Shark aggregation and tourism: Opportunities and challenges of an emerging phenomenon

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Abstract

In the last few winters, sharks have been aggregating near the Israeli Mediterranean coast, at a specific point, near Hadera power station. This unusual phenomenon has fascinated residents, visitors, kayakers, divers and swimmers. We analyse the effects of this intense human interest on the sharks, using contingent behaviour, in Hadera and in Ashkelon, where sharks are present but not the infrastructure for their observation. We also report on changes in shark behaviour due to change in tourism intensity. We find a change of about ILS 4.1 million annually for both sites but a larger individual consumer surplus in Hadera, where sharks are currently observable. Touristic intensity crosses the threshold level by about 12% and making the socio-equilibrium sustainable for both humans and sharks would have a social cost of ILS 0.157 million.

Keywords: Shark aggregation, shark behaviour, human-wildlife conflict, Mediterranean, Travel cost, tourism.

1. Introduction

Sharks (superorder Selachimorpha) are characterized by *K*-selected life history traits, including slow growth, late age-at-maturity and low fecundity. Thus, once a population is depleted, recovery to pre-exploitation levels may take several decades or longer (Kabasakal et al. 2017). Over the last 60 years, shark catches by industrial, artisanal, and sport fisheries have increased around the world, and sharks are among the most threatened marine animals (Martins et al. 2018).

Today, sharks face possibly the largest crisis of their 420-million-year history. An estimated 100 million sharks are killed by commercial fisheries every year (Berrios 2017), and a quarter of species have an elevated risk of extinction (Simpfendorfer & Dulvy 2017). Sharks are increasingly taken as bycatch in fisheries targeting other species of commercial value (Kabasakal et al. 2017). Large sharks, especially those living in shallow water, are in the most danger of extinction (Dulvy et al. 2014). Sharks are more vulnerable to over-exploitation than most teleosts and other vertebrates (Bradshaw et al. 2018).

Viewing sharks in nature is a popular tourism activity (Haskell et al. 2015). It is a global industry (Gallagher et al. 2015). Examples are the whale shark (*Rhincodon typus*) at Tofo Beach, Mozambique (Haskell et al. 2015), hand feeding (*Carcharhinus leucas*) in the Shark Reef Marine Reserve, Fiji (Brunnschweiler et al. 2018), tiger sharks (*Galeocerdo cuvier*) in the Aliwal Shoal Marine Protected Area, South Africa (Du Preez et al. 2012), and the white shark (*Carcharodon carcharias*) cage-diving in South Australia's Spencer Gulf important industry (Nazimi et al. 2018).

Wildlife tourism may have the potential to contribute to conservation (Börger et al., 2014; Brunnschweiler et al. 2018). It is said to enhance environmental education, while providing local economic benefits (Grafeld et al., 2016; Nazimi et al. 2018). As Gallagher, et al. (2015) points out; this kind of tourism may induce more alive sharks (for tourism) than dead (in a fish market). However, the tourism industry, if not properly managed, can also threaten wildlife and ecosystems. Negative impacts may include physiological changes, behavioural changes, seasonality change, residency, abundance, and disruptions of space use. Many studies have pointed out that the anthropogenic effects can be detrimental to sharks if not organized or too frequent (Schofield et al. 2015; Nazimi et al. 2018). As top predators in marine food webs, sharks provide regulatory control, maintaining the balance of the ecosystem (Kabasakal et al. 2017), and have an important role in the health of oceanic ecosystems worldwide (Martins et al. 2018).

Although sharks have historically had low economic value, today many have become indirect or direct targets of commercial and recreational fisheries around the world (Kabasakal et al. 2017). Sharks are exploited for their fins (used to produce shark-fin soup), meat (frozen, fresh, brine, smoked, salted), skin (for sandpaper and leather), cartilage (for its supposed anti-cancer properties), teeth, and liver oil (pharmaceuticals and cosmetics) (Berrios 2017). But another kind of economic value of sharks has evolved, derived from tourism and recreation. Cisneros-Montemayor (et al. 2013) suggested that globally about 590,000 shark watchers spend more than USD 314 million per year, directly supporting 10,000 jobs. The travel cost method (TCM) is a popular way to derive recreation benefits either by visitor or by visit. This is done by estimation of the consumer surplus (CS). The method is based on the assumption that there is an inverse relationship between visitation rate and the cost of a visit which provides a possible potential to estimate a downward-sloping demand curve.

