Chelonian Conservation and Biology, 2016, 15(2): 289–292

Marine Macrophytes and Plastics Consumed by Green Turtles (*Chelonia mydas*) in Hong Kong, South China Sea Region

CONNIE KA YAN NG[1,*], PUT O. ANG[2], DENNIS J. RUSSELL[3], GEORGE H. BALAZS[4], AND MARGARET B. MURPHY[1,*]

[1]*Department of Biology and Chemistry and State Key Laboratory in Marine Pollution, City University of Hong Kong, Hong Kong Special Administrative Region, People's Republic of China [kayan.ng.connie@gmail.com; mbmurphy.cityu@gmail.com];*
[2]*Chinese University of Hong Kong, Hong Kong Special Administrative Region, People's Republic of China [put-ang@cuhk.edu.hk/angey192cuhk@gmail.com];*
[3]*Department of Biology, Chemistry and Environmental Science, American University of Sharjah, Sharjah, United Arab Emirates [drussell@aus.edu];*
[4]*NOAA Pacific Islands Fisheries Science Center, National Oceanic and Atmospheric Administration, 1845 Wasp Boulevard, Honolulu, Hawaii 96818 USA [George.Balazs@noaa.gov]*
**Corresponding authors*

ABSTRACT. – **This is the first identification of marine macrophytes consumed by green turtles in Hong Kong, South China Sea: 6 red algae species (*Pterocladiella tenuis*, *Gelidium pusillum*, *Chondrus ocellatus*, *Gracilaria chorda, Grateloupia filicina*, and *Amansia glomerata*), 1 brown alga species (*Lobophora variegata*), and 1 sea grass (*Halophila ovalis*) were identified. Plastics and other foreign materials were also found in the stomach contents of 2 of the 8 individuals sampled.**

CHINESE ABSTRACT. – 這研究首次辨認於南海香港覓食綠海龜所進食的水生植物，當中包括六種紅海藻 (***Pterocladiella tenuis***, ***Gelidium pusillum***, ***Chondrus ocellatus***, ***Gracilaria chorda, Grateloupia filicina*** 及 ***Amansia glomerata***)、一種褐藻 (***Lobophora variegata***) 及一種海草 (***Halophila ovalis***)。在八隻綠海龜的樣本中，有兩隻的胃內也發現塑料及其他異物。

Of the 7 extant sea turtles species, 5 are found in the South China Sea: green turtle (*Chelonia mydas*), leatherback turtle (*Dermochelys coriacea*), olive ridley turtle (*Lepidochelys olivacea*), loggerhead turtle (*Caretta caretta*), and hawksbill turtle (*Eretmochelys imbricata*) (Wang 1993; Chan et al. 2007). The green turtle is the most common turtle recorded in the South China Sea and is the only species that nests in the area, although its nesting population is nearly extinct (Wang 1993; Chan et al. 2007; Wang and Li 2008; Ng et al. 2014). The green turtle, with the exception of the Hawaiian subpopulation, is a globally endangered species (Pilcher et al. 2012) and faces various anthropogenic threats, such as being directly hunted and also as by-catch (Cheng and Chen 1997; Wang and Li 2008), trade pressure (Pilcher et al. 2009; Lam et al. 2011), and habitat degradation of both their nesting and foraging grounds (Wang and Li 2008). A scientific understanding of the complexity and use of their habitat by sea turtles provides a crucial foundation for wildlife conservation and for formulation of effective management plans, e.g., delineation of Marine Protected Areas to properly manage foraging and other vital habitats of the species (Seminoff et al. 2002; Arthur and Balazs 2008; Gaos et al. 2012; Hart et al. 2012). Currently, there are very limited published studies about the diet of green turtles in the South China Sea. This study, therefore, aimed to provide crucially important baseline information to help characterize the ecological niche of green turtles in this region.

