only 0.1 % of total stomach volume). These species of fish tend to stay below the photic zone usually at depths greater than 300 m during the day and migrate up near the surface at night. Lanternfish make diel vertical migrations where they reach maximum densities at 100 m at night. During nightly movements some species can also come directly to the surface (Hulley, 1990). Some species of hatchetfish also make diel vertical migrations, which would bring them to within 100 m of the surface at night (Weitzman, 1986; Froese and Pauly, 2003). Because of the low numbers, it is likely that loggerhead sea turtles ingest only dead or debilitated fish rather

than actively hunt and chase such species. The presence of these species also indicates that the turtles may be feeding at night when they would be more likely to encounter the fish during their diel movement. Another prey item exhibiting diel vertical migration is the pyrosomas. Pyrosomas, which are a part of Pacific leatherback sea turtle diets (Davenport and Balazs, 1991), were also present in loggerhead sea turtle stomach samples. Pyrosomas are colonial tunicates comprising individual zooids embedded in the walls of a gelatinous tube. These colonies can become quite large (some greater than 4 meters in length) and tend to drift with ocean currents and accumulate along frontal zones which make them accessible to the sea turtle that forages opportunistically. At least one species (*P. atlanticum*) has been recorded to stay below 300 m during the



day and move up near the surface at night (Andersen and Sardou, 1994); this activity again may indicate active night foraging by the loggerhead sea turtle.

Loggerhead sea turtles may feed by swallowing floating prey whole and also by biting whole prey (or portions off a whole prey) found on large floating objects. A commonly ingested prey item, *Velevella velevella*, known as “by-the-wind-sailor” (Eldredge and Devaney, 1977), typically was found intact. *Janthina* spp., predatory gastropods whose main prey item is *Velevella velevella*, were also frequently found whole in stomachs. Small *Janthina* spp. have been observed directly on *Velevella*, and it has been hypothesized that *Janthina* use *Velevella* to settle on and use the *Velevella* as floatation until they become too large for the host (Bayer, 1963). This behavior may be a reason why whole *Janthina* and *Velevella* were often found together in stomach samples. *Janthina* spp. had been previously noted as a prey item of loggerhead sea turtles in the Azores and South Africa (Dodd, 1988) but was first identified as a prey item in the Pacific Ocean in a preliminary unpublished report by Cooke in 1992²—data that are included in the present study. The high frequency of occurrence of *Velevella velevella* and whole *Janthina* spp. support the hypothesis that loggerhead sea turtles will feed on the surface, swallowing their prey whole. Distribution of *Velevella velevella* is patchy; densities range from <1/1000 m³ to 1000/1000 m³ and densities of *Janthina* spp. are considerably less than those of *Velevella*. When optimum combinations of prevailing winds and currents converge, densities of *Velevella velevella* have been observed to be in concentrations upward of 10,000/1000 m², forming patches so large and dense they have been likened to oil tanker sludge by mariners (Evans, 1986; Parker, personal observ.). It is possible that the one turtle that had a stomach volume of 84% *Velevella* found one of these patches on which to feed. *Velevella velevella* was the one common prey item that was not found in stomachs of turtles less than 30-cm CCL. Because *Velevella* were commonly swallowed whole, it is possible that an average size *Velevella*, which range from 5 to 10 cm (Evans, 1986), might have been too large for a 13–29 cm CCL turtle to swallow whole.

The epibiotic oceanic crabs and the gooseneck barnacles (*Lepas* spp.) usually occur on floating objects; *Planes* sometimes even rides on *Velevella* (Chace, 1951). *Planes* spp. also have been observed and collected from the tail area of loggerhead sea turtle themselves (Davenport, 1994; NMFS observers³). Although approximately 80% of stomach samples with *Planes* spp. contained whole crabs, which were identified as *P. cyaneus*, there