For example, Du Preez et al. (2012) used TCM to value consumer surplus from tiger shark diving in South Africa, obtaining a value of about 2 million Rand per year. Anna & Saputra (2017) used TCM in local and foreign whale shark tourism in India and obtained IDR 142.35 billion per year.

Estimation of the benefit of a site attribute requires one to know what is the demand for trips to the site for a given level of this attribute (Alberini et al. 2007). One way to overcome this is to ask individuals about the change they expect to have in the number of trips they would take to a site under hypothetical change in an attribute. This contingent behaviour, CB) may later be lumped with observations on actual trips to the site under the current conditions of the attribute (Grijalva et al. 2002). These changes in the attributes of a site are measured through a change in behaviour; that is, visit frequency (Ready et al., 2018; Wang et al. 2017). For example, Pueyo-Ros et al. (2018) developed a combined model with TCM and CB to assess the economic value of coast restoration in Costa Brava (Spain) and to understand the influence of this restoration on visitors' behaviour. This CB method is used to analyze different policies to find the most efficient policy under changes in the quality or recovery of a touristic area (Okuyama, 2018). In this study we apply TCM to a sample of recreation participants to obtain revealed and stated preferences for trips based on the visibility (or not) of sharks at two beaches along the Israeli Mediterranean coast. We also use the pooled CB method and estimate the change in values accordingly.

Phenomenon background: In the winter months (November to April) in each of the last several years, 40–80 sharks (dusky shark, *Carcharhinus obscurus*, and sandbar shark, *Carcharhinus plumbeus*) have aggregated very close to the shore on Israel's Mediterranean coast, near the power station at Hadera (Zemah Shamir, 2018).[1] We speculate that here on the oligotrophic and highly evaporative margins of the Mediterranean, sharks that have adapted to the warm, highly saline water are attracted by water that's even warmer and saltier. The coastline is neither protected nor regulated, so these sharks may face serious negative effects, for example, being caught by artisanal or recreational fishers or being frightened or hurt by jet skis or speedboats. And alongside the human–wildlife conflict there is human–human conflict (Dickman, 2010), between the regulator and the residents, or other stakeholders such as fishers and divers.

It is important to measure the recreational potential as well as signal some potential risks of this phenomenon, which is still only a few years old. The objective of this paper is thus to address this conflict into monetary values and describe the changes in the behaviour of recreationalists under two scenarios: Sharks visit both Hadera and Ashkelon (Figure 1), but they are presently visible to tourists only at Hadera. Using TCM and CB, we consider tourist visits to Hadera and Ashkelon under two conditions: when they can see sharks there (true at Hadera, hypothetical at Ashkelon) and when they can't see sharks there (true at Ashkelon, hypothetical at Hadera. We also look at the trade-off between active tourism (diving) and sustainable ecological conditions for the sharks.

[1] http://www.bbc.com/news/av/science-environment-44174183/the-day-spa-for-pregnant-sharks