Interaction with plastics by marine wildlife, including sea turtles, occurs worldwide and continues to be an emerging threat, including entanglement and accidental ingestion (Wabnitz and Nicholas 2010; Vélez-Rubio et al. 2013). The ingestion of plastics and other anthropogenic debris is likely to cause sublethal effects on sea turtles, namely dietary dilution (McCauley and Bjorndal 1999), interference with energy metabolism or gut function (Lutz 1990), obstruction or displacement of the digestive tract (Bjorndal et al. 1994), and absorption of toxins that may interfere with endocrine function during development and reproduction (Bjorndal 1997; Oehlmann et al. 2009). Although these sublethal effects are difficult to quantify, especially in combination, these effects have conservation implications in that they may result in reduced growth rates, longer developmental periods, and decreased reproductive output and survivorship (McCauley and Bjorndal 1999). This study, therefore, also aimed to identify foreign items found in green turtles in the South China Sea.

Methods. — Stranded sea turtles (n = 8) were found by public reports and collected from locations in Hong Kong, in the northern boundary of the South China Sea. Potential causes of stranding were assessed by gross external examination together with circumstantial evidence, personal observations, and interviews with informants. Food items found in the mouth or stomach were retrieved from the stranded green turtles during necropsy performed immediately after the carcass was found and were identified to the lowest taxon possible. Foreign items such as plastics were also visually identified with the naked eye; this study did not consider microplastics or plastic fragments $<$ 5 mm in size (National Oceanic and Atmospheric Administration [NOAA] 2016). Relative volume of each food or foreign item was assessed visually. Seaweeds found in the stomach contents of stranded green turtles were identified morphologically according to Tseng (1983), and their current nomenclature status was checked with Algaebase (Guiry and Guiry 2016). Curved carapace

Table 1. Physical information and stranding details of each green turtle sampled and the dietary and foreign items found in their stomach contents, except those specimens that were collected from the mouth of a single individual found on 23 May 2013.

Date of collection (d-mo-yr)	Location	Sighting location (coordinates in WGS84)		CCL (cm)	Life stage	Dietary/foreign items found with relative volume
		East	North			
20-Mar-11	High Island, Sai Kung	114°20′51.59″	22°20′42.98″	54	Juvenile	Sea grass *Halophila ovalis* (90%), fish flesh with bone (10%)
18-Nov-11	Pier of Aberdeen	114°8′55.64″	22°14′51.96″	66	Juvenile	Unidentified algae (70%), fragments of fish (10%) and squid (10%), 13 pieces of plastic and a small plastic bag of tissue packaging (10%)
10-Jun-12	Hung Hom	114°11′35.06″	22°18′16.45″	34	Juvenile	A piece of plastic rope
13-Dec-12	Beach of Tai Long Sai Wan, Sai Kung	114°22′13.38″	22°23′53.62″	45	Juvenile	Brown alga *Lobophora variegata* (100%)
2-Apr-13	Rocky shore of Clear Water Bay, Sai Kung	114°18′6.01″	22°16′20.09″	53	Juvenile	Brown alga *Lobophora variegate* (100%)
23-May-13	Sai Chau Mei, near North Ninepin Island	114°20′45.63″	22°15′44.22″	81	Subadult	Red alga *Pterocladiella tenuis* (90%), squid (10%)
14-Sep-13	Tsing Lung Tau, Sham Tseng	114°3′1.25″	22°21′42.26″	46	Juvenile	Red algae, mainly *Gelidium pusillum* (70%) and some *Pterocladiella tenuis* (30%)
23-Sep-13	Sea area of Aberdeen	114°10′18.24″	22°13′37.06″	79	Subadult	Red algae, mainly *Chondrus ocellatus* (70%) and some *Gracilaria chorda* (15%) and *Amansia glomerata* (10%), and a crab leg (5%)

length (CCL), and the sex of each stranded green turtle as determined by external features were also recorded. The following life stages in green turtles defined by carapace length intervals were adopted by making reference to Balazs (1980): a juvenile is a posthatchling individual of up to 67 cm CCL; a subadult is an individual of CCL from 67 to 84 cm; and an adult is a reproductively mature individual of CCL > 84 cm.

