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# COASTAL SEA SURFACE TEMPERATURE RECORDS ALONG THE BAJA CALIFORNIA PENINSULA

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## Registros costeros de temperatura superficial del mar en la Península de Baja California

**RESUMEN.** El análisis de series ambientales de temperatura de alta resolución temporal en las zonas costeras permitirá caracterizar mejor las formas y escalas de variación. Las bases de datos disponibles actualmente carecen de suficiente resolución para detectar variaciones ambientales a escalas de horas y días. En este trabajo damos a conocer una colección de registros de alta frecuencia de diversos sitios a lo largo de las costas de la Península de Baja California. Hasta el momento se tienen 47 sitios; sin embargo, esta red de monitoreo pretende expandirse con el objetivo de generar bases de datos de acceso público y gratuito, proporcionando una valiosa herramienta no solo para la investigación, sino también para aplicaciones como la producción acuícola.

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The main physical factor controlling the abundance and distribution of organisms in their habitat is environmental temperature through biological process such as mortality, reproduction, recruitment and growth (Ponce-Díaz *et al*., 2003). Therefore, species that live in highly variable environments must be adapted to different thermal conditions (Lluch-Belda *et al*., 2000). The Baja California peninsula exhibits strong environmental fluctuations varying in timescales from hourly to interdecadal scales (Ponce-Díaz *et al*., 2003; Lluch-Belda *et al*., 2003; Lavin *et al*., 2003; Lluch-Cota *et al*., 2007).

To understand the way in which temperature variations affect the structure and function of marine ecosystems it is essential to analyze each one of the timescales for variation (circadian, fortnightly, monthly, seasonal, interannual, and longer term), and how they behave in different ecosystems (coastal lagoons, estuaries, shelf seas, open ocean, etc). Existing databases of sea surface temperature like HadISST1 (Rayner *et al*., 2003), OISST.v2 (Reynolds *et al*., 2002) and ERSST.v3 (Smith *et al*., 2008) are freely available, however, those databases do not have enough temporal resolution to detect large daily temperature fluctuations (Sicard *et al*., 2006; Hughes *et al*., 2009). Temperature monitoring at higher-than-monthly resolution along the coasts of Baja California generates valuable information not only for the understanding of the effects of temperature variations on coastal ecosystems, but also for applications such as the evaluation of potential locations for aquaculture of selected species, or for selection of physiologically suitable species for particular aquaculture sites.

Over the last decade several data loggers have been installed along the coasts of the Baja California peninsula and maintained with resources from projects sponsored by governmental and non-governmental sources, generating valuable data, albeit with different timescales. Recently, this data has been integrated into an online database with the purpose of:

1) Making data records available to the scientific community and farmers for scientific studies and to aid in the selection of aquaculture locations, respectively.

2) Encouraging a policy of data sharing for the benefit of the society, by providing a freely available tool for scientists and aquaculture farmers.

3) Increasing and continuing the monitoring effort by inviting scientists and other individuals whose activities are connected with coastal areas, to participate by deploying instruments at these sites.

The authors hope that this policy of cooperation will engender a general sharing of data between different research groups, and that the temperature data can be incorporated into the general database.

The temperature records are from different locations along the Pacific coast of Baja California Sur and inside the Gulf of California (Fig. 1) using digital temperature loggers (Optic Stow Away Temp, Models: WTA32-5+37 and HOBO® Pendant Temperature/Light Data Logger, Onset Computer Corp.). In most cases the data loggers were deployed at a depth of 2 m with sampling interval of 30 minutes (any difference in these conditions are indicated in the database). The data treatment included a

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calculation of basic statistic parameters (mean, maximum, minimum and standard deviation; Table 1). All invalid or outlaying data (such as data recorded during periods when the logger was outside of the water) have been discarded.

