




Research Article

Popular solunar tables fail to predict fishing success in North American recreational freshwater trout fisheries

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Abstract

The solunar theory proposes that the position of the sun and moon can be used to predict activity rates in fish and game species. Several free and premium services use this theory to provide tables predicting optimal dates and times for fishing and hunting success. The efficacy of these services was tested by comparing catch per unit effort (CPUE) in a recreational freshwater trout fishery with daily solunar values and coincidence of fishing trips with peak solunar times. CPUE was also compared to environmental variables including lunar phase, lunar illumination, and wind speed. Values predicted by each of the solunar services were strongly correlated to each other and to lunar phase, however, no significant relationship was found between CPUE and any of the solunar values tested, lunar phase, or lunar illumination. Ambient air temperature showed a positive relationship with CPUE, and was a more effective predictor of fishing success than any of the solunar tables tested.

Article highlights

- Solunar calendars that use the lunar phase and the positions of the moon and sun show no correlation to increased fishing success.
- Fishing success showed no correlation to moon phase or percent illumination.
- Of all variables tested, ambient air temperature was the only one that showed a significant correlation to catch per unit effort.

Keywords CPUE · Solunar theory · Recreational fishery · Lunar cycle · Environmental variables

1 Introduction

1.1 The solunar theory

The solunar theory proposes that the positions of the sun and moon, together with the lunar phase, can be used to predict activity rates in fish and game species. The

principle application of the theory (note that the so called “solunar theory” does not meet the scientific definition of a “theory” that is founded in repeated testing and corroboration. However, as this the name under which it is widely marketed, this informal terminology is also used here.) has been to calculate the most productive days and times for recreational fishing and hunting in marine freshwater, and

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terrestrial environments [1]. The theory suggests that two “major” peaks (the hours during which the moon is directly overhead and underfoot) and two “minor” peaks (the hours around moonrise and moonset) of activity occur each day. These periods correspond to peak high and low tides in marine environments, and Knight proposed that even terrestrial and freshwater species are influenced by what he called “inland tides.” According to the theory, days around the full and new moons and days when any major or minor peaks align with sunrise and sunset are also of increased “solunar value”, correlating with increased fishing and hunting success [2].

Many free and premium services targeted towards recreational fishers and hunters use these solunar values to predict optimal fishing and hunting for different regions, including *Fishing and Hunting Solunar Time*, *Solunar.com*, *Fishing Calendar Solunar*, *Solunar Forecast*, *Hunt Fish Sport*, *iSolunar*, and *Fishing Reminder*. While the specific calculations performed by each service vary, they each use the same three environmental variables—lunar position, lunar phase, and coincidence with sunrise and sunset—to provide an overall daily rating on some ordinal scale and major and minor peak times of predicted fishing and hunting success [2–8].

1.2 Lunar cycles and fish behavior

The application of solunar tables in predicting fishing success relies on the assumption that target species exhibit higher activity rates, including feeding, around peak solunar times [1]. Examples of behavior patterns synchronized to monthly lunar cycles are abundant across taxa [9–12], however, the vast majority of these occur in marine environments. Activity patterns linked to monthly lunar cycles include synchronization of spawning events with moon phases [9, 11] and variations in nocturnal foraging/predation activity due to differences in lunar illumination levels [10, 13]. Daily and monthly lunar cycles are also closely tied to movement and feeding patterns in coastal marine ecosystems due to their roles in driving tidal cycles [14–17].

In freshwater fishes, examples of correlations between lunar cycles and activity patterns are far fewer. Lunar synchronization of spawning events, while common in marine reef fishes, is rare in freshwater species, with most examples being documented in Lake Tanganyika cichlids [18, 19]. Radiotelemetry studies of some species have shown that lunar illumination does have an effect on behaviors such as diurnal foraging activity and migration rates [20, 21], while other species have shown no correlation between activity rates and lunar phase or illumination [22]. Each of these studies have considered only behavioral patterns linked to monthly lunar cycles (moon phase and lunar illumination) and do not test for patterns linked

to daily lunar cycles—the “inland tides” that the solunar theory asserts drive activity rates.