Results. — All the stranded green turtles were dead when first found (Table 1). The stranded green turtle found on 23 May 2013 was identified to be a subadult male individual, and its death was attributable to fishing net entanglement. Fishing lines were found tangled around its front flippers. Cause of death and sex of the other individuals could not be determined because of severe decomposition of the carcasses. Dietary items found in the stomach or mouth of 8 green turtles (CCL mean = 58 $\pm$ 17 cm; range = 34–81 cm) (Table 1; Fig. 1) stranded in Hong Kong were composed mainly of red algae, sea grass, and relatively small amounts of fish, squid, and crab. Foreign materials, such as clear plastic fragments and rope strands, were also found in the stomachs of 2 of the 8 individuals sampled (Table 1). The sea grass *Halophila ovalis* predominated in quantity along with fish remnants in the diet of 1 juvenile green turtle (CCL 54 cm). Five red algal species were identified: *Pterocladiella tenuis*, *Gelidium pusillum*, *Chondrus ocellatus*, *Gracilaria chorda*, and *Amansia glomerata*, along with 1 brown seaweed, *Lobophora variegata*. Specimens of brown alga *L. variegata* and red alga *P. tenuis*, remnants of fish and squid, were observed in 2 of the 8 green turtles sampled.

Discussion. — Rhodophyta (red algae) are known to predominate in the diet of green turtles in Australia, Hawaii, and Brazil (Fuentes et al. 2006; Russell and Balazs 2009, 2015; Reisser et al. 2013). Perhaps remnants of fish, squid, and crab found in the stomach contents came from fishing gear or from bait discarded by fishers. In this study, juvenile and subadult green turtles stranded in Hong Kong were found to be basically herbivorous, and their major staple food was red algae. We also observed that the red alga *Grateloupia filicina* was being consumed by green turtles foraging in coastal waters of Vase Rock, Liouciou Island, Taiwan (C.K.Y.N., *pers. obs*.). These red algae species are widely distributed in the Pacific, including the coasts of mainland China, Taiwan, Korea, Japan, and Southeast Asia (Guiry and Guiry 2016). Red algae can also form low lawns on rocks where they produce an extensive mat-like turf made up of *Gelidium pusillum* and *P. tenuis* that green turtles use for food (Russell and Balazs 2009, 2015). The sea grass *H. ovalis* that was identified in the South China Sea diet also occurs widely in the Indo-Pacific from southern Japan and throughout Southeast Asia and Hawaii (Russell et al. 2003; Short et al. 2010). This study presents the documentation and identification of red algae and sea