To date, data from 47 sites along the west coast of Baja California Sur and inside of the Gulf of California have been recorded (Fig. 1). Locations where the greater number of data loggers are located are: Laguna Ojo de Liebre, Bahía Ballenas, Bahía Magdalena, Bahía de La Paz and Bahía de Loreto, which are sites with economical importance given that there is fishery activity and active cultivation of benthic mollusks at these locations (Casas-Valdéz & Ponce-Díaz, 1996). Data coverage of each one of the 47 data loggers is shown in Fig. 2a, and encompasses a time span beginning in January 2000 and ending in December 2011. The site with the largest data coverage for the aforementioned time span is Laguna San Ignacio (SIG) with more than 60%, followed by one series at Laguna Manuela (LMF) with a 56% and Rancho Bueno 2 (RB2) with 38% (Fig. 2c). The time period when more sites where monitored is from 2006 to 2010 (Fig. 2b).

Table 1 shows the basic statistic descriptors (minimum, maximum, average and stan-

**Table 1**. List of 47 sites with sea surface temperature records. Sites marked in bold were used for annual cycle and frequency distribution of temperature; * sites with one record each 60 minutes; **sites with one record each 15 minutes.

| Region | | Name | Code | Minimum | Maximum | Mean | SD | N | W |
|---|---|---|---|---|---|---|---|---|---|
| Laguna Manuelas | 1 | Laguna Manuela (Boca) | LMB | 13.19 | 28.65 | 18.93 | 2.62 | 28.1834 | -114.0608 |
| | 2 | Laguna Manuela (Camas de cultivo) | LMC | 10.71 | 30.27 | 19.78 | 2.97 | 28.1371 | -114.0719 |
| | **3** | **Laguna Manuela (Fondo)*** | **LMF** | **10.74** | **36.3** | **21.56** | **4.23** | **28.1311** | **-114.0680** |
| Laguna Guerrero Negro | **4** | **Campo Chupa Lodo** | **CCH** | **10.26** | **33.22** | **20.75** | **3.44** | **27.9946** | **-114.0716** |
| Laguna Ojo de Liebre | 5 | El Conchalito | ECO | 13.85 | 30.86 | 19.15 | 3.22 | 27.7763 | -114.2781 |
| | 6 | La ventana | LVE | 14.71 | 25.51 | 18.81 | 2.78 | 27.7358 | -114.2696 |
| | 7 | El Mariscal | EMA | 17.34 | 22.89 | 20.5 | 1.73 | 27.6800 | -114.1579 |
| Bahía Tortugas | **8** | **El Rincón** | **ERI** | **11.82** | **25.22** | **17.14** | **2.67** | **27.6629** | **-114.8656** |
| | 9 | Queen | QUE | 15.11 | 25.96 | 19.88 | 1.83 | 27.7779 | -114.6362 |
| | 10 | Arvin | ARV | 13.28 | 23.13 | 17.15 | 2.02 | 27.6477 | -114.8665 |
| Bahía Asunción | 11 | Isla Asunción* | BAI | 11.96 | 33.77 | 22.55 | 6.13 | 27.1462 | -114.3767 |
| | 12 | El Rito | BAE | 12.25 | 22.99 | 16.94 | 2.64 | 27.1339 | -114.2953 |
| La Bocana | 13 | La Bocana | BOC | 12.5 | 29.95 | 20.74 | 4.03 | 26.7862 | -113.6868 |
| Punta Abreojos | 14 | Punta Abreojos | PTA | 15.28 | 29.35 | 22.12 | 3.27 | 26.8194 | -113.4347 |
| Laguna San Ignacio | **15** | **San Ignacio** | **SIG** | **7.66** | **39.96** | **21.17** | **4.43** | **26.793** | **-113.1515** |
| | 16 | Sol Azul | SAZ | 14.33 | 36.62 | 22.19 | 3.89 | 26.7914 | -113.1561 |