1.3 Lunar cycles and CPUE

The solunar theory is far from the first attempt to use lunar cycles to predict optimal conditions for fishing—traditional Maori fishermen used lunar calendars to mark optimal nights to fish for New Zealand longfin eels (*Anguilla dieffenbachii*, (Gray 1842)), which hunt by smell on nights of low lunar illumination [23, 24]. Traditional knowledge of monthly lunar cycles is also crucial in artisanal and subsistence fisheries throughout the South Pacific, where many reef fish species rely on these cues to synchronize spawning events [25]. Anglers can also use knowledge of a target species’ behavior in relation to tidal cycles to improve chances of fishing success. However, in each of these cases traditional knowledge is applied to a particular target species—as each species’ tidal movements and spawning patterns are different, there is no one set of conditions that improves fishing success generally.

Correlations between catch per unit effort (CPUE) and moon phase have been reported for several marine fisheries [26, 27], however, studies including multiple species very frequently report different patterns of correlation for each species [28–31]. Studies of other species show no correlation at all [32, 33].

Relationships between lunar cycles and CPUE are much rarer for freshwater fishes. Studies from North America and Germany report correlation between total fish caught and moon phase in pike (*Esox spp.*), with increased catch around the full and new moons [34–36]. However, of these studies, only Kuparinen et al. [34] define fishing success in terms of CPUE—the North American studies rely on total catch data reported by recreational fishers. These reports specifically address the possible bias of increased fishing effort around peak solunar days, which the authors note is a common practice [36]. Possible mechanisms responsible for increased CPUE for pike around the new and full moons proposed by the authors of Kuparinen et al. [34] include effects of lunar illumination on prey assemblages [37] and a direct biological response to lunar gravitation [38], although this question remains unstudied. These studies address only effects of monthly lunar cycles on CPUE, and do not consider the daily “major” and “minor” peak times predicted by the solunar theory. A 1950 study of multiple freshwater game fish in Clear Lake, Iowa, is the only work to test this relationship directly and found no correlation between gill net CPUE and peak solunar times as given by the original solunar tables published by Knight, the author of the solunar theory [39].

The goal of this paper is to evaluate the effectiveness of several of the most popular currently available solunar tables in predicting fishing success in recreational freshwater trout fisheries (*Oncorhynchus mykiss* (Walbaum, 1792), *Oncorhynchus clarkii* (Richardson, 1836), *Salmo trutta* (Linnaeus, 1758), *Salvelinus fontinalis* (Mitchill, 1814), *Salmo trutta* × *Salvelinus fontinalis*, *Salvelinus fontinalis* × *Salvelinus namaycush*, *Prosopium* spp.) in and around Utah, USA. In the following section, the methods applied to test this relationship are outlined. Section 3 presents the results of this experiment, and Sect. 4 provides interpretation and discussion of these results. Section 5 summarizes the conclusions drawn by this study.

2 Methods

2.1 Fishing data collection

From September of 2013 to February of 2019, an experienced angler (15 years of fishing at least once a week) recorded catch data from regular fishing trips to rivers, streams, lakes, and reservoirs in and around Utah, USA (Fig. 1). The use of data from a single angler excluded possible variations in fishing skill from the analysis, however, this does not impact the ability of the study to examine the relationship between solunar tables and CPUE. Data were collected from 361 fishing trips, occurring on 221 unique days, for a total duration of 1,355.2 h. Fishing trips occurred throughout the year, with the most unique days represented in July and November (23) and the least in February (13). Fishing trips were scheduled

based on convenience and thus occurred mostly on weekends throughout the year, however, the angler did not access solunar predictions or moon phase data during the data collection period. Techniques used include fly fishing, spinning rod fishing, and ice fishing during the winter months. The angler used the gear that he felt gave him the best chance of fishing success. Our analyses include both quantitative measurements of fishing success as well as a subjective rating by the angler, and is not affected by variability between fishing gear types. Further work along this line of research would ideally incorporate additional anglers and standardized gear, however, the present study exhibited sufficient power to examine the relationship in question. All sampling was approved under BYU Institutional Animal Care and Use Committee protocol number 19-0903.