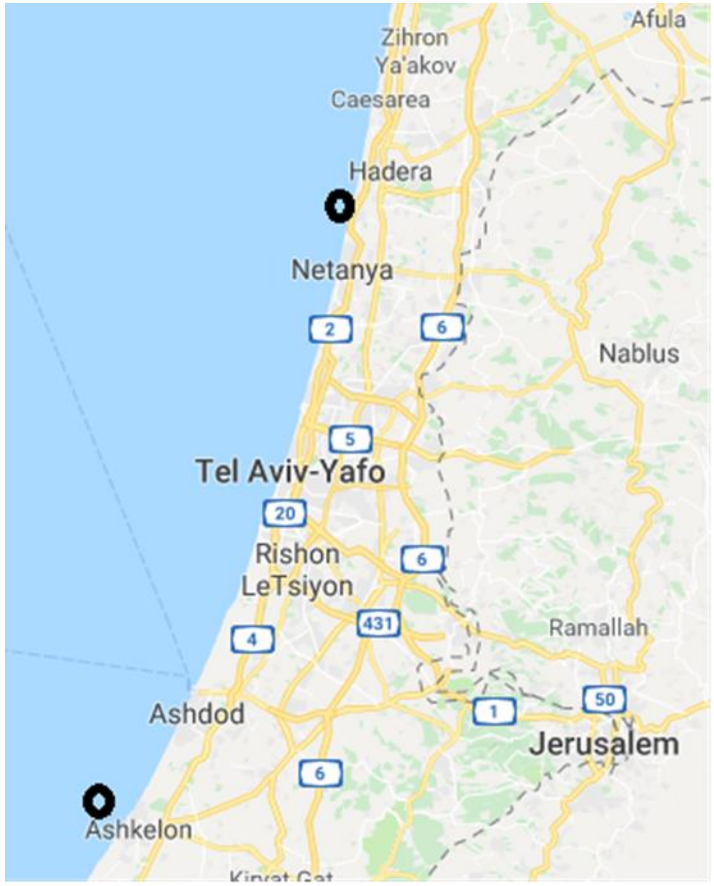

Figure 1: Shark aggregations in Hadera and Ashkelon (in black circles)

2. Materials and Methods

2.1 The travel cost model

A travel cost model combining current (revealed preferences) with CB (stated preferences) data was used to analyze how the sharks' appearance would affect the recreational value of the two sites. The cost of traveling included the petrol cost from the declared place of origin, using the rate for an average car of ILS 1.4 per kilometre. To this was added the opportunity cost of time, at one-third of the reported wage (Amoako-Tuffour and Martínez-Espiñeira, 2012). Time and distance are usually obtained using self-reported answers or programs such as Google Maps.

For the two independent models of revealed and stated preferences, an individual travel cost Poisson count model was used. The dependent variable was visits per season, and the independent variables were travel cost (TC) and the socio-demographic variables. In the pooled

TC+CB models, each individual in the data set is counted twice. One time in under the current conditions of the attribute and the second time under the hyphothetical change in the level of the given attribute. Therefore, the model should also include a dummy variable that indicates whether the number of visits for that individual was observed data or CB data (Eiswerth et al. 2000).

Thus, the demand function can be expressed as

$$(1) \quad v = f\,(c, Z, D)$$

Where v is the visitation rate to the site, c is the round-trip cost, Z is a vector of the sociodemographic characteristics of the individual, and D is the dummy variable that indicates whether the observation is under the current level of the attribute or the hypothetical change in its level (Grijalva et al. 2002).

The variables besides the travel cost are gender, age, people per household, origin (native or immigrant), education level (5 levels), membership in a green organization, and income. The Poisson count model enables the estimation of the consumer surplus of a visit to the site. If the cot coefficient is given by β_{cost}, the consumer surplus per visit is given by $(-1/\beta_{cost})$ (Hellerstein and Mendelsohn, 1993). If one uses a pooled model, an interaction term that is the product of CB and cost should be added. Its inclusion is a test to explore exploring whether the contingent scenario changes the slope of the recreational demand (Eiswerth et al., 2008). To estimate the recreational change value, the coefficients of these two variables (CB and CB × cost) must be found significant. If the interaction term is not statistically significant, one can conclude that the shift in the demand function is horizontally without any change in the slope.

2.2 **Survey and data collection**

A survey was conducted at the two different beaches, where sharks can be observed now (Hadera) or hypothetically could be observed in the future (Ashkelon). A paper-based questionnaire was used in a face-to-face setting. Visitors to the beaches were intercepted at random, and an in-person written survey was conducted. Care was taken in order to make the sample representative of the temporal distribution of trips (e.g., sampling at different hours of the day and during week and weekend days). The survey was conducted over a one-month period in February 2018, with 205 successful completions.