| Santo Domingo | **17** | **Santo Domingo** | **SDO** | **8.98** | **32.09** | **23.83** | **4.06** | **25.5655** | **-112.0731** |
| Estero San Buto | 18 | San Buto | SBU | 13.37 | 34.69 | 24.26 | 3.4 | 24.7746 | -112.0477 |
| Bahía Magdalena | **19** | **Bahía Magdalena 1(9.5m)** | **BM1** | **13.08** | **28.75** | **19.18** | **3.74** | **24.658** | **-112.0673** |
| | 20 | Bahía Magdalena 2(11m) | BM2 | 14.23 | 31.88 | 20.69 | 3.65 | 24.6319 | -111.9189 |
| | 21 | Bahía Magdalena 3(14.7m) | BM3 | 13.08 | 29.25 | 19.48 | 3.99 | 24.5504 | -111.9479 |
| | 22 | Bahía Magdalena 4(17m) | BM4 | 13.17 | 28.06 | 18.98 | 3.89 | 24.6452 | -111.9634 |
| | **23** | **Rancho Bueno 1** | **RB1** | **10.39** | **38.14** | **22.42** | **4.29** | **24.3738** | **-111.6430** |
| | 24 | Rancho Bueno 2 | RB2 | 8.68 | 38.83 | 22.86 | 4.13 | 24.3748 | -111.5773 |
| | 25 | Rancho Bueno 3 | RB3 | 12.24 | 33.54 | 22.45 | 3.76 | 24.3500 | -111.4811 |
| | 26 | El Remate | ERE | 16.31 | 31.58 | 23.01 | 3.35 | 24.3113 | -111.4022 |
| Bahía de La Paz | 27 | Punta Arenas | PAR | 18.04 | 30.56 | 25.7 | 2.65 | 24.0445 | -109.8259 |
| | 28 | Mogote (18m) | MO1 | 19.19 | 22.24 | 20.88 | 0.45 | 24.1839 | -110.3797 |
| | 29 | Mogote (7m) | MO2 | 19.95 | 23.29 | 21.61 | 0.62 | 24.1839 | -110.3797 |
| | 30 | Canal de San Lorenzo | SLO | 18.53 | 25.9 | 21.07 | 1.27 | 24.3878 | -110.3218 |
| | **31** | **Punta Diablo** | **PDI** | **15.19** | **32.98** | **22.82** | **3.18** | **24.3125** | **-110.3365** |
| | 32 | Rancho Rodríguez | RRO | 20.04 | 32.19 | 24.55 | 1.95 | 24.2019 | -110.5270 |
| | 33 | San Gabriel | SGA | 19.67 | 29.5 | 24.19 | 1.77 | 24.4268 | -110.3698 |
| | 34 | Isla Gallo(20m) | IG1 | 19.95 | 21 | 20.43 | 0.2 | 24.4631 | -110.3861 |
| | 35 | Isla Gallo(7m) | IG2 | 20.33 | 21.09 | 20.71 | 0.21 | 24.4631 | -110.3861 |
| | 36 | Isla Gaviota (22m) | GA1 | 18.71 | 22.81 | 21.59 | 0.69 | 24.2892 | -110.3406 |
| | 37 | Isla Gaviota (7m) | GA2 | 18.9 | 23.97 | 21.69 | 0.65 | 24.2892 | -110.3406 |
| | 38 | El Portugués** | EPO | 24.86 | 38.14 | 29.13 | 2.16 | 24.7476 | -110.6782 |
| | 39 | Balandra | BAL | 12.3 | 39.5 | 25.13 | 3.77 | 24.3166 | -110.3212 |
| | 40 | Enfermería | ENF | 16.99 | 37.05 | 26.19 | 4.28 | 24.2293 | -110.3193 |
| | 41 | Zacatecas | ZAC | 9.57 | 35.65 | 22.72 | 4.11 | 24.1209 | -110.4334 |
| Bahía de Loreto | 42 | Candeleros | CAN | 17.91 | 30.29 | 22.95 | 3.77 | 25.7448 | -111.2277 |
| | 43 | La Choya | LCH | 16.94 | 30.67 | 22.79 | 3.51 | 26.0449 | -111.1816 |
| | **44** | **Galeras** | **GAL** | **17.62** | **31.02** | **23.96** | **4.05** | **25.7382** | **-111.0447** |
| | 45 | Puerto Escondido | PES | 18.33 | 33.22 | 24.35 | 3.66 | 25.8096 | -111.3075 |
| Sonora | 46 | Bahía Bacoherehuis | BBA | 18.62 | 35.12 | 27.74 | 3.91 | 26.5261 | -109.1531 |
| | **47** | **Bahía Kino** | **BKI** | **13.88** | **33.63** | **24.13** | **5.28** | **28.7999** | **-111.9176** |

