

Running Head

Body Condition Index of Sea Turtles

Title

**Differences in the morphological body condition index of sea turtles between species
and size classes**

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Abstract

The body condition of animals is an important indicator of their habitats and the effects of anthropogenic activities and pollution. Body condition indices calculated from morphometric measurements have been widely employed as they are easy to use and inexpensive. In sea turtles, Fulton's condition index, calculated as the bodyweight divided by the cube of straight carapace length (SCL), has been commonly used and has been proposed that an index of ≥ 1.2 indicates a good body condition. However, comparing Fulton's condition index between different species and size classes is problematic as it does not consider the mass-length relationship. In this study, we conducted a meta-analysis to evaluate the differences between sea turtles. A literature review indicated that most studies reported the SCL-based Fulton's condition index for green turtles (*Chelonia mydas*), followed by loggerhead turtles (*Caretta caretta*) and hawksbill turtles (*Eretmochelys imbricata*). Therefore, we compared the values reported for healthy turtles of these three species. Meta-analysis supported the adequacy of 1.2 as a threshold in juvenile and adult green turtles and large juvenile and adult loggerhead turtles. High Fulton's condition index values were found for hatchlings and post-hatchlings of all three species and small loggerhead turtle juveniles. Low Fulton's condition index values were found for hawksbill turtles, particularly small juveniles. The differences in the Fulton's

37 condition index between species and size classes indicated that it should be used carefully
38 as a threshold for health condition evaluation.

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40 **Key words:** Carapace length; Fulton's condition index; health condition; literature
41 review; meta-analysis; morphometry

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INTRODUCTION

The health and body condition of endangered animals provide fundamental information in conservation biology. Body condition is an important indicator for evaluating habitats and the effects of anthropogenic activities and pollution (Johnson, 2007; Clukey *et al.*, 2017; Rodriguez & Heck, 2020). Body condition has been assessed using various techniques, including haematology and plasma biochemistry (Stevenson & Woods, 2006; Wang *et al.*, 2020; Kophamel *et al.*, 2022). The morphological body condition indices of endangered animals have been widely employed because they are easy to use and inexpensive. Various morphological condition indices have been suggested (Stevenson & Woods, 2006; Peig & Green, 2010; Sönmez, 2019); Fulton's condition index is one of the most common and is calculated as the bodyweight divided by the cube of body length (Ricker, 1975).

The body condition of sea turtles has recently become an important topic regarding their conservation as affected by marine debris (Clukey *et al.*, 2017) and fibropapillomatosis prevalence (Rossi *et al.*, 2019). Body condition indices based on morphometry have been widely used since Bjorndal *et al.* (2000a) calculated Fulton's condition index for juvenile green turtles (*Chelonia mydas*) as bodyweight / (straight carapace length [SCL])³. In addition, the haematology and plasma biochemistry of sea

turtles have also been investigated (Anderson *et al.*, 2011; Komoroske *et al.*, 2011). Morphological condition indices of sea turtles include not only the Fulton's index, but also simple mass and length ratios (Patino-Martinez *et al.*, 2012), relative factors incorporating mass-length relationships (Fukuoka *et al.*, 2015), and residuals from the mass-length relationship (Jessop *et al.*, 2004).

Fulton's condition index is a widely used simple metric, but it should be carefully interpreted. The index assumes isometric growth; therefore, comparing values between different size classes may be problematic (Peig & Green, 2010). Interspecific or interpopulation comparisons are also difficult when body dimensions or growth patterns differ. In sea turtles, Fulton's condition index has been widely used as a rough measure of nutritional status and health (Bjorndal *et al.*, 2000a; Diez & van Dam, 2002) and values exceeding 1.2 have conventionally been interpreted to indicate a good body condition (Norton & Wyneken, 2015; Maulida *et al.*, 2017; Adnyana *et al.*, 2020). However, the threshold value may change, considering that there are interspecific and/or intraspecific differences in the body shape and growth pattern of sea turtles (Wabnitz & Pauly, 2008; Álvarez-Varas *et al.*, 2019). Additionally, the carapace length, which has been used as a representative length for calculating the index, can be measured in several ways, such as by using the SCL vs. curved carapace length (CCL) (Bolten, 1999). Evaluating these

differences is important to establish a baseline condition index for sea turtles.

In this study, we reviewed the literature on morphological condition indices in sea turtles and conducted a meta-analysis of Fulton's condition index in sea turtles. This study summarises the prevalence of various morphological condition indices among sea turtle species to elucidate the knowledge gap regarding their health status. We then evaluated the differences in Fulton's condition index between species and size classes to establish a baseline sea turtle body conditions. We also evaluated differences in the index values when different length metrics were used.

MATERIALS AND METHODS

Literature review

We searched for studies using Google Scholar and Web of Science with the queries "sea turtle" and "body condition index" or "Fulton index" on 5–7 August, 2020 and 12–13 April, 2021. We additionally searched PubMed on 5–6 April, 2022, but did not include references published after April 2021. We reviewed the references therein and retained literature on morphological condition indices.

Meta-analysis of Fulton's condition index

The average and standard deviation (SD) or standard error (SE) of Fulton’s condition indices ($\text{kg}/\text{cm}^3 \times 10^4$) calculated from the SCL in the literature were used. When the data appeared only in figures, they were extracted using Plot Digitizer 2.6.8 (Huwaldt, 2001). When the data were presented as median, maximum, minimum, and/or quantile values, we estimated the average and SD using the method reported by Wan *et al.* (2014). The SCL can be measured as the length from the anterior point at the midline to the posterior notch at the midline (minimum SCL [SCLmin]) or the tip (standard SCL [SCLnt]) (Bolten, 1999). We could not differentiate these measurements in the following analysis as the literature sometimes did not clearly present which was used; however, we simulated the effects based on conversion equations (see below). We excluded studies that reported the body condition indices of unhealthy turtles to explore the standard baseline values for healthy turtles. Unhealthy turtles included dead and injured turtles, those noted as “unhealthy” in the original texts, and those with tumours with scores (Work *et al.*, 1999) of 2–3 or labelled as “developed”, “moderate”, or “severe”; however, we retained the data of turtles with “mild” tumours or a tumour score of approximately 1. We also removed literature that may have contained data on the same individuals based on the authors, locations, and study periods.

In addition to the dataset from the literature, we calculated Fulton’s condition

indices from the unstructurally searched literature that provided the bodyweights and SCLs of individuals. Furthermore, to complement the data of hawksbill turtle (*Eretmochelys imbricata*) hatchlings, we measured the bodyweight and SCL of 20 hawksbill turtle hatchlings each from 8 and 13 nests at Lankayan and Selinggaan hatcheries, Sabah, Malaysia, respectively. We calculated the Fulton's condition index and its average $\pm$ SD at each rookery by randomly selecting one hatchling from one nest. A full list of literature compiled in this study is provided in Supplementary Table S1.

Fulton's condition index has mainly been reported for three species: green turtles, loggerhead turtles (*Caretta caretta*), and hawksbill turtles (see Results). Therefore, we focused on these three species in this study. Additionally, we categorised the data into one of three size classes: "hatchling and post-hatchling", "small juvenile", and "large juvenile and adult". The "hatchling and post-hatchling" category included hatchlings measured just after emergence from the nests and post-hatchlings that were reared for several months (SCL of approximately 15 cm). The "small juvenile" and "large juvenile and adult" categories were separated at 50 cm SCL according to Bjorndal *et al.* (2000b), Gorham *et al.* (2014), and Hamabata *et al.* (2018). The "small juvenile" category included juveniles recruited to their foraging grounds after oceanic dispersal, with SCLs ranging from 20 to 50 cm. The "large juvenile and adult" category included nesting turtles, matured males,

and large juveniles with SCLs larger than 50 cm. When it was difficult to clearly assign these categories to the literature because average and SD or SE values were reported from individuals including both small juveniles and large juveniles or adults, categorisation was based on whether or not the average SCL exceeded 50 cm. Regional information was also adopted and categorised into “North Atlantic”, “South Atlantic”, “Northwest Pacific”, “Central Pacific”, and “East Pacific” based on the regional management units (RMU) in Wallace *et al.* (2010) and distinct population segments (DPS) in Conant *et al.* (2009) and Seminoff *et al.* (2015).

The differences in Fulton’s condition index between species and size classes were tested by random-effects modelling using the metafor package (Viechtbauer, 2010) in R ver 4.0.0 (R Core Team, 2020). First, we assumed a multilevel model that included regions as the upper level and studies as the lower level. We confirmed that the variance attributable to regions was small by the likelihood ratio test and variance distribution calculation using the dmetar package (Harrer *et al.*, 2019) (see Results); thus, we estimated a single-level model that included studies as random effects. Overall averages and 95% confidence intervals (CIs) were estimated for each species and size class.

Effects of different carapace length measurement

For the simulation, we randomly generated SCLnt values (N = 100) from a uniform distribution ranging from 30 to 100 cm. We then estimated the ratios of SCLnt³ / CCLnt³ or SCLnt³ / SCLmin³ using the relationship between SCLnt and CCLnt (i.e., the CCL measured from notch to tip) and SCLnt and SCLmin based on regression analyses (Limpus, 1992; Teas, 1993; Iwase & Kuroyanagi, 1999; Seminoff *et al.*, 2003; Peckham *et al.*, 2008; Okamoto *et al.*, 2012; Bjorndal *et al.*, 2013, 2016, 2017; Table 1). These ratios indicate the ratios of SCLnt-based vs. CCLnt-based (or SCLnt-based vs. SCLmin-based) Fulton's condition indices as follows:

$$\frac{Bodyweight / CCLnt^3}{Bodyweight / SCLnt^3} = \frac{SCLnt^3}{CCLnt^3}$$

We used three equations to convert SCLnt to CCLnt for green, loggerhead, and hawksbill turtles estimated from Atlantic and Pacific data. To convert SCLmin to SCLnt, we used equations estimated from Atlantic turtles because we could not find conversion equations for Pacific turtles.