were also numerous masticated crabs and pieces of crabs. These pieces could have been *P. marinus* because whole specimens are necessary to identify *Planes* spp. (Spivak and Bas, 1999); therefore the lowest taxonomic identification for this study was limited to *Planes* spp. Densities of *Planes* spp. and *Lepas* spp. are not well documented but are likely limited by the amount of substrate on which they can settle or on the amount of floating objects available. Natural drifting objects such as tree logs or pumice from volcanic eruptions have been documented since the nineteenth century (Kew, 1893, cited in Jokiel, 1990). The “floating islands,” as they have been called, continue to be important for transporting organisms, from corals to reef fish across the oceans (Jokiel, 1990). Man-made objects also supply substrate and habitat on which different organisms can settle. Buoys and logs that wash ashore often have *Lepas* spp. attached to them, some with *Lepas* spp. covering 100% of the area that was underwater (Parker, personal observ.). Although the frequency of occurrence of *Planes* spp. in stomach samples was high, the percent sample volume of *Planes* was relatively low (1.2% total volume) and the mean volume of *Planes* found was also low (5.6%, Table 2), indicating that this prey was either taken opportunistically or accidentally. It is not known whether the *Planes* were ingested along with other prey items or were actually grazed from larger floating objects. In contrast, *Lepas* spp. often occurred in very high percent volumes, indicating that the turtles were actively grazing these prey. The constant presence of *Lepas* spp. in samples strongly supports the hypothesis that loggerhead sea turtles feed not only by swallowing prey whole, but also by biting prey off larger floating objects. Small chunks of Styrofoam were still attached to the bases of some *Lepas* specimens indicating that the turtle had bitten off some of the floating object itself while grazing on prey found on the floating debris.

Among other floating items that often occurred in the turtles’ stomachs, one common element was fish eggs. Some of these fish eggs were identified as *Hirundichthys speculiger* or flying fish eggs. Amphipods were another common item but comprised a very small fraction of total gut content (<1%), indicating that they were not a targeted prey item. Amphipods were possibly ingested incidentally as epiphytes on other items or as part of the gut contents of other prey items. The proportion of man-made drift debris in our sample was low in contrast to prior studies (Balazs, 1985; Allen, 1992; Bjorndal et al., 1994; Kamezaki, 1994; Tomas et al., 2002). Plastics and other man-made debris were commonly found, occurring in about 35% of stomachs, but they comprised a very small fraction of the total gut content (<1%).

Loggerhead sea turtles also actively forage at deeper depths if high densities of prey items are present. An initial study of pelagic dive behavior of this species (Polovina et al., 2003) indicates that they regularly dive down to depths of 100 m and may also forage at those depths, which may account for the high frequency of occurrence and high total percent volume of

² Cooke, W. J. 1992. A taxonomic analysis of stomach contents from loggerhead turtles (*Caretta caretta*). AECOS report no. 697, 12 p. Prepared for NOAA, NMFS, Honolulu Laboratory, 2570 Dole Street, Honolulu, Hawaii 96822. [Available from AECOS, Inc., 45-939 Kamehameha Hwy., Rm. 104, Kaneohe, Hawaii 96744.]

³ NMFS (National Marine Fisheries Service) observers. 1997–2000. Personal commun. Pacific Islands Fisheries Science Center. 2570 Dole Street, Honolulu, HI 96822-2396.

the heteropod *Carinaria cithara*. Okutani (1961) first recorded sea turtles consuming *Carinaria* (including *Carinaria cithara*, Benson 1835), in the western North Pacific. Heteropods are found in the upper photic zone (within 100 m of the surface) but are not typically a neustonic or floating species. Recorded heteropod densities in the Pacific are variable (<1/1000 m³ to 150/1000 m³, Seapy, 1974, cited in Lalli and Gilmer, 1989). Although these densities seem very low, it is clear that in this area of the central North Pacific heteropods are numerous enough within diving depths of loggerhead sea turtles to make this an attractive prey item for the turtles.

Conclusion—Interactions with fisheries

The bycatch of nontargeted species in different fisheries has been an issue for many years (Wetherall et al., 1993; Wetherall, 1996; Gardner and Nichols, 2001; Suganuma⁴). Bycatch of sea turtles has also been an issue for the conservation management of most sea turtle species. Sea turtle mortalities have occurred in nearly all fisheries (gillnet, driftnet, trawl, and longline). During their transpacific migrations loggerhead sea turtles move through areas of multinational longline fishing (Lewison et al., 2004). Mortalities of sea turtles after longline fishery interactions have been estimated between 28% and 50% by both U.S. and Japanese researchers (Nishemura and Nakahigashi, 1990; Kleiber,⁵ McCracken⁶) and loggerhead sea turtles comprise a large percentage of the sea turtle interactions in longline fisheries, as high as 59% of sea turtles captured in the Hawaii-based longline fleet. The longline fishery as well as various other fisheries in the Pacific (Gardner and Nichols, 2001) have been implicated as part of the reason for recent declines in the loggerhead sea turtle populations both in Japan (Kamezaki and Matsui, 1997; Sato et al., 1997; Suganuma⁴) and also in Australia, and southern nesting areas (Limpus and Couper, 1994; Limpus and Reimer⁷). Research on feeding behavior may help with the mitigation of fisheries interactions.

