

Two lines of evidence indicate green sea turtle *Chelonia mydas* grazes the aggressive macroalgae *Chondria tumulosa* at Midway Atoll (Kuaihelani), Papahānaumokuākea Marine National Monument

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Abstract

Underwater video recordings and a necropsy of a recently dead adult female confirm that the green turtle, *Chelonia mydas*, readily grazes the aggressive red alga *Chondria tumulosa*. Present in Papahānaumokuākea Marine National Monument since 2016, *C. tumulosa* has demonstrated the capacity to aggressively overgrow live coral and successfully attach to calcareous reef substrate. A group of three turtles was observed grazing with one turtle exhibiting a burst of up to 18 bites of *C. tumulosa*, in a 95 sec interval. Further, upon examination of a freshly dead female turtle of the same species, fragments of *C. tumulosa* were identified in the esophagus, crop and likely also in the feces; in the freshly consumed food matter *C. tumulosa* constituted approximately 25% of plant material and was the same color as the upper canopy tissues we observed being grazed in the reef videos. This evidence, collected within one month's time, demonstrates that this native megaherbivore has the potential to remove substantial *C. tumulosa* biomass and highlights a potential role for *C. mydas* in the control and distribution of *C. tumulosa*.

Introduction

The novel, nuisance alga *Chondria tumulosa* A.R. Sherwood & Huisman 2020 (Rhodophyta; Sherwood et al. 2020) was first observed in 2016 at Manawai (Pearl and Hermes Atoll) in the Northwestern Hawaiian Islands and then collected for taxonomic identification in 2019 (Sherwood et al 2020). By 2021, this alga dominated the reefs at Manawai and had spread northwest to two other atolls (Kuaihelani and Hōlanikū) of the Papahānaumokuākea Marine National Monument (PMNM), (Lopes et al. 2023, Fumo et al. 2025). Since its description in 2020, its ecological dominance has focused critical attention on the need to better understand this alga, its origins, physiology and changes in its distribution (Lopes et al. 2023; Fumo et al. 2024, 2025; Nichols et al. 2025a, Richards Donà in prep.).

We now know that *Chondria tumulosa* forms thick mats (> 6 cm deep) which actively overgrow and replace live coral cover at depths from <2 to 19 m (Sherwood et al. 2020). The mechanism through which replacement happens is not yet clear: it is unknown whether the mats overgrow reef substrate by directly smothering corals through contact or indirectly kill them by blocking irradiance, reducing dissolved oxygen, or lowering pH as reported by Martinez et al. (2012) for another mat forming red alga. Large mats of *C. tumulosa* are now common on these three atolls, and, it is clear from the observed rapid spread that this alga has the capacity to aggressively outcompete established corals for reef substrate (Lopes et al. 2023, Fumo et al. 2024). Eggertsen et al. (2025) identified mat formation as a potent, functional trait for weedy red algae, and predicted invasions of *C. tumulosa* in other parts of the Hawaiian archipelago.

Recent field observations: During the June 2025 field season, collection efforts and observations were made within Midway Atoll National Wildlife Refuge at a lagoonal patch reef known as MID 33 (named in July 2022 by NOAA-Office of National Marine Sanctuaries while performing *C. tumulosa* distribution surveys). This reef has since become a study site for this alga. The reef consists of a series of shallow

hardbottom knolls surrounded by sand flats of about ~2.5 m depth. Each discrete knoll is relatively small in area ($\leq 100 \text{ m}^2$ area) and rises to within ~ 1 m of the surface (all authors, pers. observation). While benthic cover is now principally seen as the gold-color canopy of *C. tumulosa* (Fig. 1A), other macroalgal species include *Microdictyon setchellianum*, and species of *Cladophora*, *Padina*, a variety of crustose coralline algae and epiphytic species of *Jania* sp. (Abbott 1989; Tsuda 2014). Live (or partially live) *Porites* spp. and *Pocillopora* spp. colonies are scattered among the algal cover (Fig. 1D, F).