The survey itself was in four parts. Part A dealt with some explanations of the phenomenon, including the potential pros and cons of shark tourism. Part B dealt with the distance and time required to visit the site. We also asked about the weight given to sharks in the visit and adjusted the trip cost accordingly (Martinez-Espineira and moako-Tuffour, 2008). Part C asked about visit frequency during the last season and how it would change if there were a change in shark visibility. Part D collected socio-demographic characteristics.

2.3 Biological observations

Seasonal observations using drone surveys, diving, and on-beach observations from November 2017 through early May 2018 show that sharks are being stressed by divers, swimmers, and personal watercraft, along with increasing numbers of coastal visitors. Energy requirements, for instance the standard metabolic rate (in mg O_2/h) of sandbar sharks (*C. plumbeus*), were determined by using best-fit allometric equations referring to temperature calculated by Dowd et al. (2006). Because direct measurements in the ocean are rare and complicated, a common approach to estimating energy requirements in large marine animals is to quantify the correlation between metabolism and body mass in smaller animals, and extrapolate upwards (Payne et al. 2015).

3. Results

Descriptive statistics for the two locations are presented in table 1.

Table 1: Descriptive statistics

Variable	Mean		SD		Min		Max	
	Ashkelon	Hadera	Ashkelon	Hadera	Ashkelon	Hadera	Ashkelon	Hadera
Travel cost (ILS)	81.526	137.67	40.752	86.730	25.411	26.882	204.549	137.66
Visit before	8.885	3.339	6.677	2.879	.5	.2	24	12
Visit after	13.383	2.577	8.200	1.642	2	0	36	6
Gender	.687	.427	.467	.497	0	0	1	1
Age	34.205	39.097	12.708	13.015	12	9	68	73
People per household	4.217	4.048	1.316	1.023	1	1	7	6
Origin	.626	.893	.487	.310	0	0	1	1
Education	2.795	2.747	1.134	.997	1	0	5	4
Green	.193	.175	.397	.382	0	0	1	1
Income (ILS)	11807.2	11,215.0	4246.8	4,033.8	5000	0	20000	5

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The mean travel cost (including fuel and time) is ILS 81.5 and ILS 137.67 for Ashkelon and Hadera, respectively. This is a substantial difference, which might reduce the impact of shark visibility in Ashkelon compared to Hadera. Visit frequency increased from 8.885 to 13.383 in Ashkelon, while in Hadera it decreased from 3.339 to 2.577. These differences are for the "before" and "after" scenarios, so they should be opposite in sign, since "after" in Ashkelon means sharks appearing while in Hadera it means sharks disappearing.

Three model estimations are executed using revealed preferences ("before"), stated preferences ("after") and the pooled data CB model. The change in the benefit of a given visit before and after the change were measured by the difference in the consumer surplus under the present attribute condition and the new attribute conditions. The pooled model includes two dummy variables. One is dummy sharks, which differentiates between the two scenarios (with or without sharks). The second is dummy cost. As explained above, this variable was created as an interaction term of cost times the variable "dummy sharks". When it is 1, only the stated preferences data are included, and when it is 0, only the revealed preferences data. If the coefficients of both dummy variables are statistically significant, then the demand shifts both upward and also incur a change in slope. The results are given in table 2.