The angler recorded the date, time, and duration of each trip along with the total number of trout caught (*Oncorhynchus mykiss*, *Oncorhynchus clarkii*, *Salmo trutta*, *Salvelinus fontinalis*, *Salmo trutta* × *Salvelinus fontinalis*, *Salvelinus fontinalis* × *Salvelinus namaycush*, *Prosopium* spp.), and the number of “trophy” fish caught, defined as any trout longer than 18 inches. These totals were then converted to CPUE (fish caught per hour) and trophy CPUE (trophy fish caught per hour). The angler also recorded a subjective, qualitative rating from 0–100 describing fishing conditions that day. This measurement was strongly correlated to CPUE and trophy CPUE, but also allowed for an estimate of fish activity not influenced by potential missed strikes, equipment failure, etc.

2.2 Solunar and environmental variables

Following data collection, we compiled daily predictions of solunar value for each day from 7 different web and mobile app resources: *Fishing and Hunting Solunar Time*, *Solunar.com*, *Fishing Calendar Solunar*, *Solunar Forecast*, *Hunt Fish Sport*, *Isolunar*, and *Fishing Reminder*. For *Fishing and Hunting Solunar Time* and *Solunar.com*, two of the most popularly used solunar services, we recorded the proportion of each trip that fell within a “major” or “minor” peak.

We also recorded the moon phase in radians (0 = new moon, π = full moon) and percent illumination of each day in order to identify patterns associated with lunar cycles independent of solunar chart predictions. To identify other potential environmental variables that influence fishing success, we collected ambient temperature and wind speed during each trip from the nearest of six weather stations where historical data were available: Salt Lake City International Airport Station, Ogden-Hinckley Airport Station, Provo Municipal Airport Weather Station, Cedar City Regional Airport Station, Grand

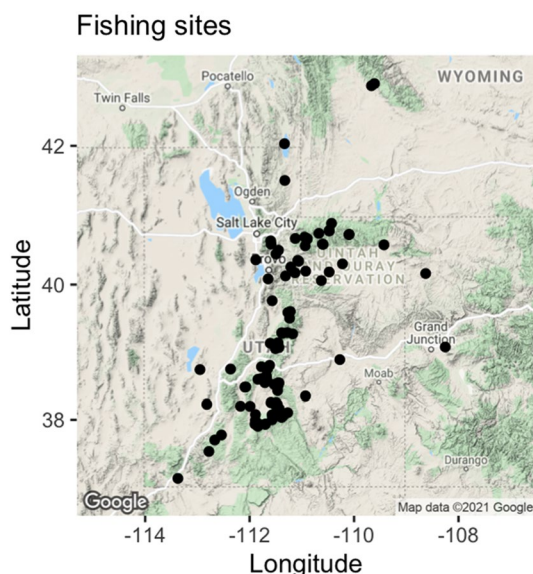


Fig. 1 Map of all fishing data collection sites

Junction Regional Airport Station, and Southwest Wyoming Regional Airport Station [40].

2.3 Statistical analysis

We performed linear regressions to predict each of our metrics fishing success (CPUE ($\log_{10}(\text{fishcaught}/\text{hour})$), trophy CPUE ($\log_{10}(\text{fishlargerthan}18''\text{ caught}/\text{hour})$), and qualitative angler rating) as functions of the daily ratings of all 7 solunar services we examined. For *Fishing and Hunting Solunar Time* and *Solunar.com*, we also tested the relationships of our three metrics of fishing success against the proportion of a fishing trip that fell within a major or minor peak time.