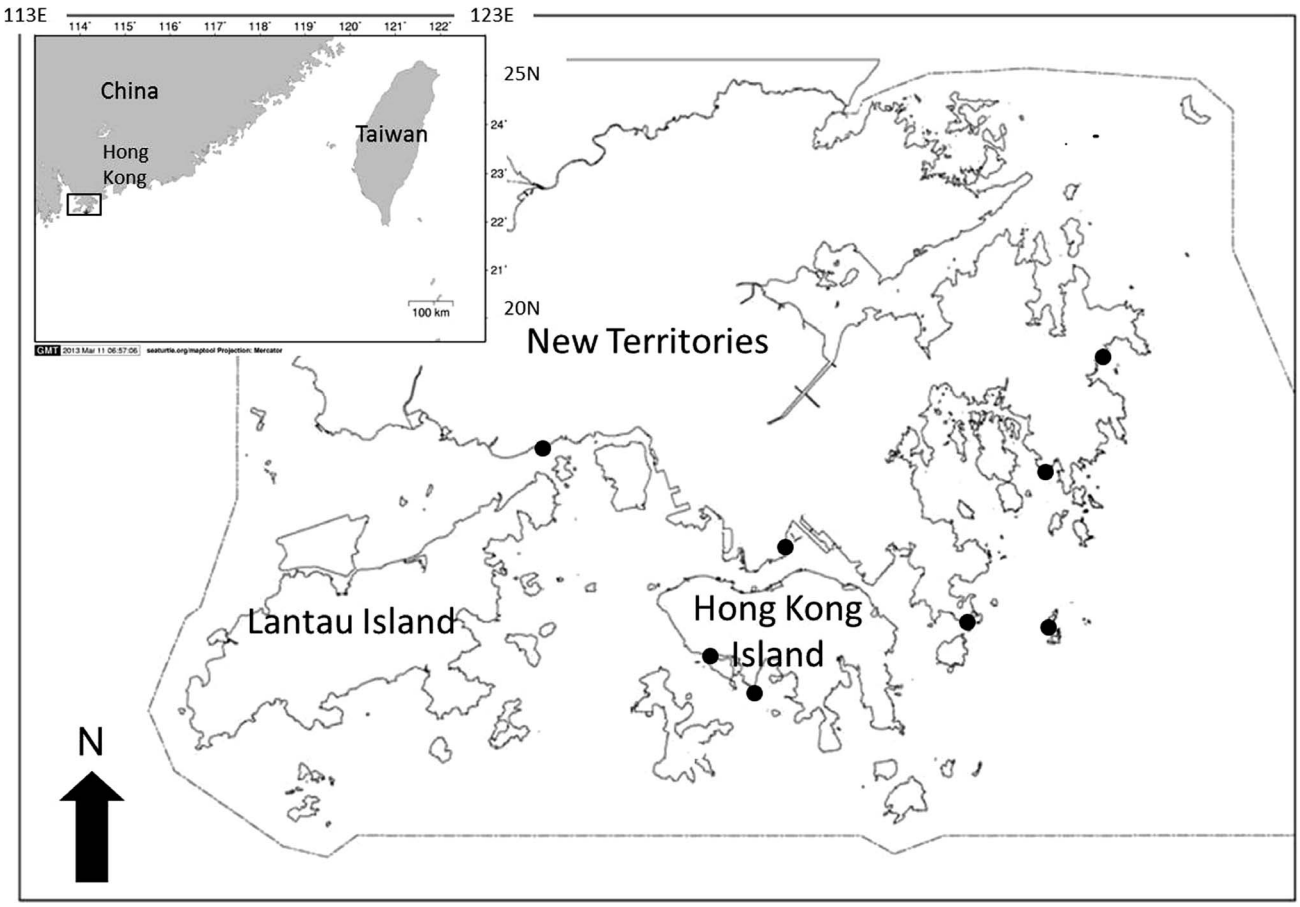

Figure 1. Stranding locations of the sampled green turtles (denoted by black points on the large map). The line in the large map outlines the maritime boundary of the Hong Kong Special Administrative Region.

grass foraged by green turtles in Hong Kong in the South China Sea, which has been underreported.

Ingestion of plastics by sea turtles occurs worldwide and continues to be an emerging threat, including entanglement and accidental ingestion (Russell et al. 2011; Nelms et al. 2015). Schuyler et al. (2013) reported that the probability of green and leatherback turtles ingesting debris is increasing significantly based on 37 studies including data from before 2000 through 2011 and that plastic was the most commonly ingested type of debris. Schuyler et al. (2014) suggested that floating plastic bags might be mistaken for jellyfish, a common natural prey item of some sea turtle species. Plastics were also found in the stomach contents of green turtles in the South China Sea as revealed by the present study. One individual was found to be more severely contaminated with plastics, with its stomach containing plastic fragments as well as a small plastic tissue package. Marine debris pollution is a worldwide problem that should be addressed at scales from the local to the global levels.

Acknowledgments. — Professional and continuous support from Prof. Paul K.S. Lam of the City University of Hong Kong and Thierry Work of the USGS National Wildlife Health Center was indispensable to this study. We would also like to acknowledge the approval of the Agriculture, Fisheries and Conservation Department of the government of the Hong Kong Special Administrative Region of the People's Republic of China for the use of data and green turtle specimens collected in Hong Kong for this study. We thank Tien-yun Tsai, Yao-wen Tsai, Tien-cheng Wang, Sophia Ching-ju Hung, and Jian-wei Zeng for their great efforts to facilitate the observation of foraging green turtles on Liouciou Island, Taiwan.

LITERATURE CITED

ARTHUR, K.E. AND BALAZS, G.H. 2008. A comparison of immature green turtle (*Chelonia mydas*) diets among seven sites in the Main Hawaiian Islands. Pacific Science 62(2):205–217.