Table 2: Econometric estimations

Scenario	Before		After		Pooled	
	Ashkelon	Hadera	Ashkelon	Hadera	Ashkelon	Hadera
Cost	-0.00637***	-0.002089*	-0.0051***	-0.002639**	-.007681***	-.00371***
Gender	0.419***	-0.231**	.27547***	0.049	-.071***	-.109
Age	-0.0041	0.011***	-.0008	0.005	.0026***	.0094***
People per household	0.03	-0.135***	.0352*	-0.16**	.022*	-.149***
Origin	-0.323***	0.118	-.248*	0.129	.392	-.049
Education	0.369***	0.318***	.217***	0.36***	.138*	.325***
Green	0.123**	0.033*	-.126	0.314**	.173*	.111*
Income	0.00009***	0.044*	.000035**	0.19***	.000025***	.0071*
Constant	2.46***	2.49***	2.724***	1.69***	3.101***	2.471***
Dummy sharks					.221***	.057*
Dummy cost					.00087	.00383
	N = 102 LR $chi^2(8)$ = 160.52 Pr > chi^2 = 0.000 LL = -264 Pseudo R^2 = 0.233	N = 103 LR $chi^2(8)$ = 78.43 Pr > chi^2 = 0.0000 LL = - Pseudo R^2 = 0.126	N = 102 LR $chi^2(8)$ = 145.80 Pr > chi^2 = 0.000 LL = -304.6 Pseudo R^2 = 0.193	N = 103 LR $chi^2(8)$ = 31.60 Pr > chi^2 = 0.0001 LL = -160 Pseudo R^2 = 0.09	N = 202 LR $chi^2(10)$ = 505.60 Pr > chi^2 = 0.0000 LL= -2176 Pseudo R^2 = 0.104	N = 205 LR $chi^2(10)$ = 180.09 Pr > chi^2 = 0.0000 LL = -516.4 Pseudo R^2 = 0.1485

*, ** and *** indicates 90%, 95% and 99% significance level.

Looking at the estimated coefficients across the three models, we can see that first, both "dummy sharks" variables are statistically significant, while the two dummy cost variables are not. That means that the effect of sharks' appearance is a parallel shift in the demand function but not in the slope of the function.

The cost coefficient is statistically negative in all three models, indicating that higher travel cost reduces visit frequency. For Ashkelon the coefficient is larger (in absolute value terms) in the "before" scenario compared to the "after". That means that the consumer surplus is lower, as expected, before sharks appear there. In Hadera it is the opposite: the cost coefficient in the "after" scenario is bigger than in the "before". That means that if the sharks abandon the Hadera beach, consumer surplus will decrease. The cost coefficient in the pooled model is higher (in absolute terms) in both locations compared to the separate scenarios, "before" and "after".[2] That might reflect the difference between the pooled and independent models. In particular, consumer surplus is smaller in the pooled model. But the difference is also a function of the (statistically significant) dummy variable.

[2] "Before" and "after" in the pooled model were estimated by calculating the predicted visit frequency under mean values for the independent variables.

Welfare effects are calculated through the changes in consumer surplus (CS) per individual, multiplied by the number of visitors in the associated scenario. To calculate the effect of the overall park attribute quality improvements on recreation demand and CS, number of trips and CS are estimated for both current and hypothetical levels of the attribute (with or without sharks). The CS per trip is given in the Poisson model by $-1/\beta_{cost}$ (Hellerstein and Mendelsohn, 1993). To calculate the difference in the entire CS, one needs to also take into account the change in number of visitors (Fishler and Tal, 2011). Hence the relevant equation is

$$(2) \quad \Delta CS = \frac{Visits_A}{\beta_{cost,A}} - \frac{Visits_B}{\beta_{cost,B}}$$

For the pooled model, the welfare effect is:

$$(2)\ \Delta CS = \frac{Visits_A}{\beta_{cost} + \beta_{Dummy\ cost}} - \frac{Visits_B}{\beta_{cost}}$$

But since dummy cost is not statistically significant, we can ignore the second term in the denominator of the first fraction in the right-hand side of the equation.

Table 3: Welfare effects

	Before		After		Difference		Pooled before		Pooled after		Difference	
	Ashkelon	Hadera	Ashkelon	Hadera	Ashkelon	Hadera	Ashkelon	Hadera	Ashkelon	Hadera	Ashkelon	Hadera
CS per trip (ILS)	157.0	478.7	196.1	378.9	39.1	-99.8	130.2	422.9	158.9	269.5	28.8	153.4
Visits	29898	21452	45066	16518	15168	-4934	24795	18952	36525	11748	11730	-7204
∑CS (ILS millions)	4.7	10.3	8.8	6.3	-4.0	4.1	3.2	8.0	5.8	3.2	2.6	-4.8
Total CS for shark presence (ILS millions)					8.2				7.4			

Table 3 presents the CS per visit under the two scenarios – “before” and “after” – as well as the pooled model. The estimated surpluses in the pooled model are smaller than in the independent ones. That is also reflected in the difference in Ashkelon but not in Hadera. For Ashkelon the difference is ILS 39 and ILS 29 for the independent and pooled models, respectively, while for Hadera it is ILS 100 and ILS 153. Not only is the difference larger in Hadera, but so too are the absolute values. This could be due to the prior experience of respondents, since sharks are already present and observable in Hadera but not in Ashkelon.