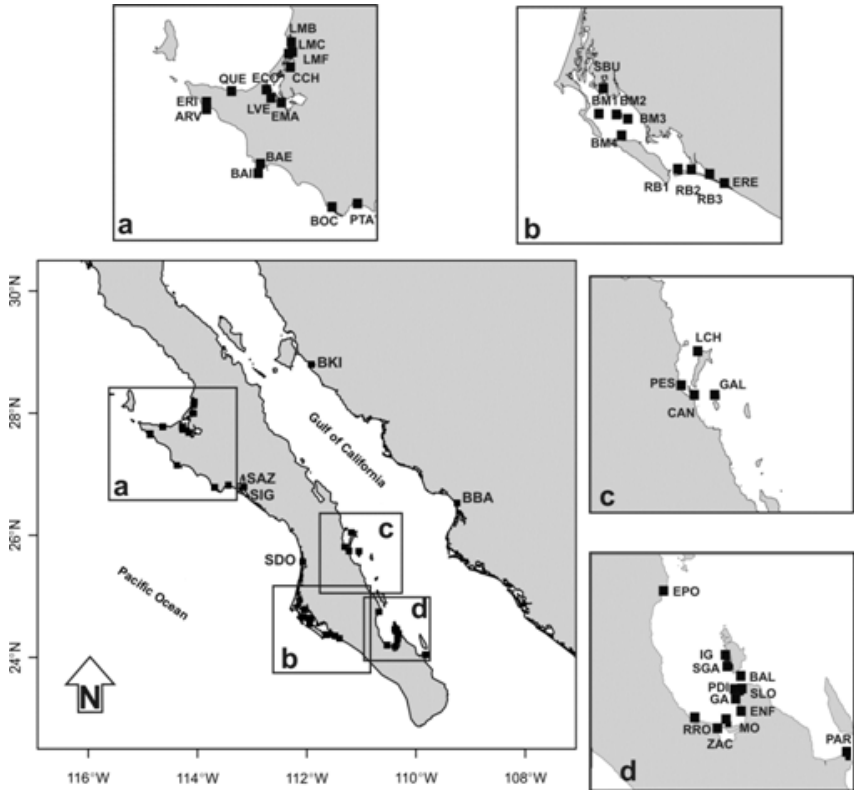


**Figure 1**. Map with location of the 47 registered sites so far along the coast of the Baja California peninsula.

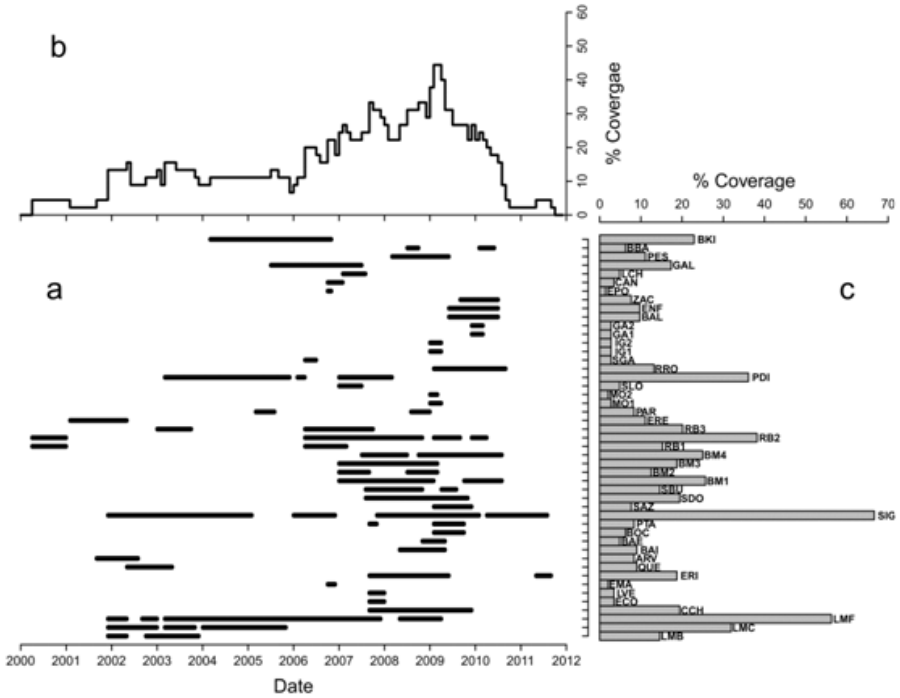


**Figure 2**. a) Total observation period for each logger with a within the 2000 to 2012 time window; x axis is graduated in month; y axis corresponds to each of the 47 sites. b) Coverage percentage for each month. c) Coverage percentage for each logger.

dard deviation) of the time series for each of the sites. Sites from the Pacific side of the peninsula (sites 1 to 26) tended to have colder average values (between 16.9 and 24.3°C) with a larger standard deviation (1.7 to 6.1) compared with sites inside the Gulf of California (sites 27 – 45; averages between 20.4 and 29.1°C and standard deviations between 0.2 and 5.3). Figure 3 shows the annual cycles of monthly averaged temperature and amplitude (daily maximum -minimum) for the ten sites with the largest and most continuous data records (Table 1). The amplitude values indicate the distribution of registered daily temperature fluctuations for each location and month. Figure 4 reports the frequency distributions of temperature of the same ten sites (Table I). This mode of presenting the temperature records of a location facilitates the rapid identification of temperature ranges and frequent values, and the comparison with physiological thermal preferences of marine populations, including those with aquacultural potential (Sicard *et al*., 2006)

It should be noted that many of the records correspond to coastal water bodies, where local dynamics (exchange rates with open ocean, local heating, depth) play a major role in shaping the temperature changes, and thus should be interpreted as representative of those water bodies and not the surrounding open coastal systems.

The online database is currently hosted in the Centro de Investigaciones Biológicas del Noroeste (CIBNOR) by the Laboratorio de Ecofisiología de Organismos Acuáticos (LEOA;