RESULTS

We identified 77 articles that reported morphological condition indices. Most studies focused on green (N = 51), followed by loggerhead (N = 16) and hawksbill turtles (N = 6) (Table 2, Supplementary Table S2). Fulton's condition index was calculated based on

the SCL in most studies ($N = 54$); however, some studies reported CCL-based indices ($N = 7$) (Table 2, Supplementary Table S2). Two studies calculated the modified Fulton's index considering carapace length $\times$ carapace width $\times$ carapace depth, instead of (carapace length)³ (Barco *et al.*, 2016; Cammilleri *et al.*, 2017). The mass-to-length ratio (mass/SCL) has been used for hatchlings (van de Merwe *et al.*, 2005, 2010; Patino-Martinez *et al.*, 2012) or post-hatchlings (Mansfield *et al.*, 2012); however, Fulton's condition index has recently been applied to hatchlings (Banerjee *et al.*, 2020; Fleming *et al.*, 2020).

We included studies that reported the SCL-based Fulton's index for green, loggerhead, and hawksbill turtles in further meta-analyses. After removing potential duplicate data and adding the data calculated in present study, data from 68 studies were used to evaluate the differences between species and size classes (Supplementary Table S3). The multilevel model showed that regions and studies explained 25.7% and 34.3% of the variation, respectively, and the effects of regions were not significant (likelihood ratio test: $\chi^2 = 0.27$, $P = 0.603$). The single-level model attributed 53.3% of the total variance to between-study heterogeneity but showed a significant effect of moderators ($Q = 186.4$, $df = 8$, $P < 0.0001$). A high Fulton's condition index was observed in "hatchling and post-hatchling" turtles (averages for green, loggerhead, and hawksbill turtles: 2.24

[95% CI: 1.87–2.61], 2.13 [1.97–2.28], 2.06 [1.82–2.30], respectively) (Fig. 1). The CIs overlapped between “small juveniles” and “large juveniles and adults” for each species (green turtle: 1.31 [1.25–1.36] and 1.41 [1.34–1.47], loggerhead turtle: 1.59 [1.45–1.73] and 1.40 [1.33–1.48], hawksbill turtle: 1.09 [0.98–1.20] and 1.26 [1.07–1.45], respectively); however, the value of small juvenile hawksbill turtles was smaller than that of green and loggerhead turtles (Figure 1).

The averages and ranges of estimated $SCLnt^3/CCLnt^3$ ratios of green turtles based on equations from Teas (1993), Bjorndal *et al.* (2017), Okamoto *et al.* (2012), and Seminoff *et al.* (2003) were 0.835 (range: 0.830–0.847), 0.887 (range: 0.865–0.897), 0.867 (range: 0.858–0.887), and 0.805 (range: 0.729–0.842), respectively. The ratios for loggerhead turtles based on equations from Teas (1993), Bjorndal *et al.* (2013), Okamoto *et al.* (2012), and Peckham *et al.* (2008) were 0.791 (range: 0.740–0.816), 0.790 (range: 0.758–0.806), 0.869 (range: 0.853–0.906), and 0.825 (range: 0.819–0.840), respectively. The ratios for hawksbill turtles based on equations from Teas (1993), Bjorndal *et al.* (2016), Iwase & Kuroyanagi (1999), and Limpus (1992) were 0.861 (range: 0.853–0.865), 0.831 (range: 0.822–0.849), 0.863 (range: 0.825–0.948), and 0.837 (range: 0.829–0.855), respectively. The estimated $SCLnt^3/SCLmin^3$ ratios for green, loggerhead, and hawksbill turtles were 1.055 (range: 1.049–1.067), 1.061 (range: 1.040–1.114), and 1.016 (range:

1.013–1.023), respectively.

DISCUSSION

Fulton's condition index has been widely applied in sea turtle studies, excluding flatback turtles (*Natator depressus*). Values of Fulton's condition index based on SCLs ≥ 1.2 have been interpreted to indicate a relatively good body condition for sea turtles (Norton & Wyneken, 2015; Maulida *et al.*, 2017; Adnyana *et al.*, 2020). Although index values ≥ 1.3 were generally observed in large green and loggerhead turtles, the meta-analysis in this study supported the adequacy of this threshold for juvenile and adult green turtles and large juvenile and adult loggerhead turtles. This study also indicated further differences in Fulton's condition index between species and size classes; thus, it should be carefully applied on body condition evaluation.

The meta-analysis indicated high Fulton's condition index values for hatchlings and post-hatchlings of all three species. This is to be expected because the bodyweight of sea turtles is not proportional to SCL^3 , but $SCL^{2.7}$ to $SCL^{2.9}$ (Wabnitz & Pauly, 2008), resulting in a decrease in Fulton's condition index as bodyweight increases (Fig. 2). The relationship between bodyweight and SCL also supports the finding that Fulton's condition index of small loggerhead juveniles was lower than that of hatchlings and post-

hatchlings, but slightly higher than that of large juveniles and adults. This tendency was not observed in green and hawksbill turtles, which may be because the index values from foraging grounds included both small juveniles and large juveniles or adults, and the categorisation was based on the average SCL. Evaluating hatchling and post-hatchling sea turtles using Fulton's condition index requires caution. Additionally, a threshold higher than 1.2 is more suitable to indicate the good body condition of small juvenile loggerhead turtles.

A lower Fulton's condition index was observed for hawksbill turtles, particularly small juveniles. The relationships between the bodyweight and SCL (Wabnitz & Pauly, 2008) indicated that the bodyweight of hawksbill turtles in relation to SCL (i.e., Fulton's condition index) is lower than that of green and loggerhead turtles (Fig. 2). This difference is likely due to the relatively depressed plastron of hawksbill turtles, which is supported by the relationship between body depth and SCL (van Dam & Diez, 1998), when compared to loggerhead turtles (Marn *et al.*, 2015). In addition, carapace widening is observed in juvenile green and loggerhead turtles (Salmon & Scholl, 2014), but not in juvenile hawksbill turtles (Salmon *et al.*, 2018), possibly resulting in lower bodyweights of juvenile hawksbill turtles in relation to SCL. Considering the differences in body proportion and the results of the meta-analysis, Fulton's condition index of values of

approximately 1.0 rather than 1.2 could be a threshold for indicating good body condition in juvenile and adult hawksbill turtles.

SCL has been used as the representative body length for calculating Fulton's condition index in sea turtles, as used by Bjorndal *et al.* (2000a). Some studies measured the CCL but converted it to SCL to calculate the SCL-based Fulton's condition factor (López-Mendilaharsu *et al.*, 2016; Rossi *et al.*, 2019; Lamont & Johnson, 2021). We found seven studies that calculated Fulton's condition factor directly using CCL. Fulton's condition index values calculated from the CCL were approximately 0.81–0.89 times lower than those calculated using the SCL in green and hawksbill turtles. Therefore, an SCL-based index value of 1.2 is equivalent to a CCL-based index value of 1.0. Moreover, CCL-based values were lower in Atlantic loggerhead turtles ($0.79 \times$ SCL-based values). There may be a regional difference in the relationship between SCL and CCL for Atlantic and Pacific loggerhead turtles that results in differences in the CCLnt-based index/SCLnt-based index ratio among conversion equations (approximately 0.79 based on Teas, 1993 and Bjorndal *et al.*, 2013 vs. 0.82–0.87 based on Okamoto *et al.*, 2012 and Peckham *et al.*, 2008).

We only evaluated three species of sea turtles, i.e., green, loggerhead, and hawksbill turtles, because data are scarce for the other species. Further studies are

required to evaluate other sea turtle species. Kemp's Ridley turtle (*Lepidochelys kempii*) may have a higher Fulton's condition index than green turtles due to interspecific morphological differences (Lamont & Johnson, 2021). Additionally, we did not evaluate the eastern Pacific green turtle subspecies, the black turtle (*Chelonia mydas agassizii*) because foraging grounds may contain both black turtle-like and ordinal green turtle-like morphotypes, and values have not been reported separately (Sielfeld *et al.*, 2019). However, a smaller Fulton's condition index has been reported in small juveniles of black turtle-like morphotypes than in ordinary green turtles (Sampson *et al.*, 2014).

In the present study, the effect of region was not significant; however, regional differences were possible sources of between-study heterogeneity. Fulton's condition index has not been reported equally from all regions and was tested as a random effect in this study. Further studies are necessary to explore regional differences. In addition, foraging aggregations sometimes contain turtles from various rookeries (Amorocho *et al.*, 2012; Nishizawa *et al.*, 2013, 2018), which may result in high individual differences and within-study heterogeneity in the condition index. Another factor for heterogeneity is the difference in carapace length measurement. SCL can be measured as notch-to-notch (SCLmin) or notch-to-tip (SCLnt) (Bolten, 1999). Calculating the index using SCLmin slightly increases the index from that based on SCLnt by 1.01–1.06 times. Defining which

length is used clearly will be important for further establishing baseline body condition index values in sea turtles.