The total change in the value of sharks' appearance is ILS 8.152 million and ILS 7.425 million for the independent and pooled scenarios, respectively. While in the independent models the net impact of the two locations is almost identical (about ILS 4 million for each location), in the pooled model the benefit in Ashkelon is ILS 2.58 million while in Hadera it is ILS 4.85 million.

To get a sense of the conflict between shark conservation and tourism, we tried to relate diving and shark fitness. Fourteen diving activities were observed, with two or more divers, using scuba gear. We observed female dusky sharks and male sandbar sharks. About 76 encounters with sharks of both species were documented. Both species changed their behaviour in the presence of the divers. The sandbar sharks (81.6%) fled quickly; the dusky sharks (18.4%) also moved away, but more casually. The vigorous flight of most of the sharks has an energetic price and can be assumed to reduce fitness. How quickly a shark disappears (vanishing point) depends on visibility; an average visibility of 15 m was used in calculations. We calculated the disturbance caused by two divers (with a 15 m radius) as significant. The derived threshold level in the living area, where sharks are staying most of the time (300 m × 150 m), is estimated at 8 divers.
According to the coastal monitoring stations, there were 1,767 divers off Hadera Beach during the last season (Nov. 2017 – May 2018). This number can be analysed under the assumptions that diving is done mostly on weekends (Friday and Saturday) and that a diving session takes an hour, hence there are six diving hours per day (10 am to 4 pm).[3] Table 4 describes the outcome of applying the different parameters.

Table 4: Diving and threshold impact

Divers per season	Number of active diving days	Divers per day	Divers per hour
1767	32	55	9.2

Free entry of divers into the sharks' area will result in an average number of divers 12% higher than the threshold level. Taking the average of the two models, we get an annual value for shark

[3] In the winter, the best time to dive is before 4 pm; after that, there is not enough light under the water. Most diving clubs prefer the early morning for diving preparations—equipment, diver instructions, etc. (https://www.snorkelingonline.com/pages/best-time-of-day-to-go-snorkeling).

appearances of ILS 4.5 million. Assuming a linear relation between the number of divers and the number of visitors, the change in active divers is 0.29 of the change in beach tourists (based on the average change in number of tourists between the two models). Hence, restricting the number of divers to an average of 8 per hour will result in a touristic welfare loss of ILS 0.157 (0.29 × 0.12 × 4.5) million.

4. Discussion

This study provides insight into some of the touristic benefits and costs that apperence of sharks can provide. This knowledge can be used as a tool to improve our managerial abilities to control for a balanced weigh between tourism and other ecosystem services (e.g., Fleischer & Tsur, 2003; Ghermandi & Nunes, 2013). The idea is a general one but specific analysys should be carried for different species since the rarer the species, the higher is its conservation value (Festa-Bianchet, 2012). Anna and Saputra (2017) found the annual value of whale shark tourism in a national park in Indonesia to be IDR 142.35 billion per year, or ILS 36.89 million (using tourist data from 2015). Other studies have found annual benefits from ILS 26.6 million to ILS 32.9 million (Cagua et al. 2014). These estimates are based on 72,000–78,000 tourists doing whale shark excursions annually. In our case study, the total number of visitors to the two beaches if we assume sharks are visible at Ashkelon is 66,520. But these visitors go to the beach for other purposes as well.

We demonstrate here also the applicability of the CB method to analyse such changes. The signs of the parameters are as expected. Also, visitor behaviour indicates an impact of cost on number of trips taken and an effect of shark visibility on visit frequency. Both coefficients have policy implications, with respect to investment in shark observation on the one hand and actions to prevent visitor overcrowding on the other hand.