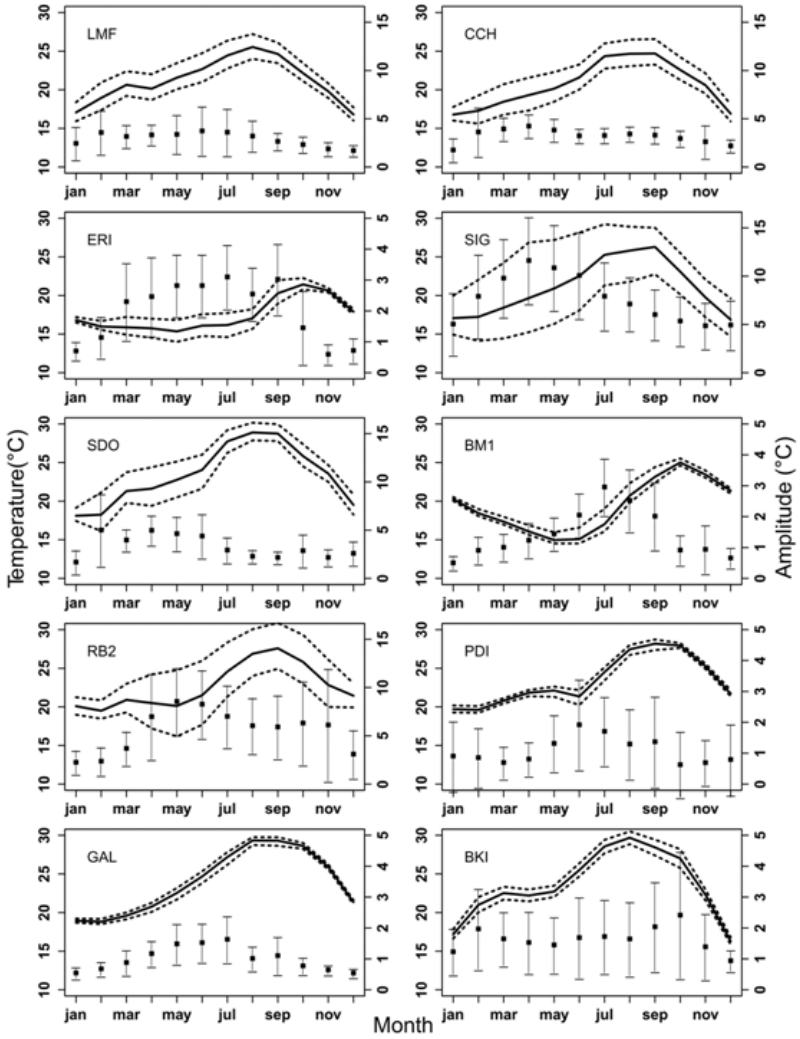


**Figure 3**. Annual cycle for the ten sites with most continuous records. Monthly mean temperature values are shown with solid lines; dashed lines correspond to monthly maximum and minimum. Mean amplitude values are indicated with squares± SD. Notice mean temperature variations according to site.

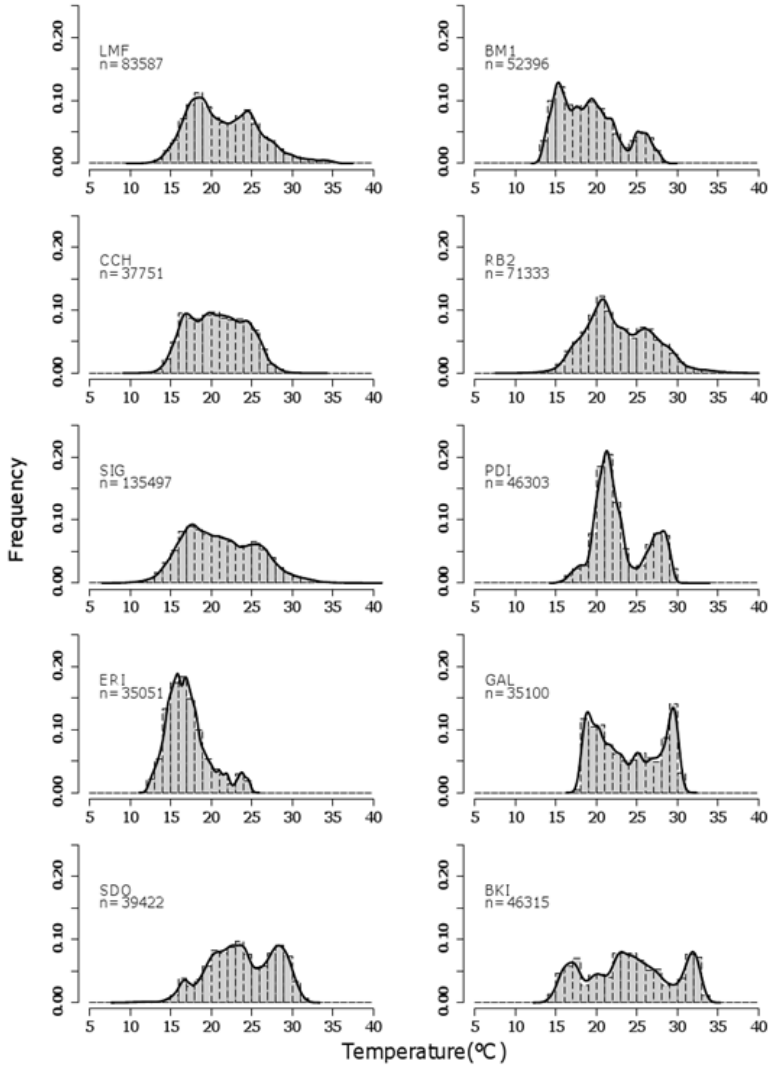


**Figure 4**. Frequency distribution of temperature for the ten sites with most continuous records (gray bars). Solid line corresponds to Kernel distribution for each site.

www.leoa.org.mx/RAF), and stored by the recently created Observatorio de los Mares y Costas de México (contact slluch@cibnor.mx). The temperature data is freely available online as a KMZ file, which is a file type supported by the Google Earth®software program. This provides a free and straightforward platform to explore and visualize the information generated from all observation sites.

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