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Climate change's impact on Lake Kinneret: Letting the data tell the story

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To the Editor:

The broad scientific consensus within Israel is that Lake Kinneret – the Sea of Galilee has reached record low levels because of climate change: a combination of reduced precipitation and increased temperature/evaporation (Givati and Rosenfeld, 2007; Givati and Rosenfeld, 2013; Samuels et al., 2010; Markel et al., 2017; Givati and Tal, 2017; Givati et al., 2019; Gophen, 2019; Tal, 2019). In his letter to the editor, Wine declares that arguments claiming "climaticization" are designed to elude government responsibility for sound environmental governance of the basin. Overpumping for agriculture, he argues, is a primary driver of the recent shrinkage of the lake. Wine also implies that water experts in Israel face restricted freedom of expression which compromises their scientific integrity. Given this iconic lake's significance for Israel's economic and recreational well-being, as well as its spiritual significance for people around the world, it is well to draw international attention to the diminished condition of the Kinneret. The trouble is that all of Wine's claims are false.

It is peculiar that in making these bold assertions Wine does not rely on any comprehensive data, in particular the regular, copious measurements undertaken by Israel's highly professional government Hydrological Service. Fortunately, Israel is a democracy with a Freedom of Information Law, and since its inception, its Water Authority has a strong tradition of transparency. Rather than cast aspersions, in this letter I prefer to simply translate and present the relevant data, at an appropriate level of resolution. These data clearly contradict Wine's claim of overpumping and mismanagement and strongly support the hypothesis of climatic change as the cause of the lake's depleted water levels.

Table 1 offers a breakdown, since the year 2000, of the extraction in the lake's watershed according to type of source, in million cubic meters (MCM). The estimated *Diversion of water by Lebanon* in the watershed has increased by 50% during this period, but the total quantity of 30 MC is quite modest relative to the total inflow to the lake. *Surface Water Demand* involves water taken from streams that drain through the watershed, primarily utilized to support agriculture. These volumes have steadily decreased over the past twenty years, as highlighted in red. These official government data from Israel's Water Authority confirm that pumping from the Lake itself has essentially been discontinued in recent years due to concerns about salinization resulting from present drawdown. During the past three years, the Kinneret only supplies some 6% (~30 MCM) of the 500 mcm that it historically delivered via Israel's National Water Carrier. Wine challenges this claim, citing a Mekorot, (Israel's national water utility's) figure of 119 MCM being pumped from the lake in 2016. The discrepancy can be explained by the release and export of water as part of the Israeli-Jordan peace agreement, as well as immediate use around the lake. But the vast majority of this water no longer enters the National Water Carrier.

Well extraction does appear to have increased by almost 50% over the past eighteen years. An uninformed observer might reach the conclusion that this contributes to a drop in the Kinneret's water levels. Indeed, Wine argues that similar to other lakes in water-limited regions, the ground/surface water interface significantly contributes to desiccation of the Kinneret. Yet, he brings no hydrological evidence to support this assertion. In fact, a detailed presentation of the different well extractions taking place in the basin suggests that the pumping of ground water in the Kinneret basin has had little impact on the lake's water levels. The central driver behind the low levels in the lake in recent years involves rising temperatures and reduced rainfall. Fig. 1 offers a presentation of groundwater extraction in the watershed during the past 25-years, according to the salient divisions in the different water resources of the basin.

It is well to consider the hydrological role in the watershed of each of the five groups of groundwater recorded above: Extraction from the *Einan Wells* (demarcated in green) undoubtedly reduces the potential flow of water to Lake Kinneret. But this ground water system has been tapped since the 1960s and the volume of water pumped has been steady during the past fifty years (Adi Tal, personal communication, May 6, 2019). Surely, it has not increased. It therefore offers no explanation for Lake Kinneret's recently reduced water levels.

The pumping of groundwater from the *Eastern Galilee* (displayed in turquoise), located some distance from the Lake has increased significantly. Yet it is critical to understand its minimal past contribution to Kinneret water levels. In the 1960s, Israel operationalized its National Water Carrier. At that time, the Kinneret's salinity levels were deemed excessively high for a national reservoir of potable water (Tal, 2002). Water quality interventions initiated then included diversion of saline springs that reached the lake, via a conduit, that collects the flow and circumvents the Kinneret, discharging the salty water south of the lake into the lower Jordan River. The Eastern Galilee aquifer feeds these salty springs. In other words, for over fifty years, much of this aquifer's waters never reached the lake anyhow but were, and continue to be, diverted away.