This study is a first approach toward economic analysis of tourism benefits from an endangered species, where tourism demand is currently rising and may have negative effects on the species. The estimated consumer surplus of recreation in Hadera, where sharks are observable, is ILS 4.14–4.85 million per season. Further, the appearance of sharks changed the individual consumer surplus by 25% and 37% for the independent and pooled models, respectively. Since this is a unique and new phenomenon in Israel, it is hard to compare that to other case studies, but a 30% increase because of one natural attribute is a significant effect.

Our results suggest that considerable recreational benefits could be generated by a shark observation option and may provide another perspective on using economic benefits as a reason for conservation (Hussain & Tschirhart, 2013; Minin et al., 2013). However, considerable additional research is necessary before these values can be used to justify additional investments, given the risk of crowding and its impact on the sharks.

The dusky shark (*C. obscurus*) and the sandbar shark (*C. plumbeus*) are in the group of marine animals who are experiencing the greatest impact of anthropogenic influence on the sea (Payne et al. 2015). It can be assumed that each encounter of the shark with divers causes an escape reaction. In the presence of divers, the sharks' energy cost increases. First, these sharks are relatively large (*C. obscurus,* 3.5–4.2 m long; C. *plumbeus,* 2.2–2.8 m long), and the estimated cost of swimming in a curved path versus a straight line increases with body mass by 0.8–19.9% (Webb 2002, Dowd et al. 2006). Thus, divers cause the sharks to use energy they might not be able to spare. Second, the water temperature increases towards the end of the season, causing a significant increase in metabolic and heart rates, and recovering from stress may take 6–10 h (Dowd et al. 2006) when the stress is significant and encounters with disturbing factors (divers) are frequent.

Thus, conflicts between shark conservation and potential tourism increase are of particular interest. Following Cisneros-Montemayor et al. (2013), Gallagher et al. (2015), Macdonald et al. (2017), Raudino et al. (2016), and Sorice et al. (2003, 2006), our analysis indicates a touristic welfare loss of ILS 0.157 million per season to keep shark disturbance to a sustainable level and may raise a call for a long-term resolution of this human–wildlife conflict (Dickman, 2010). One example solution would be a dynamic marine protected area, i.e., to close the area to fishing (Chae et. al 2012; Hausmann et al. 2017; Mwebaze and MacLeod, 2013; Shiffman and Hammerschlag, 2016) or diving at specific times.

Another solution may be to limit shark observation to certain places. This could have the benefit of keeping sharks free of touristic interaction; the risk is that the area where observation is allowed could become overcrowded. Whether the total combined benefits would increase, or decrease requires further consideration.

5. Conclusions

We used an individual count model as well as combined pooled contingent behaviour to assess the value of shark tourism in two locations in Israel: Hadera, where sharks are observable, and Ashkelon, where sharks are present but not observable. The economic value of a site with sharks is about ILS 4.1 million in each location. Currently, consumer surplus for Hadera, where sharks are observable, is higher.

People diving alongside the sharks may harm the population, since about 12% more people are doing it than the frequency thought to be sustainable (not having an impact on the sharks' behaviour). We estimate that restricting diving frequency would have an impact of ILS 0.157 million per season. This may seem a modest amount (3% of the total recreational value), but it relates only to diving. An emerging tourism industry that includes kayaking, motor boats, etc. could increase this value very rapidly.

The potential combination of shark tourism and the newly observed shark aggregations raises two important questions. The first is about the effect of this anthropogenic interference on sharks. The second question is about the impact of regulated shark tourism. To answer the first question, an extended ecological-biological analysis will be needed. But the answer to the second question may be found in this manuscript. Different levels of recreation intensity (visitors on the beach, divers, swimmers, etc.) have different effects on the sharks' fitness and different economic value. This may form the basis for zoning for different activities, on a range from passive tourism (observing the sharks from a distance) to active engagement (diving with them).

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