Upon vessel arrival at the site on two occasions, green turtles or honu (*Chelonia mydas*), were observed surfacing in the area (Fig. 2). Once in the water, we easily observed three species of native urchins, *Urosalpinx* or *Echinometra mathaei* (Fig. 1B, E), the slate pencil urchin, *Heterocentrotus mamillatus* (Fig. 1C), and the collector urchin, *Tripneustes gratilla* (Fig. 1E), interacting with the alga. The urchin grazing halos, however, are limited to small areas just outside of their immediate locations or holes in the reef (Fig. 1B, C, E). Additionally, an endemic saddle wrasse, *Thalassoma duperrey*, was observed to take occasional small bites of individual axes of *C. tumulosa*. These small bites, the small body size of this herbivore, and the small number of fish we observed appear insufficient to control the biomass of *C. tumulosa* present at this site in the Kuaihelani lagoon.

It is likely that researcher presence altered the feeding behavior of all herbivores to some extent. To determine whether fish or other herbivores were regularly grazing on *C. tumulosa* at MID 33 when humans are absent, we set up and programmed underwater cameras to record activity on the reef up to 24 h after camera deployment and retrieved them within the following few days (see *Materials and Methods* below). In this manner, we obtained novel video recordings documenting the arrival and grazing activity of an important reef megaherbivore, *Chelonia mydas*. This important Hawaiian reef ecosystem engineer visibly consumed *C. tumulosa* with large and forceful bites and in doing so left disruptions in the canopy of mats (Fig. 1A), reducing *C. tumulosa* on a larger scale than was observed for fish or urchin grazing.

Multiple grazing events by up to three turtles (Fig. 3 and videos) started at 10:03 am and ran for 50 min 8 sec. For one turtle, marked as '103MW', grazing took place in 11 separate events. Events ran from 1 bite sec^{-1} to 10 bites in 133 sec with a remarkable burst of 18 bites in 95 sec, for a total of 67 bites in 15 min 39 sec^{-1} of time on the reef and an average of 14.0 sec bite^{-1} for this individual. 103MW is a female adult, reproductively active since at least 2022 when she nested at Lalo (also in the Northwestern Hawaiian Islands-NWHI) and has been documented basking at Kuaihelani multiple times since 2021. While substantially smaller than the two unmarked turtles, she was able to rip and tear axes of *C. tumulosa* while leaving a distinct plume of sediment flushed from nearly each bite (Fig. 3B). Many fragments can also be seen floating. Analyses of this footage also show that turtle grazing attracted a number of other fish to the area, including *T. duperrey* and endemic blue-striped butterfly fish, *kikākapu*, or *Chaetodon fremblii*. Turtle grazing also removed golden canopy and revealed visible bite marks (estimated ~ 50 cm^2) into the purple understory tissues of this alga (Fig. 1A).

There were frequent interludes of nearby, but off-screen, activity that lasted for a total of 10 min 26 sec, where no turtle was on screen. Numerous forays of continued grazing outside the field of view could be identified by sediment plumes (Fig. 3B and video 4) and algal axes floating past the camera. The two unmarked turtles were also observed grazing, swimming, and surfacing in the field of view, for a total of 26 min 5 sec, a little over half of the video time.

A second video recording of 50 min 9 sec started at 10:50 am, and had only one unmarked turtle in the field of view two times for a total of 2 min 3 sec. Several grazing events were observed in that timeframe but for over 95 % of the video, no turtle was observed.

In a tragic coincidence, on July 29, 2025 a stranded dead adult female green turtle was located on land in the interior of Eastern Island, one of three small coral islets within the atoll. This female was the likely progenitor of several non-nesting crawl events on the beaches of Eastern Island in the days just prior to her death. The interior of the island, dominated by World War II era runways, is an inhospitable environment for an adult sea turtle. This unmarked, gravid female was collected and frozen whole for necropsy at a later date: the necropsy was performed on August 7, 2025. Examination of the digestive tract contents allowed us to observe fresh samples of her recently consumed food items (Fig. 4A). While the consistency of the feces is well macerated, resembling a fairly homogenous paste, *C. tumulosa* is visibly recognizable nonetheless (Fig. 4B). Once formalin-preserved plants were examined microscopically, preserved specimens of these digestive tract contents yielded at least 21 fragments of *C. tumulosa* that ranged in size from 2 to 10 mm in length; axes were ~ 1 mm in diameter. Fragments were soft degraded tissues, making cross-section difficult but overall traits were consistent with *C. tumulosa* following descriptions found in Sherwood et al. (2020). Additionally, longer pieces of other red algae were identified such as multi-branched axes of *Hypnea* spp at > 12 mm lengths and intact lamina of *Amansia* spp which were also intact and ~ 9 mm in length.