We also performed linear regressions testing our metrics of fishing success against each environmental variable: moon phase ($\cos(2 \times \text{radians})$, resulting in a value of 1 for the new and full moons and 0 for the quarter moons), percent lunar illumination, temperature ($^{\circ}\text{F}$), and wind speed (mph).

All statistical analyses were performed using the stats package in R 4.0.2 [41].

3 Results

3.1 Solunar tables

Over all trips, a total of 2141 fish were caught, including 361 trophy fish (over 18 inches), for a mean CPUE of 2.71 (fish/hour), mean trophy CPUE of 0.32 (trophy/hour), and mean angler rating of all trips was 48.2. In total, 23.3% (14.4%) of the duration of the combined trips fell within a major peak and 16.2% (8.5%) fell within a minor peak predicted by *Fishing and Hunting Solunar Time* (*Solunar.com*), while 61% (77.1%) fell outside of either predicted peak. We failed to detect significant relationships between the daily ratings of any of the examined solunar services and our three metrics of fishing success with an α of 0.05 and

after multiple testing correction ($\alpha^* = \alpha/n = 0.05/9 = 5.55 \times 10^{-3}$) (Table 1; Fig. 2) [42]. Power analysis conducted in R using the ‘pwr’ package, version 1.3–0 [43] calculated that with one model parameter, 219 error degrees of freedom (from 221 unique days sampled), our study had 99% power to detect an effect of size $f^2 = 0.15$ (a medium effect size, as suggested by [44]) at a 0.05 significance level.

When we analyzed the relationships between fishing success and major and minor peak times, we detected no correlation for most relationships (Table 2). Two significant regression equations were found that describe the ability of coincidence of fishing trips with *Fishing and Hunting Solunar Time* minor peaks to predict CPUE and our qualitative angler rating. However, in both cases these relationships had negative slope coefficients (Fig. 3)— a trip that falls completely within a *Fishing and Hunting Solunar Time* minor peak is expected to catch 42.5% less fish per hour ($100 * 10^{-0.24} - 1 = -42.5$) and receive an angler rating 18 points lower than a trip completely outside the minor peak.

3.2 Environmental Variables

We found no relationship between our metrics of fishing success and moon phase, lunar illumination, or wind speed (Table 3; Fig. 4). However, we found significant regression equations describing the ability of temperature to predict CPUE and angler rating (Table 3). For each increase of 10 $^{\circ}\text{F}$ in temperature, CPUE (fish/hour) is expected to increase by roughly 1% ($100 * 10^{0.004} - 1 = 0.93$) and angler rating is expected to increase by 2.5 (Fig. 4).

4 Discussion

We did not detect any significant relationship between the solunar ratings of the services we tested and our metrics of fishing success. As both measures of CPUE correlated strongly with the qualitative measure of fishing

Table 1 P-values for linear regressions of CPUE and qualitative angler rating against daily solunar values. No regression reached significance ($p < 0.006$)

	CPUE ($\log_{10}(\text{fish}/\text{hour})$)	Trophy CPUE ($\log_{10}(\text{fish} > 18''/\text{hour})$)	Angler rating
<i>Fishing and Hunting Solunar Time</i>	0.730	0.863	0.609
<i>Solunar.com</i>	0.999	0.770	0.399
<i>Fishing Calendar Solunar</i>	0.883	0.244	0.985
<i>Solunar Forecast</i>	0.903	0.374	0.483
<i>Hunt Fish Sport</i>	0.986	0.051	0.888
<i>Isolunar</i>	0.817	0.950	0.425
<i>Fishing Reminder</i>	0.391	0.264	0.842