BALAZS, G.H. 1980. Synopsis of biological data on the green turtle in the Hawaiian Islands. NOAA Tech. Memor. NMFS-SWFC-7, 141 pp.

BJORNDAL, K.A. 1997. Foraging ecology and nutrition of sea turtles. In: Lutz, P.L. and Musick, J.A. (Eds.). The Biology of Sea Turtles. Boca Raton, FL: CRC Press, pp. 397–409.

BJORNDAL, K.A., BOLTEN, A., AND LAGUEUX, C. 1994. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. Marine Pollution Bulletin 28:154–158.

CHAN, S.K.F., CHENG, I.J., ZHOU, T., WANG, H.J., GU, H.X., AND SONG, X.J. 2007. A comprehensive overview of the population and conservation status of sea turtles in China. Chelonian Conservation and Biology 6(2):185–198.

CHENG, I.J. AND CHEN, T.H. 1997. The incidental capture of five species of sea turtle by coastal set-net fisheries in the eastern waters of Taiwan. Biological Conservation 82:255–259.

FUENTES, M.P.B., LAWLER, I.R., AND GYURIS, E. 2006. Dietary preferences of juvenile green turtles (*Chelonia mydas*) on a tropical reef flat. Wildlife Research 33:671–678.

GAOS, A.R., LEWISON, R.L., WALLACE, B.P., YAÑEZ, I.L., LILES, M.J., NICHOLS, W.J., BAQUERO, A., HASBÚN, C.R., VASQUEZ, M., URTEAGA, J., AND SEMINOFF, J.A. 2012. Spatial ecology of critically endangered hawksbill turtles *Eretmochelys imbricata*: implications for management and conservation. Marine Ecology Progress Series 450:181–194.

GUIRY, M.D. AND GUIRY, G.M. 2016. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org (5 March 2016).

HART, K.M., LAMONT, M.M., FUJISAKI, I., TUCKER, A.D., AND CATHY, R.R. 2012. Common coastal foraging areas for loggerheads in the Gulf of Mexico: opportunities for marine conservation. Biological Conservation 145:185–194.

LAM, T., XU, L., TAKAHASHI, S., AND BURGES, E.A. 2011. Market forces: an examination of marine turtle trade in China and Japan. Hong Kong: TRAFFIC East Asia, 58 pp.

LUTZ, P. 1990. Studies on the ingestion of plastic and latex by sea turtles. In: Shomura, R.S. and Godfrey, M.L. (Eds.). Proceedings of the Second International Conference on Marine Debris. NOAA Tech. Memor. NMFS-SWFS-154. US Department of Commerce, pp. 719–735.

MCCAULEY, S.J. AND BJORNDAL, K.A. 1999. Conservation implications of dietary dilution from debris ingestion: sublethal effects in post-hatchling loggerhead sea turtles. Conservation Biology 13(4):925–929.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA). 2016. Office of Response and Restoration, Marine Debris Program, ''Plastics''. https://marinedebris.noaa.gov/info/plastic.html (6 August 2016).

NELMS, S.E., DUNCAN, E.M., BRODERICK, A.C., GALLOWAY, T.S., GODFREY, M.H., HAMANN, M., LINDEQUE, P.K., AND GODLEY, B.J. 2015. Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science. doi:10.1093/icesjms/fsv165.

NG, C.K.Y., DUTTON, P.H., CHAN, S.K.F., CHEUNG, K.S., QIU, J.W., AND SUN, Y.A. 2014. Characterization and conservation concern of green turtles (*Chelonia mydas*) nesting in Hong Kong, China. Pacific Science 68(2):231–243.

OEHLMANN, J., SCHULTE-OEHLMANN, U., KLOAS, W., JAGNYTSCH, O., LUTZ, I., KUSK, K.O., WOLLENBERGER, L., SANTOS, E.M., PAULL, G.C., VAN LOOK, K.J.W., AND TYLER, C.R. 2009. A critical analysis of the biological impacts of plasticizers on wildlife. Philosophical Transactions of the Royal Society of London Biological Sciences 364:2047–2062.