The "*Basalt Aquifer*" in the Golan Heights (marked in purple) is located 600 m above sea level. The closest stream from the wells is located at a distance of 15 km. According to present hydrological modeling (Daphne, 2018), pumping here only modestly affects the groundwater's internal balance, at most, reducing base flow drainage by 2–3 MCM year and probably less.

During the past decades, 10 MCM has been pumped in the "*Hurshat Tal and Huleh 11*" wells (blue). Yet, the water from these wells is released into nature, to supplement stream flow in the Upper Galilee – streams which after several kilometers reach the Jordan River and the

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Table 1
Extractions (in MCM) from the Kinneret Basin: 2000–2017.
Source: Israel Water Authority, 2019.

Year	Diversion by Lebanon	Well extraction	Surface water demand in upper basin	Amt. pumped to national water carrier	Total
2000	20	61	92	230	403
2001	20	63	81	160	323
2002	20	63	86	153	322
2003	20	58	102	414	595
2004	20	50	104	527	701
2005	20	41	103	401	565
2006	20	59	91	242	412
2007	20	58	85	224	386
2008	20	74	80	267	441
2009	20	72	81	133	307
2010	28	79	76	165	348
2011	28	72	86	197	382
2012	28	76	105	193	403
2013	28	71	114	239	452
2014	28	80	110	125	344
2015	28	71	100	50	248
2016	28	96	100	24	248
2017	30	93	85	34	242

Kinneret. So the groundwater pumping actually contributes to raising the water levels in the lake.

Some five years ago, the new *Shamir*/*Shonit* wells began exploiting an ancient, aquifer located 1500 m below surface in the Golan Heights. Carbon testing dates these waters at 20,000 to 40,000 years old. The preponderance of hydrological opinion is that these waters never were linked to the Kinneret drainage system. Even if they are somehow connected, movement is very slow and any impact from the 5 MCM pumped annually would hardly be felt so immediately.

In short, the collective impact of pumping groundwater on Lake Kinneretis is de minimus – if at all. Some local water managers argue that the pumping may actually serve to increase the inflow: As mentioned 8 to 9 MCM of groundwater pumped in wells near Hurshat Tal are released into the Banias stream, which feeds the Jordan and subsequently empties into the Lake. The Huleh 10 well releases an additional 2 MCM each year to the Snir stream. Finally when the Huleh 7 well began providing 3–4 MCM annually to Israel's northern city of Qiriyat Shmoneh, a parallel amount of water was released to the Kinneret from the nearby Ein Zahav stream (Markel, personal communication, May 5, 2019).

Even if groundwater utilization affects Kinneret water levels, the orders of magnitude involved do not support claims of lake shrinkage due to groundwater exploitation. Figs. 2–3 show the dramatic drop in stream flow in three of the major tributaries to the Lake: In recent years, the current in the Snir stream has dropped to roughly half of the annual average flow which was typically over 100 MCM. The percentage reduction in the flow of the Jordan River is even greater. Even if the 93 MCM of groundwater extraction taking place in the basin affect the Kinneret level, the numbers are too small to explain the reduced flow in the major tributaries to the lake which involves a drop of hundreds of MCMs. This is especially true when – as described above – groundwater extraction now adds 30 to 40 MCMs to the direct surface water flow into the lake.

The drop in the Kinneret water levels is, however, explained convincingly by the reduced precipitation and increased evaporation of recent years. Fig. 4 shows aggregated annual rainfall as measured in the two meterological stations in the Kinneret watershed – Marom Golan and Kfar Giladi. Average rainfall during the last five years has only been 572 mm — 71% of the annual average, which based on nearly a century of measurements, is rouughly 800 mm. It is important to emphasize that hydrological models (Givati and Tal, 2017) show that reduction in flow is not equal to the reduction in rainfall, but rather far greater.

When the increased evaporation associated with the one degree rise in summer temperatures measured during the past decades (Ziv et al., 2012) is added, the picture that emerges is fairly clear: The attenuated flow in the Lake's major tributaries is caused by reduced rainfall and increased evaporation. Groundwater pumping has had little if any effect on the level of Lake Kinneret. These weather-associated factors, which are likely to be manifestations of climate change, appear to be the primary driver behind Lake Kinneret's recent historic lows and the associated salinity increase as described in Tal (2019).