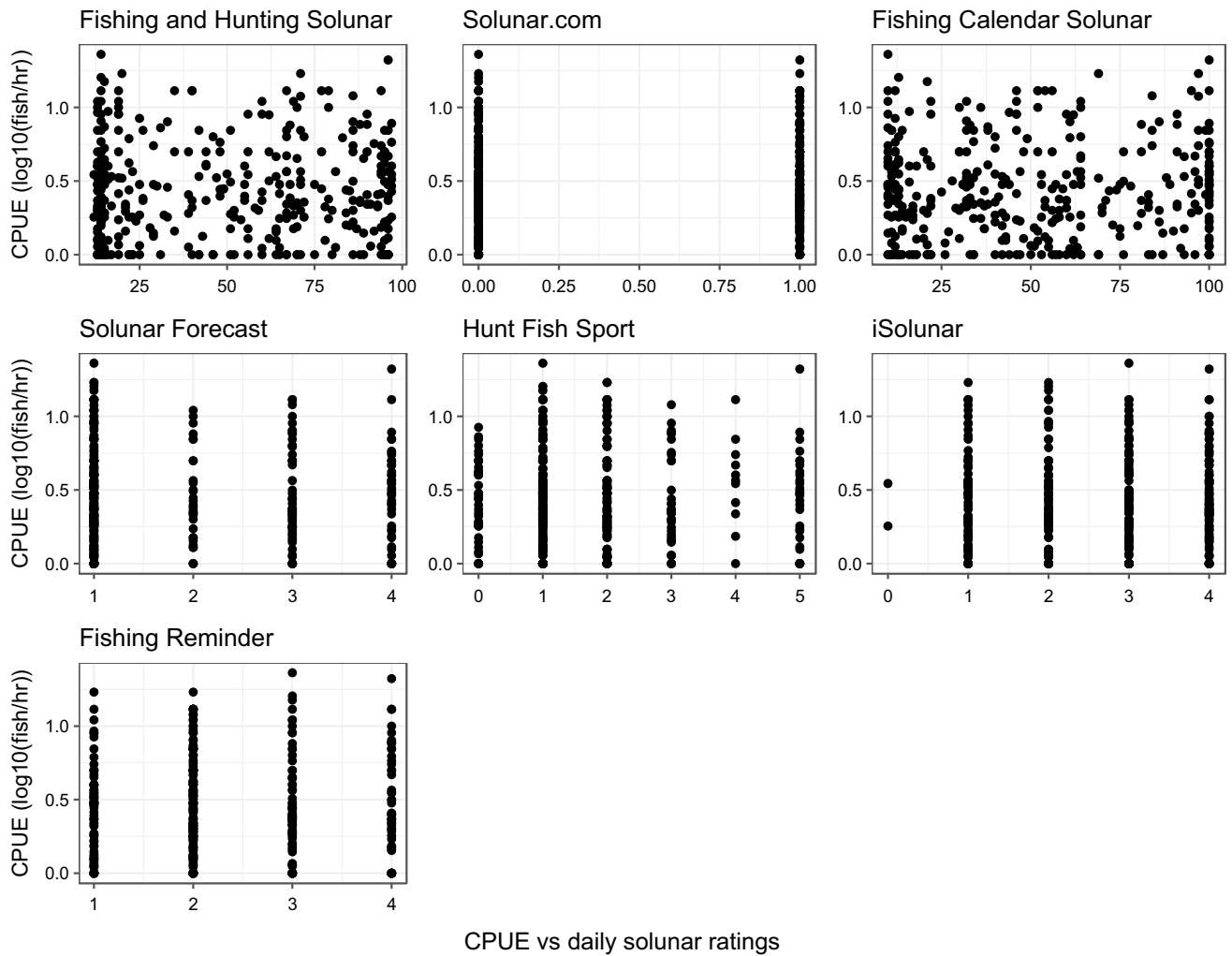


Fig. 2 Relationships between CPUE (fish caught per hour) and daily solunar ratings for all seven services studied. No significant relationships were found

Table 2 P-values for linear regressions of CPUE and qualitative angler rating against the proportion of the trip that fell in a major or minor peak time as provided by Fishing and Hunting Solunar

Time and Solunar.com. Most relationships showed no significant correlation ($p < 0.006$). Slopes coefficients are provided for significant relationships, and these are noted in bold