Future directions

Eggertsen et al. (2025) suggest “palatability” as a functional trait which can help predict an alga’s invasive potential, being linked to a species’ competitive success through “top-down control by herbivores” reducing biomass. While foraging green turtles may help crop biomass, at the same time there is potential for their role in further spread, considering *C. tumulosa*’s photosynthetic performances (Richards Donà et al. in prep) and fragmentation tendencies. Green sea turtle is known to eat other invasive red algae that are part of the non-native flora of the Main Hawaiian islands including: *Acanthophora spicifera*, *Gracilaria salicornia* and *G. tikvahiae*, as well as *Hypnea musciformis* (Russell and Balazs 2000) and likely *Eucheuma denticulatum* given observations in Kāneohe Bay in 2018 (Bahr et al. 2015, 2018).

Our observations demonstrate the palatability of *C. tumulosa*, sensu Eggertsen et al. (2025) for *Chelonia mydas* suggesting the green turtle has a role to play in control of this aggressive species. While *C. tumulosa* has been present at Kuaihelani since at least 2022, we do not know how long this grazing behavior has been occurring in this location. The contribution *C. tumulosa* makes to the whole diet of

animals at Kuaihelani remains unknown, although the necropsy gives us a slight indication. The nutritional value of *C. tumulosa* to green sea turtles remains unknown (c.f. Siegwalt et al. 2022 for a seagrass). Furthermore, we do not know whether there is truly a preference for *C. tumulosa*, or whether its consumption in this location is borne out of availability at Kuaihelani (c.f. Bahr et al. 2018). In the Caribbean, food preferences of green sea turtles are suspected to have played a role in the spread and distribution of an introduced seagrass (*Halophila stipulacea*) in part because it is a less preferred food source when compared with the two principal native species which constitute seagrass meadows there (Christianen et al. 2019, Siegwalt et al. 2022, Whitman et al. 2019).

Despite the limited observations of grazing and a single documented confirmation of ingestion and digestion, this knowledge, collected within one month, elevates the role of the green turtle in opportunities for control of this alga, and as a remote possibility of the species role as a vector for spread of *C. tumulosa*. This new knowledge needs to be folded into management actions across the Hawaiian archipelago. Beginning each spring, the breeding turtle populations from both the Monument and the Main Hawaiian Islands migrate to nesting sites in the NWHI: 96% of Hawaiian green sea turtle nesting occurs at Lalo for several months before the individuals return to their respective foraging grounds (Balazs et al. 2015, Seminoff et al. 2015). As a result of this insight, the Monument has reprioritised the need to deploy eDNA sampling at Lalo, given that atoll's central role in turtle movement throughout the Hawaiian archipelago. This testing will capitalize on a low cost procedure for eDNA sampling and *C. tumulosa* primer which were recently validated within the Monument (Nichols and Marko 2025, Nichols et al. 2025b).

Materials and Methods

Camera observation From June 4 – July 1, 2025 the well-established *Chondria tumulosa* population at patch reef MID 33 (28°14'35.7"N 177°20'15.0"W) was repeatedly visited for observational studies and sample collection for related acclimation studies. A GoPro Hero 13 camera in underwater housing was attached to a simple upright piece of rebar facing the reef substrate and was secured in a concrete block, resting in the sand (Fig 5). In order to allow any animals disturbed by vessel arrival and human activity to return to the area, the camera was set on delayed capture settings and set to record for a duration of three hours. A full three hour recording was never achieved for a single deployment. 282.5 total minutes of video over the course of an anticipated 9 hours of recording time were captured on 3 days/deployments (June 13, 21 and Jul 1). In addition, a carangid fish (possibly *Caranx ignobilis*) dislodged the position of the camera at one point, resulting in 50 minutes of video (included in the above total of 282.5 minutes) no longer focused on the reef. Inherent limitations of the technology included size of memory card and overheating issues (known for this model) which caused the camera to turn off prematurely in order to cool down. The resolution of file recorded also interacted to limit the unit's ability to record for three hours as dictated by the settings.