Learning more about the life history of loggerhead sea turtles and understanding more about the movements, foraging behavior, and prey of these turtles are important for making well-informed management decisions because foraging behavior may change as seasons change and as these turtles move through different habitats (Bjorndal, 1997). Although our study indicates that these turtles forage mainly on floating or near-surface prey in the open ocean, studies in different areas show different feeding habits. The oceanic, near-surface feeding behavior of loggerhead sea turtles is likely one reason for the numerous longline fishery interactions in the central North Pacific. The recorded dive data for these turtles indicate that they spend a large percentage of their time near the surface—as much as 78% of their time is spent within 10 m of the surface (Polovina et al., 2003b). Juvenile loggerhead sea turtles are rarely found in the waters adjacent to Japan (Uchida, 1973); the juvenile turtles are thought to use the Kuroshiro Current to move out into the Pacific and the southern edge of the Subarctic Gyre during their eastward movement toward foraging grounds in the Eastern Pacific (Bowen et al., 1995). In the Atlantic, however, small neonate loggerhead sea turtles have been found associated with drifts of floating material, especially *Sargassum* rafts (Witherington, 2002), and although large, regular drifts of floating material are rare in the Pacific, small loggerhead sea turtles may also be associated with floatsam (Pitman, 1990).

Studies have indicated that foraging changes throughout the lifecycle of loggerhead sea turtles (van Nierop and den Hartog, 1984; Plotkin et al., 1993; Godley et al., 1997; Tomas et al., 2001). In the Pacific, oceanic immature turtles (present study) forage on different prey from that foraged by subadults in the pelagic and neritic areas off Baja California (Nichols et al., 2000; Peckham and Nichols, 2003; Seminoff et al., 2004), and adults in benthic neritic habitats, in turn, forage on different prey near Japan and China (Hitase et al., 2002). Japanese loggerhead sea turtles foraging in the Eastern Pacific target *Pleuroncodes planipes*, the pelagic red crab, which occurs year round off Baja California. These turtles interact with the artisanal fisheries in the area which are both pelagic and benthic fisheries (Gomez-Gutierrez and Sanchez-Ortiz, 1997; Bartlett, 1998; Gomez-Gutierrez et al., 2000; Peckham and Nichols, 2003). Loggerhead sea turtles have also been found on the Gulf of California side of Baja California, likely foraging on the large abundance of invertebrate fauna found there (Brusca, 1980), and these turtles face fishing pressure from the artisanal gillnet fishery in this area (Seminoff et al., 2004).

⁴ Suganuma, H. 2002. Population trends and mortality of Japanese loggerhead turtles, *Caretta caretta*, in Japan. In Proc. Western Pacific Sea Turtle Coop. Res. and Mgmt. Workshop (I. Kinan, ed.), p. 74–77. Western Pacific Regional Fishery Management Council, 1164 Bishop Street, Suite 1400, Honolulu, HI 96813.

⁵ Kleiber, P. 1998. Estimating annual takes and kills of sea turtles by the Hawaiian longline fishery, 1991–1997, from observer program and logbook data. Administrative report H-98-08, 21 p. Southwest Fisheries Science Center, Nat. Mar. Fish. Serv., NOAA, 2570 Dole St., Honolulu, HI 96822.

⁶ McCracken, M. L. 2000. Estimation of sea turtle take and mortality in the Hawaiian longline fisheries. Administrative report H-00-06, 29 p. Southwest Fisheries Science Center, Nat. Mar. Fish. Serv., NOAA, 2570 Dole St., Honolulu, HI 96822.

⁷ Limpus, C. J., and D. Reimer. 1994. The loggerhead turtle, *Caretta caretta*, in Queensland: a population in decline. In Proceedings of the Australian marine turtle conservation workshop (R. James, compiler), p. 39–59. Queensland Dep. Environ and Heritage and Aust. Nat. Conserv. Agency, GPO Box 787, Canberra ACT 2601, Australia.