	CPUE (log10(fish/hour))		Trophy CPUE (log10(fish > 18"/hour))		Angler rating	
	P value	slope	P value	slope	P value	slope
<i>Fishing and Hunting Solunar Time major peaks</i>	0.765	0.19	0.849	0	0.949	- 0.318
<i>Fishing and Hunting Solunar Time minor peaks</i>	0.001	- 0.24	0.444	- 0.095	0.005	- 17.882
<i>Solunar.com major peaks</i>	0.362	- 1.589	0.865	- 0.096	0.846	1.125
<i>Solunar.com minor peaks</i>	0.052	- 2.927	0.168	- 0.199	0.15	-

conditions (angler rating), we conclude that the lack of a significant relationship is not a result of high within treatment variability. As we had expected, we detected a high degree of correlation between the daily ratings of all of the solunar tables we tested and between all of

these tables and the moon phase (Fig. 5)—an average of 61% of the variance of all daily solunar ratings was explained by moon phase ($\cos(2 \cdot \text{radians})$), with services giving the highest solunar values around the new and full moons. While solunar tables rely heavily on the moon

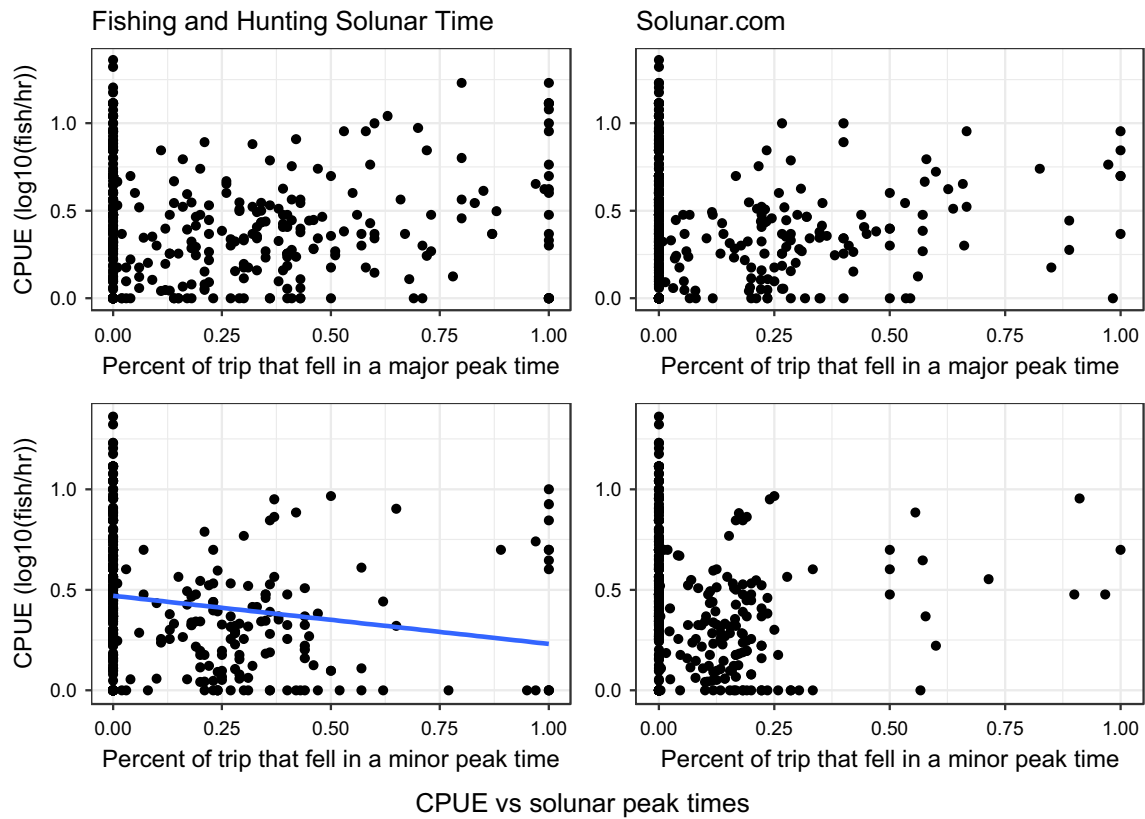


Fig. 3 The relationship between CPUE (fish caught per hour) and the percent of each trip that fell in a major or minor peak time as provided by the two most popular solunar services, *Fishing and*