Wine relies on articles about Soviet mismanagement of the Aral Sea, Iranian mismanagement of Urmia Lake and the desiccation of California's Owens Lake in the 1940s to support his claim that Israel is disingenuously “climaticizing” water shortages to obfuscate its irresponsible management decisions and to evade responsibility. Such spurious comparisons ultimately constitute argument by assertion. Israel's water management bureaucracy is widely recognized as scientifically sophisticated, cautious, far-sighted and innovative — a model of adaptive management and evidence-based policies (Tal, 2016). It bears little resemblance to the water management agencies associated with Wine's examples.

It is well to note, that in his letter, Wine takes issue with the country's leading local limnologists and climatologists who have written on the issue, relying primarily on his own research and irrelevant articles to support his view. But as my previous letter notes, in his

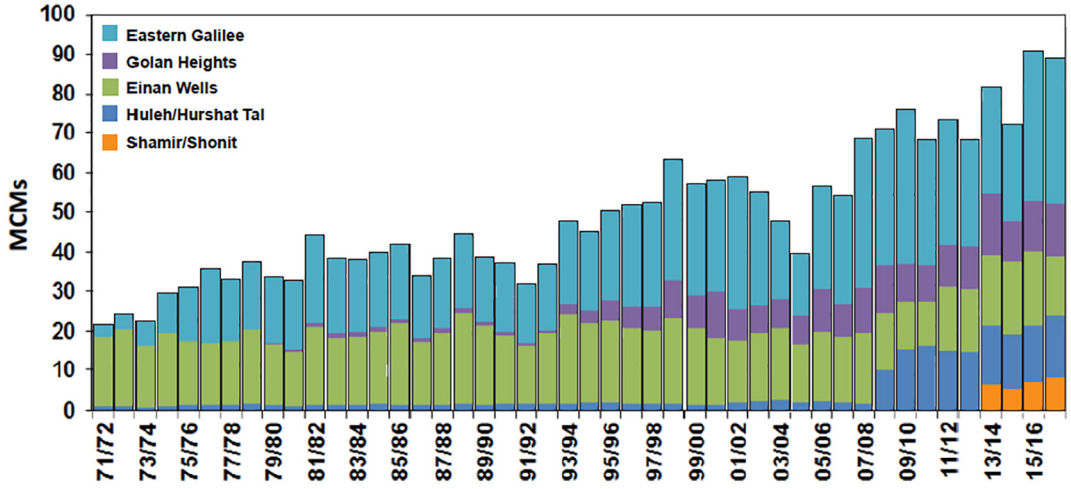

Fig. 1. Groundwater Extraction in Kinneret Basin by Category, 2012–2017.
Source: Israel Hydrological Service, 2019.

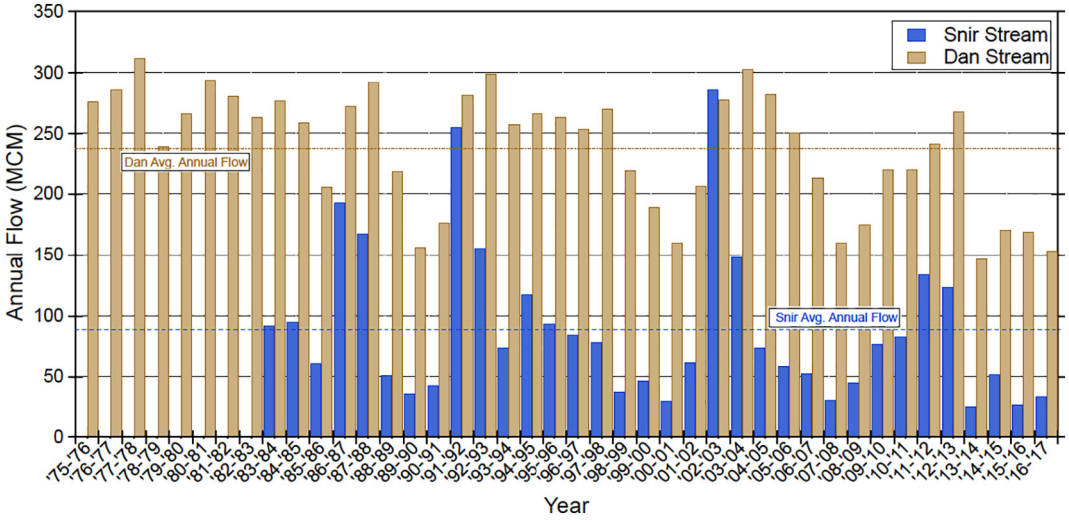

Fig. 2. The Dan and Snir Stream, Annual flow 1975–2017.
Source: Israel Hydrological Service, 2019.