In conclusion, caution should be applied when using Fulton's condition index as a body condition indicator for sea turtles. Using Fulton's condition index for different species and size classes is problematic, as it does not consider the mass-length relationship (Peig & Green, 2010). Different threshold values for good body condition must be implemented for species and size classes. Morphometric body condition indices that incorporate mass-length relationships have been calculated for sea turtles (relative condition index: Labrada-Martagón *et al.*, 2010, 2011, 2013; Fukuoka *et al.*, 2015; scaled mass index: Bell *et al.*, 2019). Fulton's condition index is a simple metric that can be used to assess sea turtle body conditions. Because accidental errors can always occur when measuring bodyweight and length, the proposed threshold values for good body condition in this study must be carefully applied for individual body condition evaluation. Nonetheless, this study proposed baseline Fulton's condition index values for adequate sea turtle habitats and body conditions, which will be compared in future studies.

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598

Figure legend

Fig. 1 Forest plot of Fulton's body condition index values estimated using meta-analysis. The mean and 95% confidence interval (CI) values are shown in the right column, and the dashed line shows the value of 1.2.

Fig. 2 The relationship between Fulton's body condition index and straight carapace length (SCL) estimated from the relationships between bodyweight and SCL in green (Bodyweight = $0.000206 \text{ SCL}^{2.895}$), loggerhead (Bodyweight = $0.000282 \text{ SCL}^{2.823}$), and hawksbill turtles (Bodyweight = $0.000278 \text{ SCL}^{2.736}$) (Wabnitz & Pauly, 2008). Green, loggerhead, and hawksbill turtles are illustrated by solid, dashed, and dotted lines, respectively.

612 **Table 1.** Equations for converting the curved carapace length of sea turtles measured from
613 notch to tip (CCLnt) or notch to notch straight carapace length (SCLmin) to the notch to
614 tip straight carapace length (SCLnt)

Conversion	Species	Location	Equation	Reference
CCLnt to SCLnt	Green	West Atlantic	$SCLnt\ (cm) = 0.294 + (0.937 \times CCLnt)$	Teas (1993)
		West Atlantic	$SCLnt\ (cm) = -0.5385 + (0.9698 \times CCLnt)$	Bjorndal <i>et al.</i> (2017)
		Japan, Pacific	$SCLnt\ (mm) = 4.584 + (0.946 \times CCLnt)$	Okamoto <i>et al.</i> (2012)
		East Pacific	$SCLnt\ (cm) = -2.168 + (0.965 \times CCLnt)$	Seminoff <i>et al.</i> (2003)
	Loggerhead	West Atlantic	$SCLnt\ (cm) = -1.442 + (0.948 \times CCLnt)$	Teas (1993)
		West Atlantic	$SCLnt\ (cm) = -0.899 + (0.939 \times CCLnt)$	Bjorndal <i>et al.</i> (2013)
		Japan, Pacific	$SCLnt\ (mm) = 8.621 + (0.940 \times CCLnt)$	Okamoto <i>et al.</i> (2012)
		East Pacific	$SCLnt\ (cm) = 0.369 + (0.932 \times CCLnt)$	Peckham <i>et al.</i> (2008)
	Hawksbill	West Atlantic	$SCLnt\ (cm) = -0.212 + (0.955 \times CCLnt)$	Teas (1993)
		West Atlantic	$SCLnt\ (cm) = 0.4496 + (0.9326 \times CCLnt)$	Bjorndal <i>et al.</i> (2016)
		Japan, Pacific	$SCLnt\ (cm) = 1.91 + (0.920 \times CCLnt)$	Iwase & Kuroyanagi (1999)
		Australia	$SCLnt\ (cm) = 0.449 + (0.935 \times CCLnt)$	Limpus (1992)
SCLmin to SCLnt	Green	West Atlantic	$SCLnt\ (cm) = 0.238 + (1.0138 \times SCLmin)$	Bjorndal <i>et al.</i> (2017)
	Loggerhead	West Atlantic	$SCLnt\ (cm) = 0.999 + (1.003 \times SCLmin)$	Bjorndal <i>et al.</i> (2013)
	Hawksbill	West Atlantic	$SCLnt\ (cm) = 0.1424 + (1.0409 \times SCLmin)$	Bjorndal <i>et al.</i> (2016)

615

616

617 **Table 2.** Number of studies that have reported the morphometric body condition index

618 for each sea turtle species

Index	N	Green	Loggerhead	Hawksbill	Olive Ridley	Kemp's Ridley	Leatherback
Fulton (SCL-based)	54	34	14	5	4	3	2
Fulton (CCL-based)	7	6				1	
Modified Fulton	2		2				
Relative	4	4					
Residual	6	4		1			1
Mass/Length	4	2	1				1
log(Mass)/log(Length)	3	3					
Scaled mass index	1	1					
Total*	77	51	16	6	4	4	4

619 *Some studies have reported indices of multiple species or multiple indices; therefore,

620 the total numbers are different from the summation of the columns. See Supplementary