Hunting Solunar Time and Solunar.com. Linear regression model fit (line) and 95% confidence interval (shaded region) are given for significant relationships ($p < 0.006$)

Table 3 P-values for linear regressions of CPUE and angler rating against moon phase ($\cos(2 \cdot \text{radians})$), percent illumination, temperature, and wind speed. Slope coefficients are given for significant relationships ($p < 0.006$), and these are noted in bold

	CPUE (log10(fish/hour))		Trophy CPUE (log10(fish > 18"/hour))	Angler rating
	P-value	slope		
Moon phase ($\cos(2 \cdot \text{radians})$)	0.758		0.509	0.237
Percent lunar illumination	0.737		0.362	0.861
Temperature	2.49 e-6	0.004	0.016	7.16 e-4 0.252
Wind Speed	0.374		0.134	0.187

phase for generating predictions about fishing success, we found no correlation between CPUE and moon phase (Fig. 5). This is in contrast to Kuparinen et al. [34], who did report increased CPUE around the full and new moons in a recreational *Essox* spp. fishery. As species of different taxa may exhibit very different behavioral and feeding patterns, it is likely that any relationship between CPUE and lunar phase is species specific.

We found that temperature alone was a better predictor of fishing success than any of the available free or premium solunar tables. This is likely due to increased

rates of growth and metabolism in the summer months ([45]. Other environmental variables such as turbidity, net primary productivity, hydrology, and dissolved oxygen levels may also be useful in predicting fishing success [34, 46, 47]. However, it is important to note that the effects of any of these variables on feeding or activity rates will likely not be uniform across all taxa. It is extremely unlikely that any panel of environmental variables could be used to predict increased catch per unit effort across all possible target species, as the solunar theory claims to do [1, 2].

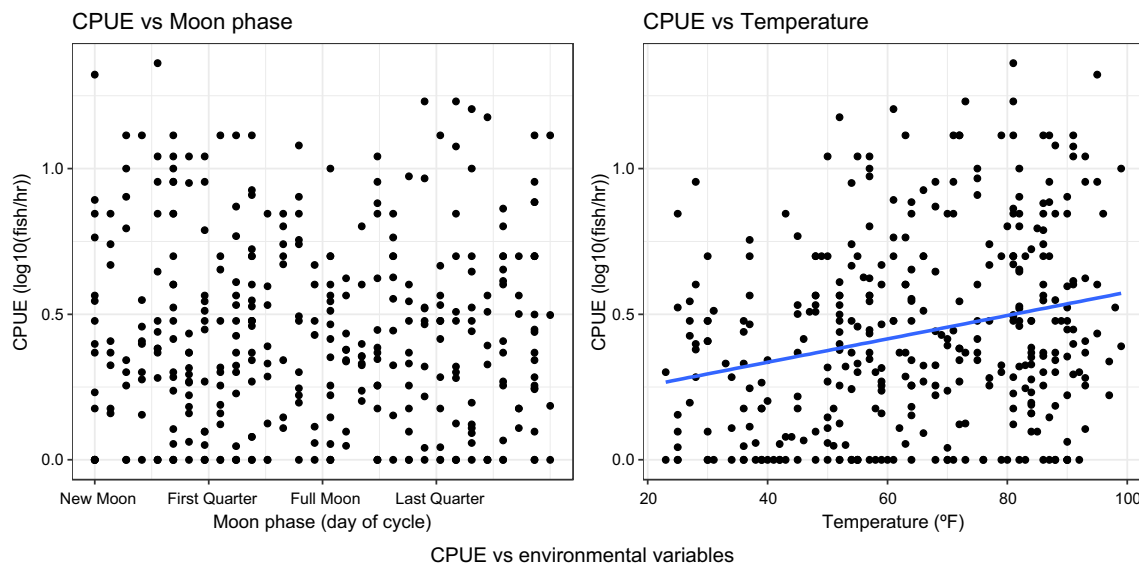


Fig. 4 The relationship between CPUE log(fish/hour) and two of the environmental variables tested. A linear regression of CPUE against $\cos(2 \times \text{moon phase in radians})$ (a periodic function with peaks at the new and full moons) found no significant relationship.