The time of day at which recordings began varied: two sets of observations were captured at 12:00 pm. One observation began recording at 10:00 am. The time and date of the observation described in this

paper was at 10:00 am on Jul 1, 2025. One turtle was already in the frame at the start of the recording so here we report on a minimum amount of time spent grazing.

Over the course of the deployments, we repositioned the camera twice from its original location (Fig. 5), attempting to capture both wide angle and up-close shots of interactions. Images were grabbed from the archived videos as screenshots and modified with the auto feature in Apple software “Photos” Version 10.0 (760.6.150) for light, white balance, levels and sharpness.

Necropsy Standard necropsy procedures from the manual *Sea Turtle Necropsy Manual for Biologists in Remote Refuges* (Work 2000) were followed. Esophageal and crop contents were sampled and preserved in a 10% formalin (90% seawater) solution. Photos of stomach and intestine contents were taken during the necropsy; preserved samples and photos were shared with algae experts (co-authors) for species identification and verification.

Declarations

Acknowledgments

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Figures

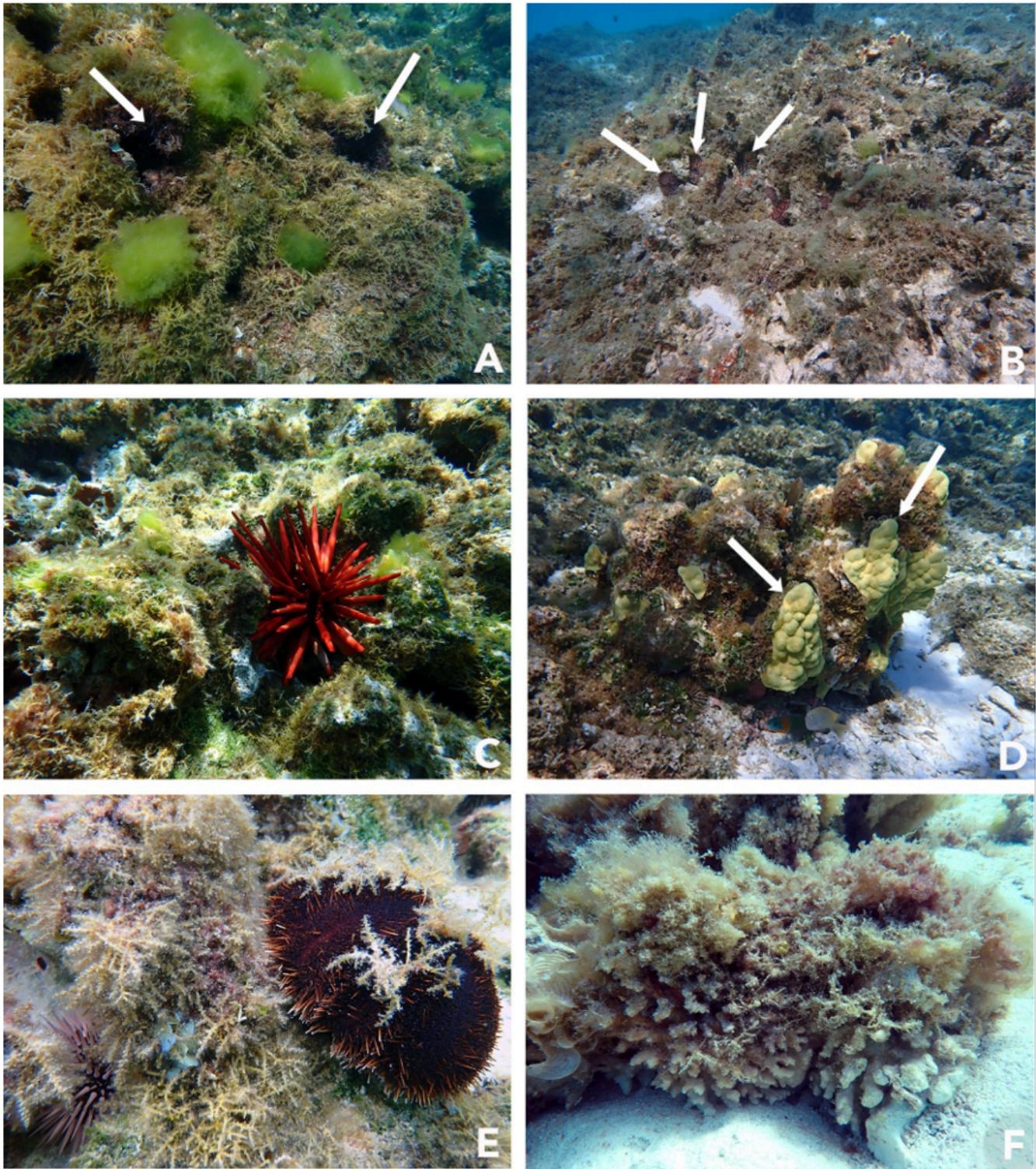


Figure 1

Dominant *Chondria tumulosa* cover at MID33 with some visible urchin species. A) Reef covered in *C. tumulosa* mats with dark understory areas where the mat canopy has been removed in ovalish shaped regions, amidst golden canopy (arrows). Also observed: discrete patches of green *Cladophora* spp. B) *Echinometra mathaei* urchin burrows (arrows) within the *C. tumulosa* cover. C) *Heterocentrotus mamillatus* slate pencil urchin within mats. D) *Porites lobata* stony coral colony with ~ 20% live coral

tissue cover remaining (arrows) under growing *C. tumulosa* mats. E) *E. mathaei* and *T. gratilla* and with *C. tumulosa*. F) Nearly complete overgrowth of *C. tumulosa* on *Pocillopora* spp. colony. Photos from 2024 and 2025; photo credits: all authors and Jonathan Plissner, photo D.



Figure 2

Chelonia mydas, spotted at surface departing from MID33 as the vessel arrived.