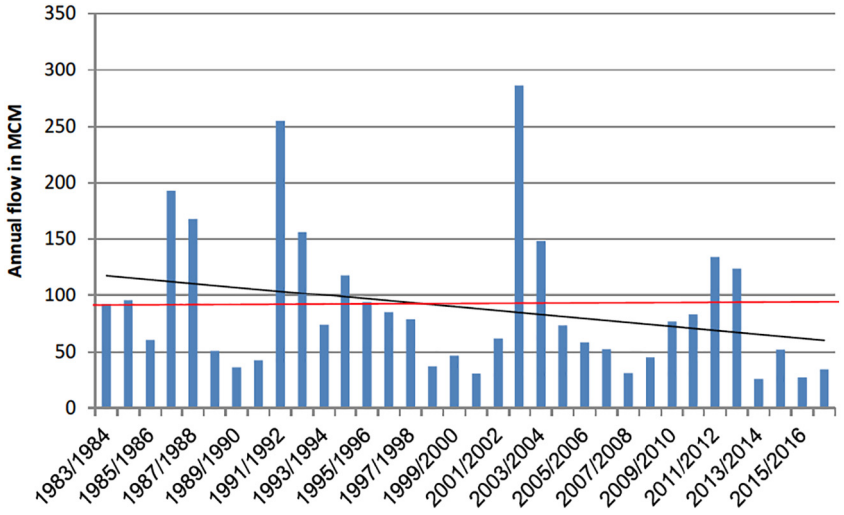

Fig. 3. Upper Jordan River (At "Pkak" Bridge), Annual flow: 1983–2016.
Source: Israel Hydrological Service, 2019.

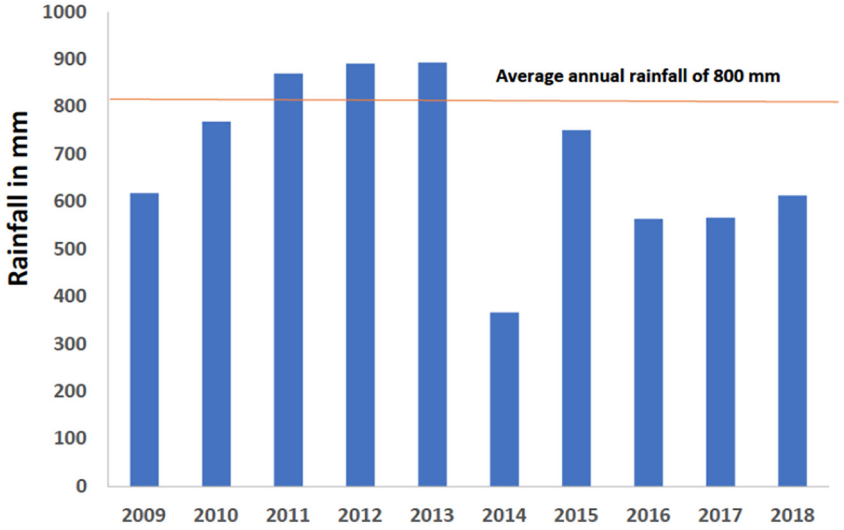

Fig. 4. Annual Rainfall in Kinneret Basin: 2009–2018.
Source: Israel Hydrological Service, 2019.

publications, and by his own admission, Wine et al. lacked access to the wealth of data which are available about the Kinneret basin. I am posting the relevant excel files on the STOTEN's website so that the scientific community and Dr. Wine can reach their own conclusions based on sixty years of systematic monitoring.

While it is true that typically it takes decades to confirm long-term changes in the climate, these are hardly ordinary times. Thankfully, the UN Climate Change convention and Israeli water managers have embraced the precautionary principle. They are not waiting for absolute scientific certainty before adapting to what appears to be significant changes in the precipitation and temperatures in the Galilee and the resulting impact on Lake Kinneret.

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