621 Table S2 for further details.

622

Fig. 1

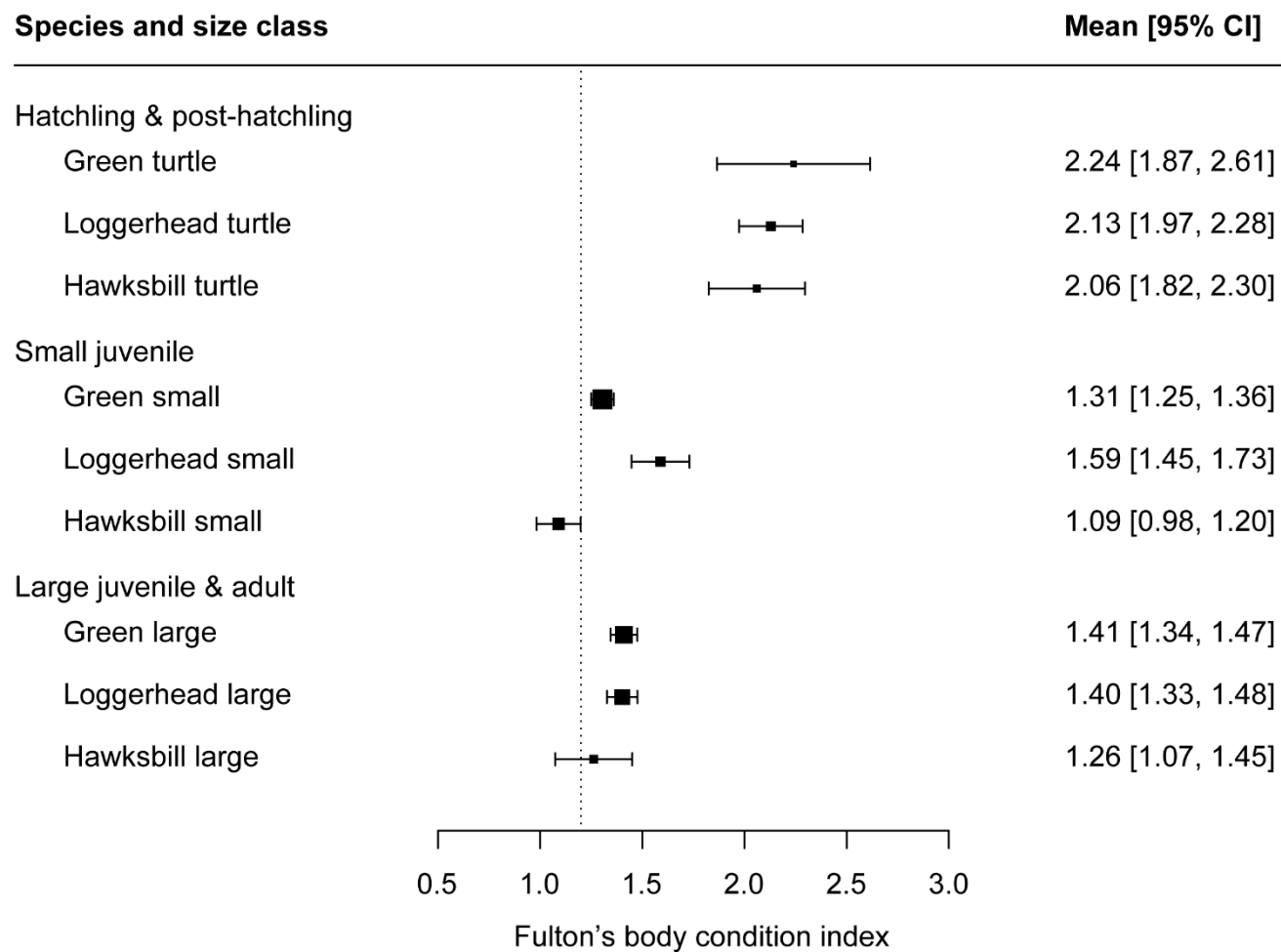


Fig. 2

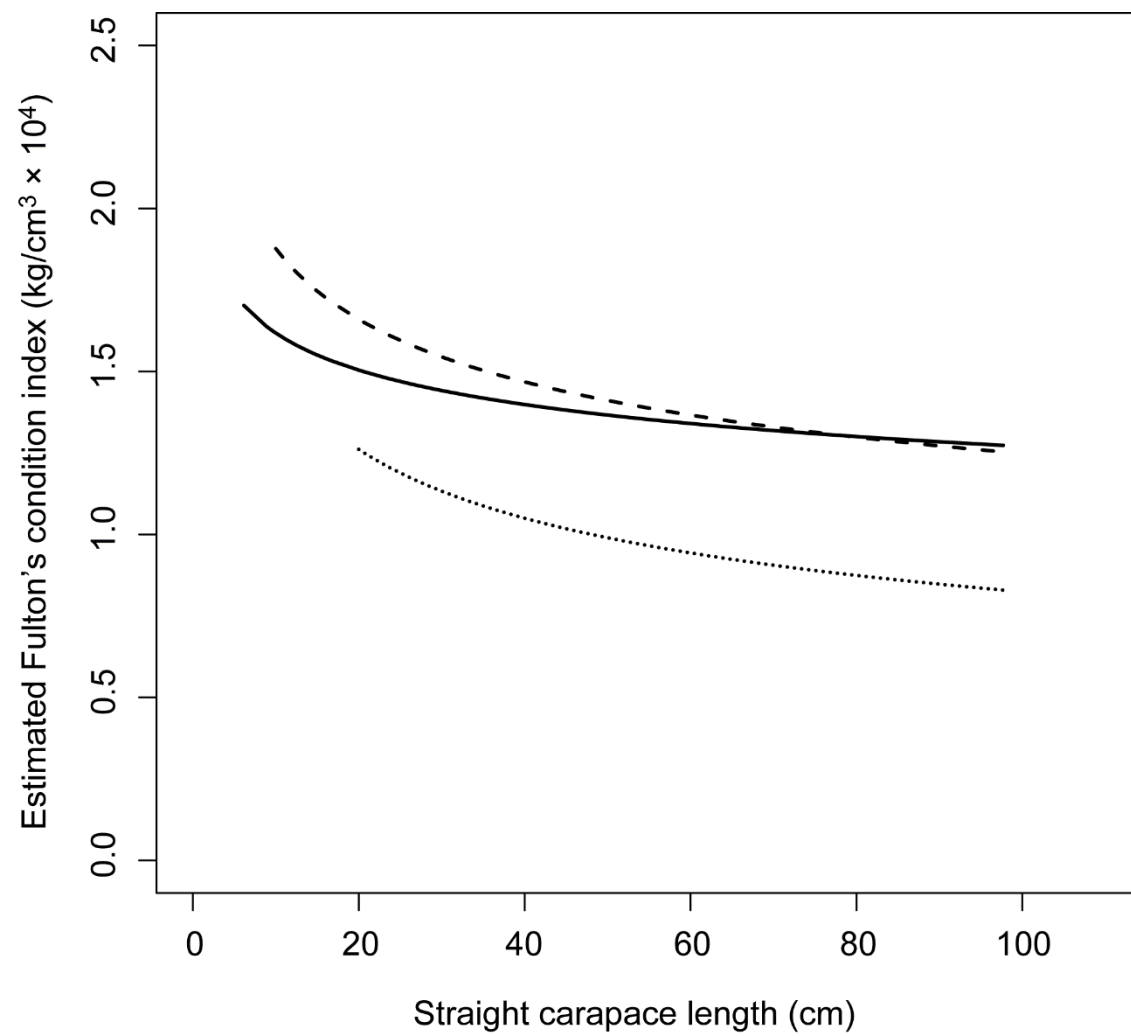


Table S1. Full list of literatures searched and analysed in the present study				
Ref no	Authors	Year	Title	Journal
1	Adnyana IBW, Christianen MJA, Hitipeuw C, Dethmers K	2020	The Body Condition Index and Genetic Connectivity among Foraging Green Turtle Populations in Indonesia at Different Scales : A Case Study From Berau Green Turtle Rookery, East Kalimantan - Indonesia	International Journal of Life Sciences Research 8:46–61
2	Álvarez-Varas R, Contardo J, Heidemeyer M, Forero-Rozo L, Brito B, Cortés V, Brain MJ, Pereira S, Vianna JA	2017	Ecology, health and genetic characterization of the southernmost green turtle (<i>Chelonia mydas</i>) aggregation in the Eastern Pacific: implications for local conservation strategies	Lat. Am. J. Aquat. Res., 45(3): 540–554
3	Arthur KE, Limpus CJ, Roelfsema CM, Udy JW, Shaw GR	2006	A bloom of <i>Lyngbya majuscula</i> in Shoalwater Bay, Queensland, Australia: An important feeding ground for the green turtle (<i>Chelonia mydas</i>)	Harmful Algae 5: 251–265
4	Avens L, Goshe LR, Harms CA, Anderson ET, Hall AG, Cluse WM, Godfrey MH, Braun-McNeill J, Stacy B, Bailey R, Lamont MM	2012	Population characteristics, age structure, and growth dynamics of neritic juvenile green turtles in the northeastern Gulf of Mexico	Mar Ecol Prog Ser 458: 213–229
5	Banerjee SM, Frey A, Kurler CM, Perrault JR, Stewart KR	2020	Morphological variation in leatherback (<i>Dermochelys coriacea</i>) hatchlings at Sandy Point National Wildlife Refuge, US Virgin Islands	Endang Species Res 41: 361–372
6	Barco S, Law M, Drummond B, Koopman H, Trapani C, Reinheimer S, Rose S, Swingle WM, Williard A	2016	Loggerhead turtles killed by vessel and fishery interaction in Virginia, USA, are healthy prior to death	Mar Ecol Prog Ser 555: 221–234
7	Bell IP, Meager J, van de Merwe JP, Hof CAM	2019	Green turtle (<i>Chelonia mydas</i>) population demographics at three chemically distinct foraging areas in the northern Great Barrier Reef	Science of the Total Environment 652:1040–1050
8	Bjorndal KA, Bolten AB, Chaloupka MY	2000	Green turtle somatic growth model: Evidence for density dependence	Ecological Applications 10: 269–282
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10	Bjorndal KA, Parsons J, Mustin W, Bolten AB	2013	Threshold to maturity in a long-lived reptile: interactions of age, size, and growth	Mar Biol 160:607–616
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12	Blumenthal JM, Austin TJ, Bell CDL, Bothwell JB, Broderick AC, Ebanks-Petrie G, Gibb JA, Luke KE, Olynik JR, Orr MF, Solomon JL, Godley BJ	2009	Ecology of Hawksbill Turtles, <i>Eretmochelys imbricata</i> , on a Western Caribbean Foraging Ground	Chelonian Conservation and Biology 8: 1–10
13	Cammilleri G, Calvaruso E, Pantano L, Cascio GL, Randisi B, Macaluso A, Vazzana M, Caracappa G, Giangrosso G, Vella A, Ferrantelli V	2017	Survey on the presence of non-dioxine-like PCBs (NDL-PCBS) in loggerhead turtles (<i>Caretta caretta</i>) stranded in south Mediterranean coasts (Sicily, southern Italy)	Environmental Toxicology and Chemistry 36: 2997–3002
14	Clukey KE, Lepczyk CA, Balazs GH, Work TM, Lynch JM	2017	Investigation of plastic debris ingestion by four species of sea turtles collected as bycatch in pelagic Pacific longline fisheries	Marine Pollution Bulletin 120: 117–125
15	Clukey KE, Lepczyk CA, Balazs GH, Work TM, Li QX, Bachman MJ, Lynch JM	2018	Persistent organic pollutants in fat of three species of Pacific pelagic longline caught sea turtles: Accumulation in relation to ingested plastic marine debris	Science of the Total Environment 610–611: 402–411
16	de Deus SantosMR, Martins AS, Baptiste C, Work TM	2015	Health condition of juvenile <i>Chelonia mydas</i> related to fibropapillomatosis in southeast Brazil	Dis Aquat Org 115: 193–201
17	Delgado C, Valente A, Quaresma I, Costa M, Dellinger T	2011	Blood biochemistry reference values for wild juvenile loggerhead sea turtles (<i>Caretta caretta</i>) from Madeira Archipelago	Journal of Wildlife Diseases 47: 523–529
18	Diez CE, van Dam RP	2002	Habitat effect on hawksbill turtle growth rates on feeding grounds at Mona and Monito Islands, Puerto Rico	Mar Ecol Prog Ser 234: 301–309
19	Espinoza-Romo BA, Sainz-Hernández JC, Ley-Quinoñez CP, Hart CE, Leal-Moreno R, Aguirre AA, Zavala-Norzagaray AA	2018	Blood biochemistry of olive ridley (<i>Leidochelys olivacea</i>) sea turtles foraging in northern Sinaloa, Mexico	PLoS ONE 13: e0199825
20	Fleming KA, Perrault JR, Stacy NI, Coppenrath CM, Gainsbury AM	2020	Heat, health and hatchlings: associations of in situ nest temperatures with morphological and physiological characteristics of loggerhead sea turtle hatchlings fromFlorida	Conserv Physiol 8: coaa046
21	Flint M, Morton JM, Limpus CJ, Patterson-Kane JC, Mills PC	2010	Reference intervals for plasma biochemical and hematologic measures in loggerhead sea turtles (<i>Caretta caretta</i>) from Moreton Bay, Australia	Journal of Wildlife Diseases 46: 731–741
22	Flint M, Eden PA, Limpus CJ, Owen H, Gaus C, Mills PC	2015	Clinical and Pathological Findings in Green Turtles (<i>Chelonia mydas</i>) from Gladstone, Queensland: Investigations of a Stranding Epidemic	EcoHealth 12: 298–309
23	Flint M, Brand A-F, Bell IP, Hof CAM	2019	Monitoring the health of green turtles in northern Queensland post catastrophic events	Science of the Total Environment 660: 586–592
24	Fukuoka T, Narazaki T, Sato K	2015	Summer-restricted migration of green turtles <i>Chelonia mydas</i> to a temperate habitat of the northwest Pacific Ocean	Endang Species Res 28: 1–10
25	Jessop TS, Sumner JM, Limpus CJ, Whittier JM	2004	Interplay between plasma hormone profiles, sex and body condition in immature hawksbill turtles (<i>Eretmochelys imbricata</i>) subjected to a capture stress protocol	Comparative Biochemistry and Physiology Part A 137:197–204
26	Jessop TS, Hamann M, Limpus CJ	2004	Body condition and physiological changes in male green turtles during breeding	Mar Ecol Prog Ser 276: 281–288
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28	Keller JM, Kucklick JR, Stamper MA, Harms CA, McClellan-Green PD	2004	Associations between Organochlorine Contaminant Concentrations and Clinical Health Parameters in Loggerhead Sea Turtles from North Carolina, USA	Environmental Health Perspectives 112: 1074–1079
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30	Keller JM, McClellan-Green PD, Lee MA, Arendt MD, Maier PP, Segars AL, Whitaker JD, Keil DE, Peden-Adams MM	2005	Mitogen-induced lymphocyte proliferation in loggerhead sea turtles: comparison of methods and effects of gender, plasma testosterone concentration, and body condition on immunity	Veterinary Immunology and Immunopathology 103:269–281
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35	Labrada-Martagón V, Tenorio Rodríguez PA, Méndez-Rodríguez LC, Zenteno-Savín T	2011	Oxidative stress indicators and chemical contaminants in East Pacific green turtles (<i>Chelonia mydas</i>) inhabiting two foraging coastal lagoons in the Baja California peninsula	Comparative Biochemistry and Physiology, Part C 154:65–75
36	Labrada-Martagón V, Méndez-Rodríguez LC, Mangel M, Zenteno-Savín T	2013	Applying generalized linear models as an explanatory tool of sex steroids, thyroid hormones and their relationships with environmental and physiologic factors in immature East Pacific green sea turtles (<i>Chelonia</i>)	Comparative Biochemistry and Physiology, Part A 166:91–100
37	Lamont MM, Johnson D	2021	Variation in Species Composition, Size and Fitness of Two Multi-Species Sea Turtle Assemblages Using Different Neritic Habitats	Front. Mar. Sci. 7:608740