Converting CCL to straight carapace length (SCL; using the conversion equation: $CCL = 1.388 + (1.053) SCL$, in Bjorndal et al., 2000), size classes found in our study ranged from 11.5 cm to 68.9 cm SCL with a mean of 41.2 [± 12.4] cm SCL. The East Pacific recruits were slightly larger with means of 46.9–61.9 cm SCL (Seminoff et al., 2004). Most of these turtles were immature to subadult turtles, and only a few were adult-size turtles. According to Zug et al. (1995), the loggerhead sea turtles recruiting to the nearshore and neritic habitats of Baja California are likely 10 years of age or older, indicating that these turtles might spend as many as 10 years before arriving at their East Pacific foraging habitat. After returning to the West Pacific, satellite telemetry has found that adult loggerhead sea turtles also reside in both neritic and pelagic habitats (Baba et al., 1992, 1993; Kamezaki et al., 1997; Sakamoto et al., 1997) putting them at risk of interaction with nearshore gillnet fisheries as well as pelagic longline fisheries. Hitase et al. (2002) found a size difference between adults in neritic and oceanic habitats—the postnesting females that chose oceanic habitats were smaller (mainly <80.0 cm) than those that used neritic habitats for postnesting foraging—and also suggested that some adult turtles may not recruit to neritic areas near Japan and China. This may be evidence that some loggerhead sea turtles remain in the oceanic habitat their whole life cycle, returning nearshore only to mate or nest. In the Atlantic, juveniles as well as adults of this species can be found in neritic foraging habitats of the Gulf of Mexico, and these turtles can have interactions with coastal trawl and other coastal fisheries in the area (Plotkin et al., 1993). Juvenile turtles have also been observed and captured in areas along the eastern coast of the United States where they have been found feeding on benthic invertebrates (Burke et al., 1990; Epperly et al., 1990). Very small, neonate loggerhead sea turtles have been found associating with and foraging in *Sargassum* drifts while they are transported by the Gulf Stream into the mid-Atlantic (Witherington, 2002); therefore, the harvest of *Sargassum* or trawling through this area would affect these juveniles. There is some evidence that juvenile Atlantic loggerhead sea turtles may move between coastal and pelagic forage habitats, which would expose them to both coastal and pelagic fisheries (Witzell, 2002). In the Mediterranean, both juvenile and adult loggerhead sea turtles also have variety of foraging behaviors. In the eastern Mediterranean, postpelagic juveniles and adults forage mainly in neritic habitats on benthic prey items where they would interact with coastal trawl and other artesianal fisheries (Godley et al., 1997). In the western Mediterranean, juvenile turtles of this species forage in both pelagic as well as neritic habitats, where they are at risk of fishery interactions in many different fisheries including longline, trawling, and coastal fisheries (Tomas et al., 2001). Postpelagic juveniles in the Mediterranean may be recruits from the Atlantic Ocean or may come from the endemic Mediterranean population. Adult loggerhead sea turtles have been

noted to also move between the eastern and western basins of the Mediterranean in response to seasonal temperature changes (Bentivegna, 2002). During this migration between two benthic feeding areas, some of the turtles would spend extensive amounts of time in the pelagic habitat likely foraging on pelagic prey items. This intra-Mediterranean movement puts these turtles at risk of interactions with a multinational fishery contingent of pelagic as well as coastal fisheries (Bentivegna, 2002).

One possible way to mitigate increased fisheries interactions in the Pacific and other areas might be to identify specific loggerhead foraging areas for protection, such as the area around Baja California, Mexico. In the central North Pacific, our study (Fig. 1), as well as recent satellite tracking studies of juvenile and adult loggerhead sea turtles (Hitase et al., 2002; Parker et al., 2003; Polovina et al., 2004), has indicated that the area west of and around the Emperor seamounts, between 160° and 180°E might also be an important foraging habitat. Most of the turtles in our study were collected from this area (Fig. 1) and one juvenile spent 10 months west of the Emperor Seamounts, between 160° and 170°E, before its satellite transmitter stopped transmitting data (Parker et al., 2003). In this area, the southern edge of the Kuroshiro Extension Current forms numerous eddies that are semipermanent features throughout the year. Reduction of fishing effort or other fishery mitigation techniques in this area may greatly decrease the number of fisheries interactions that Pacific loggerhead sea turtles experience. International cooperation is needed in order to manage these foraging habitats. More studies also need to be done on the ecology of these turtles so that fishery interactions at all life stages can be addressed and so that a total picture of the life history of this species can be obtained.

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