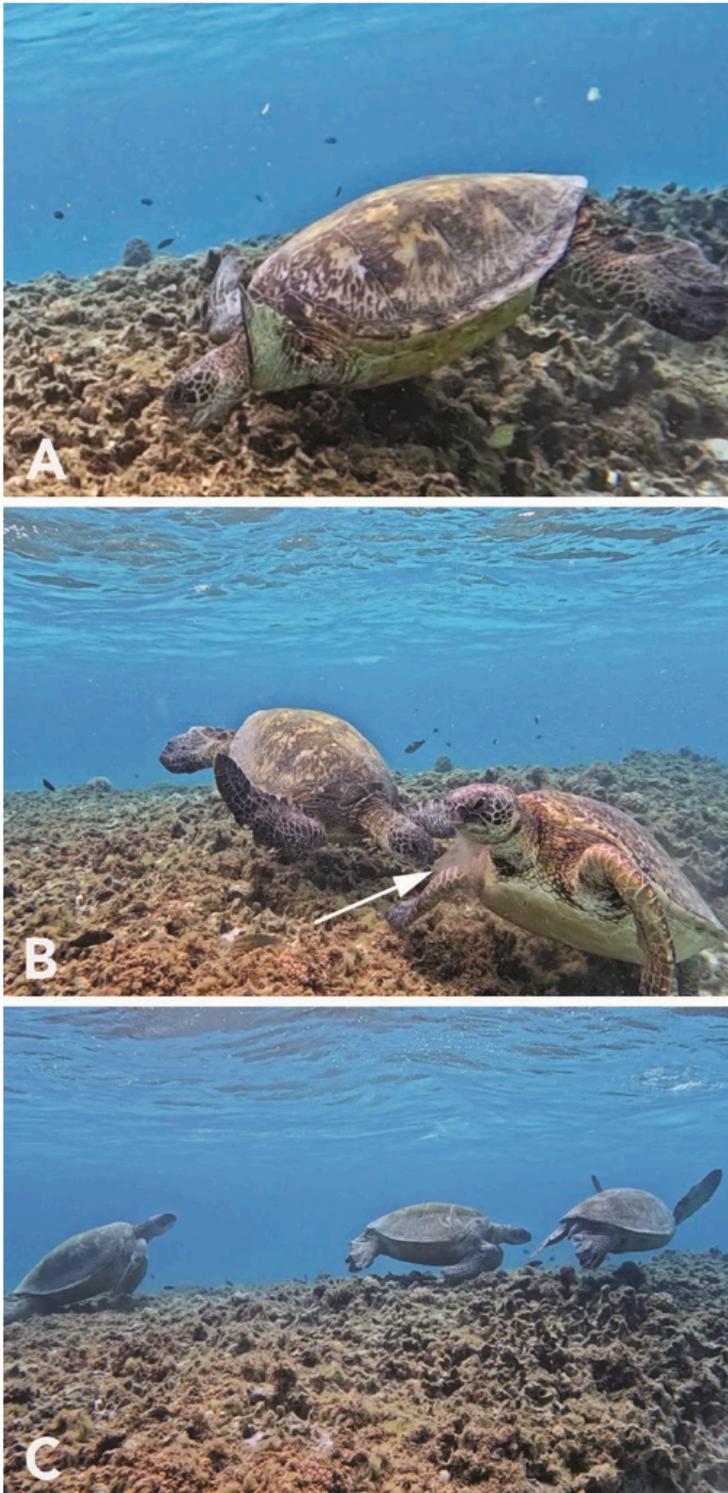


Figure 3

Chelonia mydas at MID33. A) Open-mouthed female taking bites of *C. tumulosa*. B) Two females feeding with visible sediment plume exiting the mouth of the turtle in the foreground (arrow) and algal debris in the water column above the reef. C) All three turtles captured in the same frame.

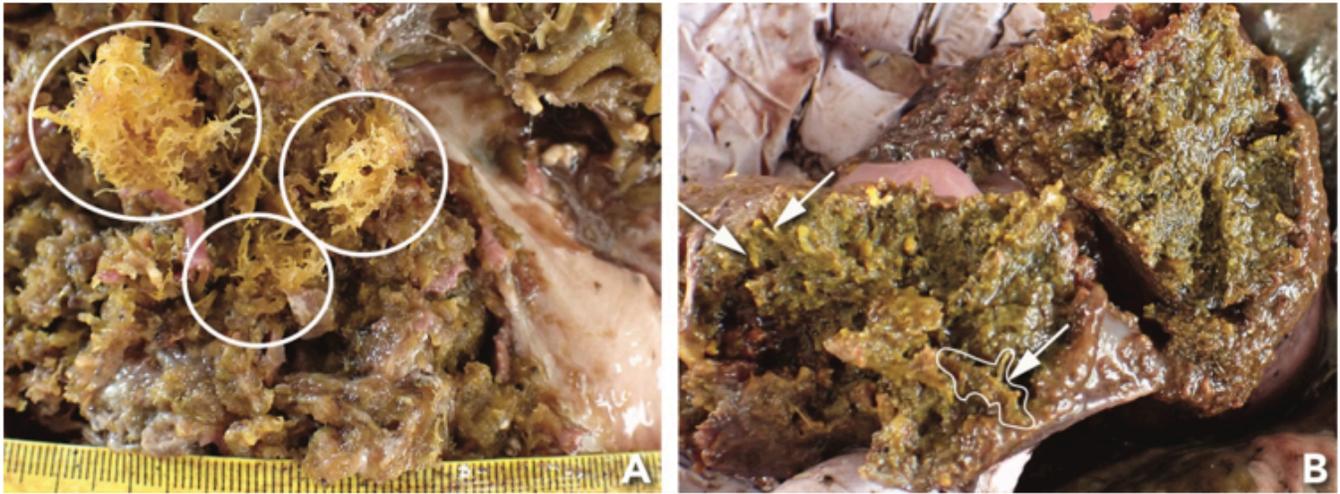


Figure 4

Digestive tract contents of stranded female sea turtle. A) Upper digestive tract with clearly recognizable, undigested *C. tumulosa* fragments (white circles). B) Fecal matter in the lower intestine with small, mostly digested pieces of *C. tumulosa* (white arrows). One fairly intact piece outlined in white.



Figure 5

A) Snorkeling researcher with video camera setup. B) Camera from angle showing distance from reef.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [C.mydasandC.tumulosa1103MWeatingandturtleinteraction.mp4](#)
- [C.mydasandC.tumulosa2twoturtles.mp4](#)
- [C.mydasandC.tumulosa3threeturtles.mp4](#)
- [C.mydasandC.tumulosa4plume.mp4](#)