38	Li T-S, Chang C-C	2020	The impact of fibropapillomatosis on clinical characteristics, blood gas, plasma biochemistry, and hematological profiles in juvenile green turtles (<i>Chelonia mydas</i>)	Bull Mar Sci. 96(4):723–734
39	López-Castro MC, Koch V, Mariscal-Loza A, Nichols WJ	2010	Long-term monitoring of black turtles <i>Chelonia mydas</i> at coastal foraging areas off the Baja California Peninsula	Endang Species Res 11: 35–45
40	López-Mendilaharsu M, Vélez-Rubio GM, Lezama C, Aisenberg A, Bauz á A, Berrondo L, Calvo V, Caraccio N, Estrades A, Hernández M, Laporta M, Martínez-Souza H, Morales M, Quirici V, Ríos M, Fallabrino	2016	Demographic and tumour prevalence data for juvenile green turtles at the Coastal-Marine Protected Area of Cerro Verde, Uruguay	Marine Biology Research 12:541–550
41	Mansfield KL, Wyneken J, Rittschof D, Walsh M, Lim CW, Richards PM	2012	Satellite tag attachment methods for tracking neonate sea turtles	Mar Ecol Prog Ser 457: 181–192
42	Marn N, Jusup M, Catteau S, Kooijman SALM, Klanjšček T	2019	Comparative physiological energetics of Mediterranean and North Atlantic loggerhead turtles	Journal of Sea Research 143:100–118
43	Maulida et al. 2015	2017	Geometry Morphometry and Health Status of Hawksbill Turtle (<i>Eretmochelys imbricata</i> Linnaeus, 1766) in Maratua Island, East Kalimantan-Indonesia	ICBS Conference Proceedings International Conference on Biological Science (2015) 2017: 100–110
44	McFadden KW, Gómez A, Sterling EJ, Naro-Maciel E	2014	Potential impacts of historical disturbance on green turtle health in the unique & protected marine ecosystem of Palmyra Atoll (Central Pacific)	Marine Pollution Bulletin 89:160–167
45	McMichael E, Seminoff J, Carthy R	2008	Growth rates of wild green turtles, <i>Chelonia mydas</i> , at a temperate foraging habitat in the northern Gulf of Mexico: assessing short-term effects of cold-stunning on growth	Journal of Natural History 42: 2793–2807
46	Monzón-Argüello C, Cardona L, Calabuig P, Camacho M, Crespo-Picazo JL, García-Párraga D, Mayans S, Luzardo OP, Orós J, Varo-Cruz N	2018	Supplemental feeding and other anthropogenic threats to green turtles (<i>Chelonia mydas</i>) in the Canary Islands	Science of the Total Environment 621: 1000–1011
47	Ogunjobi JA, Surulere OC	2020	Sea turtles in Ilaje, Nigeria: Status, sighting periods and conservation awareness	Nature Conservation Research 5: 28–35
48	Page-Karjian A, Norton TM, Krimer P, Groner M, Nelson SE, Gottdenker NL	2014	Factors influencing survivorship of rehabilitating green sea turtles (<i>Chelonia mydas</i>) with fibropapillomatosis	Journal of Zoo and Wildlife Medicine 45: 507–519
49	Patino-Martinez J, Marco A, Quiñones L, Hawkes L	2012	A potential tool to mitigate the impacts of climate change to the caribbean leatherback sea turtle	Global Change Biology 18: 401–411
50	Patricio AR, Diez CE, van Dam RP, Godley BJ	2016	Novel insights into the dynamics of green turtle fibropapillomatosis	Mar Ecol Prog Ser 547: 247–255
51	Patricio AR, Varela MR, Barbosa C, Broderick AC, Ferreira Airaud MB, Godley BJ, Regalla A, Tilley D, Catry P	2018	Nest site selection repeatability of green turtles, <i>Chelonia mydas</i> , and consequences for offspring	Animal Behaviour 139: 91–102
52	Perrault JR, Stacy NI, Lehner AF, Mott CR, Hirsch S, Gorhamd JC, Buchweitz JP, Bresette MJ, Walsh CJ	2017	Potential effects of brevetoxins and toxic elements on various health variables in Kemp's ridley (<i>Lepidochelys kempi</i>) and green (<i>Chelonia mydas</i>) sea turtles after a red tide bloom event	Science of the Total Environment 605–606: 967–979
53	Perrault JR, Levin M, Mott CR, Boverly CM, Bresette MJ, Chabot RM, Gregory CR, Guertin JR, Hirsch SE, Ritchie BW, Weege ST, Welsh RC, Witherington BE, Page-Karjian A	2021	Insights on Immune Function in Free-Ranging Green Sea Turtles (<i>Chelonia mydas</i>) with and without Fibropapillomatosis	Animals 11: 861
54	Pina A, Martins S, Abu-Raya M, Marco A	2020	Body condition of loggerhead turtles <i>Caretta caretta</i> nesting in Cabo Verde is independent of their reproductive output	Zoologia Caboverdiana 8:23–31
55	Plot V, Jenkins T, Robin J-P, Fossette S, Georges J-Y	2013	Leatherback Turtles Are Capital Breeders: Morphometric and Physiological Evidence from Longitudinal Monitoring	Physiological and Biochemical Zoology 86:385–397
56	Rezaie-Atagholipour M, Imani F, Ghezellou P, Seminoff JA	2021	Feeding ecology of juvenile green turtles in food-poor habitats of the Persian Gulf	Marine Biology 168:4
57	Roark AM, Bjørndal KA, Bolten AB, Leeuwenburgh C	2009	Biochemical indices as correlates of recent growth in juvenile green turtles (<i>Chelonia mydas</i>)	Journal of Experimental Marine Biology and Ecology 376: 59–67
58	Rossi S, Sánchez-Sarmiento AM, Santos RG, Zamana RR, Prioste FES, Gattamorta MA, Ochoa PFC, Grisi-Filho JHH, Matushima ER	2019	Monitoring green sea turtles in Brazilian feeding areas: relating body condition index to fibropapillomatosis prevalence	Journal of the Marine Biological Association of the United Kingdom 99:1879–1887
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61	Santos RG, Andrades R, Boldrini MA, Martins AS	2015	Debris ingestion by juvenile marine turtles: An underestimated problem	Marine Pollution Bulletin 93: 37–43
62	Schock TB, Keller JM, Rice M, Balazs GH, Bearden DW	2013	Metabotyping of a Protected Non-Model Organism, Green Sea Turtle (<i>Chelonia mydas</i>), using ¹ H NMR Spectroscopy and Optimized Plasma Methods for Metabolomics	Current Metabolomics 1: 279–290
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66	Stacy NI, Lynch JM, Arendt MD, Avens L, Braun McNeill J, Cray C, Day RD, Harms CA, Lee AM, Peden-Adams MM, Thorvalson K, Segars AI, Norton TM	2018	Chronic debilitation in stranded loggerhead sea turtles (<i>Caretta caretta</i>) in the southeastern United States: Morphometrics and clinicopathological findings	PLoS ONE 13(7): e0200355
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79	Hart KM, Fujisaki I	2010	Satellite tracking reveals habitat use by juvenile green sea turtles <i>Chelonia mydas</i> in the Everglades, Florida, USA	Endang Species Res 11: 221–232
80	Makowski C, Seminoff JA, Salmon M	2006	Home range and habitat use of juvenile Atlantic green turtles (<i>Chelonia mydas</i> L.) on shallow reef habitats in Palm Beach, Florida, USA	Marine Biology 148: 1167–1179
81	Mott CR, Salmon M	2011	Sun Compass Orientation by Juvenile Green Sea Turtles (<i>Chelonia mydas</i>)	Chelonian Conservation and Biology 10 : 73–81
82	Fukuoka T, Narazaki T, Kinoshita C, Sato K	2019	Diverse foraging habits of juvenile green turtles (<i>Chelonia mydas</i>) in a summer-restricted foraging habitat in the northwest Pacific Ocean	Marine Biology 166:25
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85	Crear DP, Lawson DD, Seminoff JA, Eguchi T, LeRoux RA, Lowe CG	2017	Habitat Use and Behavior of the East Pacific Green Turtle, <i>Chelonia mydas</i> , in an Urbanized System	Bull. Southern California Acad. Sci. 116: 17–32
86	Eguchi T, Bredvik J, Graham S, LeRoux R, Saunders B, Seminoff JA	2020	Effects of a power plant closure on home ranges of green turtles in an urban foraging area	Endang Species Res 41: 265–277
87	MacDonald BD, Lewison RL, Madrak SV, Seminoff JA, Eguchi T	2012	Home ranges of East Pacific green turtles <i>Chelonia mydas</i> in a highly urbanized temperate foraging ground	Mar Ecol Prog Ser 461: 211–221
88	Arendt MD, Segars AL, Byrd JJ, Boynton J, Whitaker JD, Parker L, Owens DW, Blanvillain G, Quattro JM, Roberts MA	2012	Distributional patterns of adult male loggerhead sea turtles (<i>Caretta caretta</i>) in the vicinity of Cape Canaveral, Florida, USA during and after a major annual breeding aggregation	Mar Biol 159:101–112
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90	Barco SG, Burt ML, DiGiovanni Jr. RA, Swingle WM, Williard AS	2018	Loggerhead turtle <i>Caretta caretta</i> density and abundance in Chesapeake Bay and the temperate ocean waters of the southern portion of the Mid-Atlantic Bight	Endang Species Res 37: 269–287
91	Mansfield KL, Wyneken J, Porter WP, Luo J	2014	First satellite tracks of neonate sea turtles redefine the ‘lost years’ oceanic stage	Proc. R. Soc. B 281: 20133039
92	Scott R, Biastoch A, Roder C, Stiebens VA, Ezizguirre C	2014	Nano-tags for neonates and ocean-mediated swimming behaviours linked to rapid dispersal of hatchling sea turtles	Proc. R. Soc. B 281: 20141209
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94	Minamikawa S, Naito Y, Sato K, Matsuzawa Y, Bando T, Sakamoto W	2000	Maintenance of neutral buoyancy by depth selection in the loggerhead turtle <i>Caretta caretta</i>	The Journal of Experimental Biology 203, 2967–2975
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96	Sato K	2014	Body temperature stability achieved by the large body mass of sea turtles	The Journal of Experimental Biology 217, 3607–3614
97	Narazaki T, Sato K, Abernathy KJ, Marshall GJ, Miyazaki N	2009	Sea turtles compensate deflection of heading at the sea surface during directional travel	The Journal of Experimental Biology 212, 4019–4026
98	Narazaki T, Sato K, Abernathy KJ, Marshall GJ, Miyazaki N	2013	Loggerhead Turtles (<i>Caretta caretta</i>) Use Vision to Forage on Gelatinous Prey in Mid-Water	PLoS ONE 8: e66043
99	Kinoshita C, Fukuoka T, Niizuma Y, Narazaki T, Sato K	2018	High resting metabolic rates with low thermal dependence induce active dives in overwintering Pacific juvenile loggerhead turtles	Journal of Experimental Biology 221, jeb175836
100	Saito T, Kurita M, Okamoto H, Kakizoe Y, Parker D, Briscoe D, Rice M, Polovina J, Balazs G	2018	Satellite tracking immature loggerhead turtles in temperate and subarctic ocean habitats around the Sea of Japan	Micronesia 2018-03: 1–20
101	Berube MD, Dunbar SG, Rützler K, Hayes WK	2012	Home Range and Foraging Ecology of Juvenile Hawksbill Sea Turtles (<i>Eretmochelys imbricata</i>) on Inshore Reefs of Honduras	Chelonian Conservation and Biology 11: 33–43
102	Hart KM, Sartain AR, Fujisaki I, Pratt Jr. HL, Morley D, Feeley MW	2012	Home range, habitat use, and migrations of hawksbill turtles tracked from Dry Tortugas National Park, Florida, USA	Mar Ecol Prog Ser 457: 193–207
103	Okuyama J, Shimizu T, Abe O, Yoseda K, Arai N	2010	Wild versus head-started hawksbill turtles <i>Eretmochelys imbricata</i> : post-release behavior and feeding adaptations	Endang Species Res 10: 181–190
104	Okuyama J, Kataoka K, Kobayashi M, Abe O, Yoseda K, Arai N	2012	The regularity of dive performance in sea turtles: a new perspective from precise activity data	Animal Behaviour 84: 349–359
105	Kobayashi M	2012	Ecological, Behavioral, and Physiological Evidence of the Hawksbill Turtle Reproduction in Captivity	Bull. Fish. Res. Agen. 36:107–142