The relationship between CPUE (fish/hour) and air temperature for all fishing trips found a significant positive relationship. Linear regression model fit (line) and 95% confidence interval (shaded region) are given ($p < 0.006$)

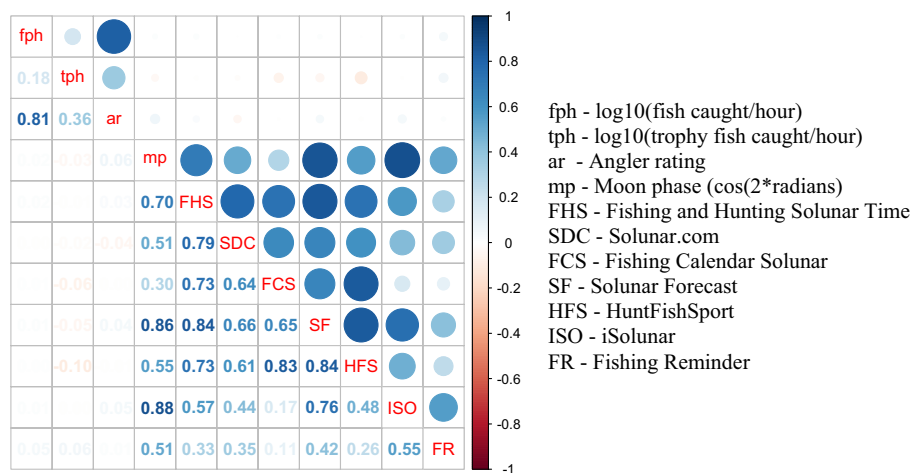


Fig. 5 Correlation matrix of each of our measures of fishing success (fish/hour, trophy fish/hour, and subjective angler rating) against moonphase ($\cos(2 \times \text{radians})$) and the daily ratings of the seven solunar services in the study. Correlation coefficients are below the diagonal, which are represented visually by circles above the diag-

onal. *Fph* log10(fish caught/hour), *tph* log10(trophy fish caught/hour), *ar* Angler rating, *mp* Moon phase ($\cos(2 \times \text{radians})$), *FHS* Fishing and Hunting Solunar Time, *SDC* Solunar.com, *FCS* Fishing Calendar Solunar, *SF* Solunar Forecast, *HFS* HuntFishSport, *ISO* iSolunar, *FR* Fishing Reminder

5 Conclusions

We conclude that solunar rating is not an effective measure for predicting fishing success in recreational freshwater trout fisheries in Utah. None of the daily ratings from seven of the most popular solunar table services showed any significant relationship to increased CPUE. Coincidence

of fishing trips with “peak solunar times”, as reported by the two most popular services, also showed no relationship to increased CPUE. A simple measure of ambient temperature proved to be a more effective predictor of fishing success. As responses to lunar cycles (or any other environmental variable) are often species specific, it is

highly unlikely that any panel of environmental variables can predict increased fishing or hunting success generally.

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Author contributions JK conceived the study, and JK and CQ led study design. Data processing was performed by CQ, and CQ and JG performed all statistical analyses. The first draft of the manuscript was written by CQ and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability The complete dataset along with full reproducible code are available and will be provided upon request.

Declarations

Conflict of interest The authors have no potential conflicts of interest to disclose.

Ethical approval All protocols involving animals were approved under Brigham Young University's Institutional Animal Care and Use Committee.

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