PILCHER, N.J., CHALOUPKA, M.Y., AND WOODS, E. 2012. *Chelonia mydas* (Hawaiian subpopulation). IUCN Red List of Threatened Species 2012: e.T16285718A16285879. http://dx.doi.org/10.2305/IUCN.UK.2012-1.RLTS.T16285718A16285879.en (5 August 2016).

PILCHER, N., CHAN, E.H., AND HIEW, K. 2009. Battling the direct poaching of sea turtles in south-east Asia. Workshop on Regional Cooperation to Address Poaching of Sea Turtles, Kuala Terengganu, Malaysia, 3 pp.

REISSER, J., PROIETTI, M., SAZIMA, I., KINAS, P., HORTA, P., AND SECCHI, E. 2013. Feeding ecology of the green turtle (*Chelonia mydas*) at rocky reefs in western South Atlantic. Marine Biology 160:3169–3179.

RUSSELL, D.J. AND BALAZS, G.H. 2009. Dietary shifts by green turtles (*Chelonia mydas*) in the Kane'ohe Bay region of the Hawaiian Islands: a 28-year study. Pacific Science 63:181–192.

RUSSELL, D.J. AND BALAZS, G.H. 2015. Increased use of non-native algae species in the diet of the green turtle (*Chelonia mydas*) in a primary pasture ecosystem in Hawaii. Aquatic Ecosystem Health and Management 18(3):342–346.

RUSSELL, D.J., BALAZS, G.H., PHILLIPS, R.C., AND KAM, A.K.H. 2003. Discovery of the sea grass *Halophila decipiens* (Hydrocharitaceae) in the diet of the Hawaiian green turtle, *Chelonia mydas*. Pacific Science 57(4):393–397.

RUSSELL, D.J., HARGROVE, S., AND BALAZS, G.H. 2011. Marine sponges, other animal food and nonfood items found in digestive tracts of the herbivorous marine turtle *Chelonia mydas* in Hawaii. Pacific Science 65(3):375–381.

SCHUYLER, Q., HARDESTY, B.D., WILCOX, C., AND TOWNSEND, K. 2013. Global analysis of anthropogenic debris ingestion by sea turtles. Conservation Biology 28(1):129–139.

SCHUYLER, Q., WILCOX, C., TOWNSEND, K., HARDESTY, B.D., AND MARSHALL, N.J. 2014. Mistaken identity? Visual similarities of marine debris to natural prey items of sea turtles. BMC Ecology 14:14.

SEMINOFF, J.A., RESENDIZ, A., AND NICHOLS, W.J. 2002. Home range of green turtles *Chelonia mydas* at a coastal foraging area in the Gulf of California, Mexico. Marine Ecology Progress Series 242:253–265.

SHORT, F.T., CARRUTHERS, T.J.R., WAYCOTT, M., KENDRICK, G.A., FOURQUREAN, J.W., CALLABINE, A., KENWORTHY, W.J., AND DENNISON, W.C. 2010. *Halophila ovalis*. IUCN Red List of Threatened Species. Version 2014.2. www.iucnredlist.org (1 November 2014).

TSENG, C.K. 1983. Common Seaweeds of China. Beijing: Science Press, 316 pp.

VÉLEZ-RUBIO, G.M., ESTRADES, A., FALLABRINO, A., AND TOMÁS. J. 2013. Marine turtle threats in Uruguayan waters: insights from 12 years of stranding data. Marine Biology 160:2797–2811.

WABNITZ, C. AND NICHOLS. W.J. 2010. Plastic pollution: an ocean emergency [editorial]. Marine Turtle Newsletter 129:1–4.

WANG, Y.M. 1993. Current status and prospect of sea turtle resources and research in South China Sea. Chinese Journal of Ecology 12(6):60–61.

WANG, Y.M. AND LI, W. 2008. Sea turtle survey, monitoring and awareness promotion programme in Mainland China. Final Report supported by US Fish and Wildlife Service, Department of Interior, 47 pp.

Received: 5 March 2016
Revised and Accepted: 16 August 2016
Handling Editor: Jeffrey A. Seminoff