Table S2. List of studies that reported the morphological body condition					
Ref no	Reference	Species	Index	Region	Location
1	Adnyana et al. 2020	Green	Fulton (SCL)	Northwest Pacific	Berau, Indonesia
2	Álvarez-Varas et al. 2017	Green	Fulton (SCL)	East Pacific	Atacama, Chile
3	Arthuer et al. 2006	Green	Residual	Southwest Pacific	Queensland, Australia
4	Avens et al. 2012	Green	Fulton (SCL)	North Atlantic	Florida, USA
5	Banerjee et al. 2020	Leatherback	Fulton (SCL)	North Atlantic	US Virgin Islands
6	Barco et al. 2016	Loggerhead	Fulton (SCL), modified Fulton	North Atlantic	Virginia, USA
7	Bell et al. 2019	Green	$\log(\text{Mass})/\log(\text{Length})$, Scaled mass index	Southwest Pacific	northern GBR, Australia
8	Bjorndal et al. 2000	Green	Fulton (SCL)	North Atlantic	Great Inagua, Bahama
9	Bjorndal & Bolten 2010	Hawksbill	Fulton (SCL)	North Atlantic	Great Inagua, Bahama
10	Bjorndal et al. 2013	Green	Fulton (CCL)	North Atlantic, South Atlantic	Ascension Island, Suriname, Tortuguero, Costa Rica
11	Bjorndal et al. 2014	Kemp	Fulton (CCL)	North Atlantic	Mexico
12	Blumenthal et al. 2009	Hawksbill	Fulton (SCL)	North Atlantic	Cayman Islands
13	Cammilleri et al. 2017	Loggerhead	modified Fulton	Mediterranean	Sicily, Southern Italy
14	Clukey et al. 2017	Green, Loggerhead, Olive, Leatherback	Fulton (SCL)	Central Pacific	Hawaii / American Samoa
15	Clukey et al. 2018	Green, Loggerhead, Olive	Fulton (SCL)	Central Pacific	Hawaii / American Samoa
16	de Deus Santos et al. 2015	Green	Fulton (CCL)	South Atlantic	Espírito Santo, Brazil
17	Delgado et al. 2011	Loggerhead	Fulton (SCL)	North Atlantic	Madeira Island
18	Diez & van Dam 2002	Hawksbill	Fulton (SCL)	North Atlantic	Puerto Rico
19	Espinoza-Romo et al. 2018	Olive	Fulton (SCL)	East Pacific	Mexico
20	Fleming et al. 2020	Loggerhead	Fulton (SCL)	North Atlantic	Florida, USA
21	Flint et al. 2010	Loggerhead	Fulton (SCL)	Southwest Pacific	Queensland, Australia
22	Flint et al. 2015	Green	$\log(\text{Mass})/\log(\text{Length})$	Southwest Pacific	Queensland, Australia
23	Flint et al. 2019	Green	$\log(\text{Mass})/\log(\text{Length})$	Southwest Pacific	Queensland, Australia
24	Fukuoka et al. 2015	Green	Relative	Northwest Pacific	Sanriku, Japan
25	Jessop et al. 2004a	Hawksbill	Residual	Southwest Pacific	Queensland, Australia
26	Jessop et al. 2004b	Green	Residual	Southwest Pacific	Queensland, Australia
27	Jessop et al. 2002	Green	Residual	Southwest Pacific	Queensland, Australia
28	Keller et al. 2004	Loggerhead	Fulton (SCL)	North Atlantic	North Carolina, USA
29	Keller et al. 2006	Loggerhead	Fulton (SCL)	North Atlantic	North Carolina, USA
30	Keller et al. 2005	Loggerhead	Fulton (SCL)	North Atlantic	North Carolina, Georgia, northern Florida, USA
31	Keller et al. 2014	Green	Fulton (SCL)	Central Pacific	Hawaii
32	Koch et al. 2007	Green	Fulton (SCL)	East Pacific	Baja California Sur, Mexico
33	Krueger et al. 2011	Hawksbill	Fulton (SCL)	North Atlantic	Barbados
34	Labrada-Martagón et al. 2010	Green	Fulton (SCL), Relative	East Pacific	Baja California Sur, Mexico
35	Labrada-Martagón et al. 2011	Green	Relative	East Pacific	Baja California Sur, Mexico
36	Labrada-Martagón et al. 2013	Green	Relative	East Pacific	Baja California Sur, Mexico
37	Lamont & Johnson 2021	Green, Loggerhead, Kemp	Fulton (SCL)	North Atlantic	Santa Rosa Island and St. Joseph Bay, Northwest Florida
38	Li & Chang 2020	Green	Fulton (SCL)	Northwest Pacific	Taiwan
39	López-Castro et al. 2010	Green	Fulton (SCL)	East Pacific	Baja California Sur, Mexico
40	López-Mendilaharsu et al. 2016	Green	Fulton (SCL)	South Atlantic	Uruguay
41	Mansfield et al. 2012	Loggerhead	Mass/Length	North Atlantic	Florida, USA

42	Marn et al. 2019	Loggerhead	Fulton (SCL)	North Atlantic, Mediterranean	
43	Maulida et al. 2015	Hawksbill	Fulton (SCL)	Northwest Pacific	Indonesia
44	McFadden et al. 2014	Green	Fulton (SCL)	Central Pacific	Palmyra Atoll
45	McMichael et al. 2008	Green	Fulton (SCL)	North Atlantic	northern Gulf of Mexico, USA
46	Monzón-Argüello et al. 2018	Green	Fulton (SCL)	North Atlantic	Canary Islands
47	Ogunjobi & Surulere 2020	Olive	Fulton (SCL)	North Atlantic	Ondo State, Nigeria
48	Page-Karjian et al. 2014	Green	Fulton (SCL)	North Atlantic	Georgia and Florida, USA
49	Patino-Martinez et al. 2012	Leatherback	Mass/Length	North Atlantic	Caribbean Colombia
50	Patrício et al. 2016	Green	Fulton (SCL)	North Atlantic	Puerto Rico
51	Patrício et al. 2018	Green	Fulton (SCL)	North Atlantic	Guinea-Bissau
52	Perrault et al. 2017	Green, Kemp	Fulton (SCL)	North Atlantic	Florida, USA
53	Perrault et al. 2021	Green	Fulton (SCL)	North Atlantic	Florida, USA
54	Pina et al. 2020	Loggerhead	Fulton (SCL)	North Atlantic	Boavista Island, Cabo Verde
55	Plot et al. 2013	Leatherback	Residual	South Atlantic	French Guiana
56	Rezaie-Atagholipour et al. 2021	Green	Fulton (CCL)	Indian Ocean	Persian Gulf
57	Roark et al. 2009	Green	Fulton (SCL)	North Atlantic	Grand Cayman, British West Indies
58	Rossi et al. 2019	Green	Fulton (SCL)	South Atlantic	Brazil
59	Sampson et al. 2014	Green	Fulton (SCL)	East Pacific	Colombia
60	dos Santos et al. 2010	Green	Fulton (SCL)	South Atlantic	Brazil
61	Santos et al. 2015	Green	Fulton (CCL)	South Atlantic	Brazil
62	Schock et al. 2013	Green	Fulton (SCL)	Central Pacific	Hawaii
63	Seminoff et al. 2003	Green	Fulton (SCL)	East Pacific	Baja California, Mexico
64	Sielfeld et al. 2019	Green	Fulton (SCL)	East Pacific	Chile
65	Stamper et al. 2005	Loggerhead	Fulton (SCL)	North Atlantic	North Carolina, USA
66	Stancy et al. 2018	Loggerhead	Fulton (SCL)	North Atlantic	North Carolina, South Carolina, Georgia, and Florida, USA
67	Sterling et al. 2013	Green	Fulton (SCL)	Central Pacific	Palmyra Atoll
68	Stewart et al. 2016	Green	Fulton (SCL)	North Atlantic	Barbados
69	Swarthout et al. 2010	Kemp	Fulton (SCL)	North Atlantic	northern Gulf of Mexico, USA
70	Thomson et al. 2009	Green	Fulton (CCL), Residual	Indian Ocean	Western Australia, Australia
71	van de Merwe et al. 2005	Green	Mass/Length	Northwest Pacific	Terengganu, Malaysia
72	van de Merwe et al. 2010	Green	Mass/Length	Northwest Pacific	Terengganu, Malaysia
73	Vander-Zanden et al. 2012	Green	Fulton (CCL)	North Atlantic	West Indies
74	Velez-Zuazo et al. 2014	Green	Fulton (SCL)	East Pacific	Peru
75	Work et al. 2004	Green	Fulton (SCL)	Central Pacific	Hawaii
76	Work et al. 2005	Green	Fulton (SCL)	Central Pacific	Hawaii
77	Work et al. 2015	Green	Fulton (SCL)	Central Pacific	Hawaii

Table S3. Dataset used for the meta-analysis of Fulton's body condition index based on the straight carapace length (SCL)								
Ref no	Reference	species	region	size class	mean	v	se	n
4	Avens et al. 2012	Green	NorthAtlantic	Small juvenile	1.17	0.0009	0.001093	753
8	Bjorndal et al. 2000	Green	NorthAtlantic	Small juvenile	1.34	NA	0.0198	NA
8	Bjorndal et al. 2000	Green	NorthAtlantic	Small juvenile	1.29	NA	0.0099	NA
8	Bjorndal et al. 2000	Green	NorthAtlantic	Small juvenile	1.24	NA	0.01	NA
8	Bjorndal et al. 2000	Green	NorthAtlantic	Small juvenile	1.25	NA	0.0098	NA
8	Bjorndal et al. 2000	Green	NorthAtlantic	Small juvenile	1.24	NA	0.0102	NA
8	Bjorndal et al. 2000	Green	NorthAtlantic	Small juvenile	1.23	NA	0.0098	NA
8	Bjorndal et al. 2000	Green	NorthAtlantic	Small juvenile	1.27	NA	0.0098	NA
45	McMichael et al. 2008	Green	NorthAtlantic	Small juvenile	1.4	0.0256	0.053333	9
45	McMichael et al. 2008	Green	NorthAtlantic	Small juvenile	1.3	0.0016	0.007303	30
48	Page-Karjian et al. 2014	Green	NorthAtlantic	Small juvenile	1.15	0.0208	0.04	13
50	Patricio et al. 2016	Green	NorthAtlantic	Small juvenile	1.315	0.0189	0.005281	679
50	Patricio et al. 2016	Green	NorthAtlantic	Small juvenile	1.345	0.016154	0.017975	50
52	Perrault et al. 2017	Green	NorthAtlantic	Small juvenile	1.32	0.0064	0.025298	10
68	Stewart et al. 2016	Green	NorthAtlantic	Large juvenile & Adult	1.4	0.01	0.030151	11
68	Stewart et al. 2016	Green	NorthAtlantic	Small juvenile	1.2	0.01	0.02357	18
37	Lamont & Johnson 2021	Green	NorthAtlantic	Small juvenile	1.38	0.0841	0.023522	152
37	Lamont & Johnson 2021	Green	NorthAtlantic	Small juvenile	1.31	0.0324	0.020513	77
53	Perrault et al. 2021	Green	NorthAtlantic	Small juvenile	1.29	0.0121	0.0275	16
53	Perrault et al. 2021	Green	NorthAtlantic	Small juvenile	1.32	0.0144	0.028284	18
53	Perrault et al. 2021	Green	NorthAtlantic	Small juvenile	1.26	0.0081	0.027136	11
78	Blumenthal et al. 2010	Green	NorthAtlantic	Small juvenile	1.821738	0.773976	0.35916	6
79	Hart & Fujisaki 2010	Green	NorthAtlantic	Small juvenile	1.372368	0.032901	0.074051	6
80	Makowski et al. 2006	Green	NorthAtlantic	Small juvenile	2.232891	0.712024	0.344486	6
81	Mott 2010, Mott et al. 2011	Green	NorthAtlantic	Small juvenile	1.247498	0.018145	0.02157	39
6	Barco et al. 2016	Loggerhead	NorthAtlantic	Large juvenile & Adult	1.58	0.0324	0.048107	14
17	Delgado et al. 2011	Loggerhead	NorthAtlantic	Small juvenile	1.58	0.0001	0.001925	27
20	Fleming et al. 2020	Loggerhead	NorthAtlantic	Hatchling & PostHatchling	2.15	0.0037	0.01	37
20	Fleming et al. 2020	Loggerhead	NorthAtlantic	Hatchling & PostHatchling	2.41	0.0306	0.03	34
20	Fleming et al. 2020	Loggerhead	NorthAtlantic	Hatchling & PostHatchling	2.41	0.045	0.03	50
28	Keller et al. 2004	Loggerhead	NorthAtlantic	Large juvenile & Adult	1.48	0.0225	0.022361	45
65	Stamper et al. 2005	Loggerhead	NorthAtlantic	Large juvenile & Adult	1.543	0.025696	0.024735	42
65	Stamper et al. 2005	Loggerhead	NorthAtlantic	Large juvenile & Adult	1.528	0.06786	0.067261	15
66	Stancy et al. 2018	Loggerhead	NorthAtlantic	Large juvenile & Adult	1.56	0.0289	0.014524	137
37	Lamont & Johnson 2021	Loggerhead	NorthAtlantic	Large juvenile & Adult	1.46	0.04	0.033333	36
88, 89	Arendt et al. 2012a, 2012b	Loggerhead	NorthAtlantic	Large juvenile & Adult	1.428081	0.010236	0.018788	29
90	Barco et al. 2018	Loggerhead	NorthAtlantic	Large juvenile & Adult	1.562132	0.026574	0.03197	26
91	Mansfield et al. 2014	Loggerhead	NorthAtlantic	Hatchling & PostHatchling	1.641879	0.056986	0.057898	17
9	Bjorndal & Bolten 2010	Hawksbill	NorthAtlantic	Small juvenile	1.17	0.0064	0.011926	45
12	Blumenthal et al. 2009	Hawksbill	NorthAtlantic	Small juvenile	1.25	0.0289	0.015205	125

12	Blumenthal et al. 2009	Hawksbill	NorthAtlantic	Small juvenile	1.24	0.0324	0.018665	93
18	Diez & van Dam 2002	Hawksbill	NorthAtlantic	Small juvenile	1.18	NA	NA	82
18	Diez & van Dam 2002	Hawksbill	NorthAtlantic	Small juvenile	1.16	NA	NA	63
18	Diez & van Dam 2002	Hawksbill	NorthAtlantic	Small juvenile	1.24	NA	NA	41
33	Krueger et al. 2011	Hawksbill	NorthAtlantic	Small juvenile	1.17	NA	NA	NA
33	Krueger et al. 2011	Hawksbill	NorthAtlantic	Small juvenile	1.18	NA	NA	NA
101	Berube et al. 2012	Hawksbill	NorthAtlantic	Small juvenile	1.23736	0.053079	0.103033	5
102	Hart et al. 2012	Hawksbill	NorthAtlantic	Large juvenile & Adult	1.206868	0.011871	0.062903	3
40	Lopez-Mendilaharsu et al. 2016	Green	SouthAtlantic	Small juvenile	1.25	0.0196	0.006299	494
58	Rossi et al. 2019	Green	SouthAtlantic	Small juvenile	1.32	0.0576	0.010545	518
58	Rossi et al. 2019	Green	SouthAtlantic	Small juvenile	1.36	0.0484	0.018935	135
54	Pina et al. 2020	Loggerhead	NorthAtlantic	Large juvenile & Adult	1.49	0.0169	0.007325	315
92	Scot et al. 2014	Loggerhead	NorthAtlantic	Hatchling & PostHatchling	2.138431	0.030682	0.034352	26
1	Adnyana et al. 2020	Green	NorthwestPacific	Large juvenile & Adult	1.3	0.0441	0.020793	102
1	Adnyana et al. 2020	Green	NorthwestPacific	Large juvenile & Adult	1.26	0.0256	0.014792	117
1	Adnyana et al. 2020	Green	NorthwestPacific	Large juvenile & Adult	1.24	0.04	0.020966	91
38	Li & Chang 2020	Green	NorthwestPacific	Small juvenile	1.27	0.02809	0.035732	22
24, 82	Fukuoka et al. 2015, 2019	Green	NorthwestPacific	Large juvenile & Adult	1.4434	0.018284	0.04507	9
83	Okuyama et al. 2013	Green	NorthwestPacific	Large juvenile & Adult	1.4076	0.076264	0.09764	8
84	Okuyama et al. 2009	Green	NorthwestPacific	Hatchling & PostHatchling	2.3405	0.046855	0.08837	6
84	Okuyama et al. 2009	Green	NorthwestPacific	Hatchling & PostHatchling	2.0452	0.091313	0.08723	12
93, 94, 95,	Sato et al. 1994, 1995; Minamikawa et al. 2000; Hatase et al. 2002; Sato 2	Loggerhead	NorthwestPacific	Large juvenile & Adult	1.412658	0.011354	0.023827	20
97, 98, 99	Narazaki et al. 2009, 2013; Kinoshita et al. 2018	Loggerhead	NorthwestPacific	Large juvenile & Adult	1.507146	0.022968	0.030935	24
100	Saito et al. 2018	Loggerhead	NorthwestPacific	Small juvenile	1.690999	0.069841	0.053945	24
100	Saito et al. 2018	Loggerhead	NorthwestPacific	Large juvenile & Adult	1.379612	0.004827	0.028364	6
43	Maulida et al. 2015	Hawksbill	NorthwestPacific	Small juvenile	1.05	0.0036	0.018091	11
103, 104	Okuyama et al. 2010, Okuyama et al. 2012	Hawksbill	NorthwestPacific	Small juvenile	0.929253	0.007684	0.029219	9
105	Kobayashi 2012	Hawksbill	NorthwestPacific	Large juvenile & Adult	1.325006	0.014122	0.048515	6
This study	This study	Hawksbill	NorthwestPacific	Hatchling & PostHatchling	2.05478	0.127043	0.126017	8
This study	This study	Hawksbill	NorthwestPacific	Hatchling & PostHatchling	2.060516	0.00955	0.027104	13
21	Flint et al. 2010	Loggerhead	NorthwestPacific	Large juvenile & Adult	1.14	0.007362	0.016827	26
21	Flint et al. 2010	Loggerhead	NorthwestPacific	Large juvenile & Adult	1.07	0.012905	0.017962	40
14	Clukey et al. 2017	Green	CentralPacific	Small juvenile	1.39	0.0001	0.003162	10
31	Keller et al. 2014	Green	CentralPacific	Large juvenile & Adult	1.39	0.0064	0.023094	12
31	Keller et al. 2014	Green	CentralPacific	Large juvenile & Adult	1.31	0.0676	0.072111	13
31	Keller et al. 2014	Green	CentralPacific	Large juvenile & Adult	1.46	0.0324	0.049923	13
62	Schock et al. 2013	Green	CentralPacific	Large juvenile & Adult	1.48	0.023532	0.054235	8
62	Schock et al. 2013	Green	CentralPacific	Large juvenile & Adult	1.33	0.008409	0.026472	12
67	Sterling et al. 2013	Green	CentralPacific	Large juvenile & Adult	1.38	0.0256	0.011202	204
75	Work et al. 2004	Green	CentralPacific	Large juvenile & Adult	1	0.1521	0.104232	14
14	Clukey et al. 2017	Loggerhead	CentralPacific	Large juvenile & Adult	1.46	0.0081	0.040249	5
2	Alvarez-Varas et al. 2017	Green	EastPacific	Large juvenile & Adult	1.66	0.0784	0.074833	14

32	Koch et al. 2007	Green	EastPacific	Large juvenile & Adult	1.37	0.016641	0.011186	133
32	Koch et al. 2007	Green	EastPacific	Large juvenile & Adult	1.3	0.012321	0.010937	103
34	Labrada-Martag?n et al. 2010	Green	EastPacific	Small juvenile	1.47	0.0049	0.031305	5
34	Labrada-Martag?n et al. 2010	Green	EastPacific	Large juvenile & Adult	1.67	0.36	0.12	25
39	Lopez-Castro et al. 2010	Green	EastPacific	Large juvenile & Adult	1.32	0.0256	0.01338	143
39	Lopez-Castro et al. 2010	Green	EastPacific	Large juvenile & Adult	1.34	0.0289	0.006917	604
39	Lopez-Castro et al. 2010	Green	EastPacific	Large juvenile & Adult	1.27	0.0529	0.015507	220
39	Lopez-Castro et al. 2010	Green	EastPacific	Large juvenile & Adult	1.38	0.0169	0.016925	59
63	Seminoff et al. 2003	Green	EastPacific	Large juvenile & Adult	1.44	0.014532	0.0348	12
63	Seminoff et al. 2003	Green	EastPacific	Large juvenile & Adult	1.39	0.025407	0.0426	14
63	Seminoff et al. 2003	Green	EastPacific	Large juvenile & Adult	1.38	0.027221	0.0426	15
63	Seminoff et al. 2003	Green	EastPacific	Large juvenile & Adult	1.46	0.025407	0.0426	14
63	Seminoff et al. 2003	Green	EastPacific	Large juvenile & Adult	1.41	0.025461	0.0387	17
63	Seminoff et al. 2003	Green	EastPacific	Large juvenile & Adult	1.43	0.025472	0.0532	9
63	Seminoff et al. 2003	Green	EastPacific	Large juvenile & Adult	1.47	0.025453	0.0603	7
63	Seminoff et al. 2003	Green	EastPacific	Large juvenile & Adult	1.42	0.025407	0.0426	14
64	Sielfeld et al. 2019	Green	EastPacific	Large juvenile & Adult	1.567	0.037326	0.03864	25
64	Sielfeld et al. 2019	Green	EastPacific	Large juvenile & Adult	1.7056	0.031898	0.031572	32
64	Sielfeld et al. 2019	Green	EastPacific	Large juvenile & Adult	1.6315	0.158723	0.048672	67
64	Sielfeld et al. 2019	Green	EastPacific	Large juvenile & Adult	1.525	0.01428	0.068993	3
74	Velez-Zuazo et al. 2014	Green	EastPacific	Large juvenile & Adult	1.5	0.0256	0.01123	203
74	Velez-Zuazo et al. 2014	Green	EastPacific	Large juvenile & Adult	1.55	0.0196	0.011068	160
59	Sampson et al. 2014	Green	EastPacific	Large juvenile & Adult	1.38	0.0225	0.005492	746
59	Sampson et al. 2014	Green	EastPacific	Large juvenile & Adult	1.49	0.0484	0.013339	272
85	Crear et al. 2017	Green	EastPacific	Large juvenile & Adult	1.5688	0.493633	0.26555	7
86, 87	Eguchi et al. 2020, MacDonald et al. 2012	Green	EastPacific	Large juvenile & Adult	1.380677	0.034795	0.029494	40